SOLAW TR08

Agriculture and water quality interactions: a global overview

SOLAW Background Thematic Report - TR08

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Abbreviations and acronyms

As	Arsenic
Ca^{2+}	Calcium ion
CA	Conservation Agriculture
Fe	Iron
g	Gram
GAP	Good agricultural practices
GLADIS	Global Land and Water Degradation System
ha	hectare
IPNM	Integrated plant nutrition management
IPM	Integrated pest management
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resource Management
kWh	Kilo Watt hour
LADA	Land degradation of drylands
mg	Milligram
Mg^{2+}	Magnesium ion
N	Nitrogen
Na^{+}	Sodium ion
RO	Reverse osmosis
s	Second
US EPA	United States Environmental Protection Agency
µg	Microgram
UNEP	United Nations Environmental Programme
WHO	World Health Organization

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Executive summary and main messages

Water quality and agriculture interactions are many and complex. The development of large irrigation schemes has been an important contributor to global food security, particularly in arid areas, but it has also been associated with land and water salinity problems. Both, expansion and intensification of agriculture have led to an increasing use of fertilizers and pesticides that, when not well managed, has degraded the water quality of rivers, lakes and marine water bodies. Intensification of livestock farming systems is a case in point: concentrating inputs increases the potential transmission of pollution from both animal waste and fodder production and, if not managed or regulated well, eutrophication of freshwater bodies can easily result. At the same time, such is the level of water scarcity and pollution that millions of farmers worldwide are driven to irrigate with marginal quality water such as wastewater from urban areas or saline agricultural drainage water. Minimizing both the production and food safety risks and, at the same time, maximizing benefits when using such water is an enormous challenge. Additionally, concerns about the use of naturally occurring arsenic-laden groundwater in agriculture are growing and, therefore, this emerging issue will need special attention. These are all examples of the complex interactions between agriculture and water quality that are systematically analysed in this report.

Agricultural induced water salinization

Salinity is the most important criterion for evaluating the quality of irrigation water because of the potential crop yield reductions that can result from the use of saline water which inhibits water uptake by plants.

Agricultural practice tends to induce accumulation of salt in land and water. Salts accumulated in soils can be mobilized by irrigation practice through the modification of water circulation across land. In addition pumping of groundwater can induce saline intrusion in coastal aquifers or the migration of low quality water from underlying aquifers. Major soil and water salinity problems have been reported in large irrigation schemes in China, India, Argentina, the Sudan and many countries in Central Asia, where more than 16 million ha of irrigated land are salinized through the combination of these processes. Globally, 34 million ha (11 percent of the irrigated area) are estimated to be affected by some degree of salinity.

Leaching and drainage are required to maintain the salt balance in the soil profile and to sustain crop yields in arid areas, but this drainage needs to be carefully managed to prevent salinization of water bodies. Some drainage water management options include minimizing drainage by conserving water, reuse of drainage water, safe disposal or treatment of drainage water.

Another crucial issue in coastal plains and islands is the prevention of saline intrusion induced by groundwater pumping. Two main approaches taken in dealing with this problem are to: (i) reduce groundwater abstraction in coastal areas; and (ii) actively control the freshwater-saline interface by injecting freshwater.

Water pollution from agriculture

The most important water pollution problems related to agriculture are: (i) excess nutrients accumulating in surface and coastal waters that cause eutrophication, hypoxia and algal blooms; (ii) accumulation of nitrates in groundwater; and (iii) pesticides accumulated in groundwater and surface water bodies.

Water pollution caused by nutrients (particularly nitrate) and pesticides has increased as intensive farming methods have proliferated, such as increased use of chemical fertilizers and higher concentrations of animals in smaller areas. Sources of pollution are generally diffuse but others can be concentrated (e.g. slurry management under zero grazing).

The 1980s saw a progressive worsening of water quality owing to the growth of intensive livestock farming (chickens, pigs) in areas that were already saturated, and of intensive crop-growing involving the use of chemical weedkillers and over fertilization. Developed countries have had major problems of water pollution from agriculture and trends indicate that intensified farming systems and agrochemical consumption are being extended in emerging economies.

The control of water pollution from agriculture clearly needs to occur within broader integrated water resource management frameworks that ensures linked land water use together with re-use management. Specific actions need to be carried out by polluters and implemented at the relevant scales (e.g. national, regional, municipal, local, project-level). Improved agricultural practices to minimise environmental impacts include integrated plant nutrient management, integrated pest management, conservation agriculture and livestock waste management. In addition, sustained regulation and water quality monitoring programmes at all scales are essential for planning and assessment.

Use of treated and untreated wastewater in agriculture

Population growth and rapid urbanization are increasing pressure on fresh water resources. The lack of acceptable quality water and a high level of local water demand is leading to increased water scarcity and stress and is consequently driving the use of non-conventional waters, such us treated or raw wastewater.

Wastewater use for irrigated agriculture is especially important in urban and peri-urban areas where it can serve as a new source of water and fertilizer if it has been properly managed to minimize environmental and health risks.

The resulting schemes for wastewater use can be heterogeneous, but common patterns can be detected in different countries:

- Lack of quality water and poverty driving untreated wastewater use in urban and peri-urban agriculture is a common pattern in Sub-Saharan Africa and other poor regions where there is no economic capacity to afford conventional sanitation and wastewater treatment facilities. This poses health, environmental and agriculture risks if no additional measures are applied.
- Water scarcity together with health and environmental protection are the main drivers for reclaimed wastewater use in high-income countries. This is a common pattern in countries such as Israel, Spain, Australia or the United States (California and Florida) where highly effective sanitation and treatment technology is used in planned reclamation facilities. This is a costly approach but risk is reduced almost to zero.
- Water scarcity driving treated wastewater use in emerging (middle income) countries is a common pattern in areas where low cost technologies are applied to provide partially treated wastewater for irrigation. This approach poses moderate risks to health, the environment and agriculture yield.

A robust policy and institutional framework needs to be in place to maximize benefits and minimize the risks related to the use of wastewater for irrigation. These frameworks are lacking in many countries, where wastewater use for agriculture takes place. Public institutions (health, agriculture, water) responsibilities and jurisdictions need to be clear and coordination mechanisms are necessary.

Cost effective and appropriate wastewater treatment suited for the end use of wastewater is fundamental. In most developing countries wastewater treatment is not economically feasible in the short term and interim solutions may be needed to protect farmers and public health. In these countries affordable and easily adoptable risk management strategies are preferable. Adopting multiple-barrier approaches can reduce human and crop exposure to toxic compounds and pathogens.

In addition farmers need to be provided with specific guidelines to support production and access to markets and effective dissemination and education campaigns to facilitate the adoption of such guidelines are critical.

Use of saline or desalinated water in agriculture

Salinized and sodic drainage water and groundwater are often used for irrigation. Use of this water poses agriculture and environmental risks owing to soil salinization and water quality degradation downstream.

Although no global assessment exists, the use of saline or sodic water is a common practice in many countries such as Bangladesh, China, Egypt, India, Iran, Pakistan, Syria, Spain and the United States, notably for the irrigation of salt-tolerant plants and trees, but also conventional grains and forage.

When managing salinity it is important to bear in mind that many land and irrigation areas have varying levels of tolerance to increases in salinity. Therefore, salinity needs to be considered in the context of the particular asset at risk and the value of that asset. Salinity risk assessment should be carried out to determine the intensity of the measures to apply and the methods to follow. In areas identified as having a high hazard level, a good salinity monitoring programme should be developed. In addition, actions aiming to prevent further salinization of land and water or to remedy saline or sodic soils should be implemented. These actions include more efficient irrigated agriculture, effective drainage measures, crop selection or treatment of saline drainage before reuse.

Desalination of saline groundwater and brackish drainage water have arisen as one of the options available to cope with the problem of water salinization, in addition it is used for augmenting freshwater resources when seawater is desalinated. Even when the technology presents interesting opportunities, the main constraint to widespread use of desalinated water for agriculture is high energy consumption and associated costs.

Use of arsenic laden waters

Naturally occurring arsenic in groundwater has been reported in more than 20 countries worldwide and, in many, shallow groundwater is used for drinking and irrigation. Natural arsenic in groundwater at concentrations above the drinking water standard of 10 µg/litre is not uncommon, and the realization that water resources can contain insidious toxic concentrations of naturally-occurring chemical constituents, such as arsenic, is fairly recent and increasingly urgent.

First estimates of arsenic toxicity (arsenosis) from drinking water, causing skin lesions and various types of cancers, indicate about 130 million people are impacted. Sources of arsenic that have been created by people, such as mineral extraction and processing wastes, poultry and swine feed additives, pesticides and highly soluble arsenic trioxide stockpiles are not uncommon and have caused the contamination of soils and groundwaters. Arsenic accumulation in the food chain (e.g. arsenic transfer in rice in Asia) is a major concern that needs to be tackled globally and, most importantly, the scale of the problem needs to be better quantified.

Finally, management options are being developed and successfully tested to prevent and mitigate Arsenic (As)-contamination of agricultural land. For example strategies for management of arsenic that would enable continuing rice production in polluted areas include: (i) growing rice in an aerobic environment where As is adsorbed on oxidized Fe (iron) surfaces and is largely unavailable to rice; (ii) switching from As-contaminated shallow groundwater to non-contaminated surface or deep groundwater to avoid further build up of soil As; or (iii) identification or development of arsenic tolerant rice varieties, where arsenic uptake is also low.

1. Introduction

There are many and very complex agriculture and water quality interactions. In this paper we explore the main water quality impacts from agriculture, including livestock, and the use of marginal quality water, also in agriculture. While linkages between water quality and aquaculture or forestry are also relevant, these subjects are better covered in other FAO publications (e.g. FAO 2008a or FAO 2001) and are out of the scope of this report.

Section 2 explores the role of agriculture as a driver of salinization and pollution: Many large irrigation schemes around the world, especially in arid areas, have been suffering from salinization of land and water. Globally 34 million ha are now impacted. Expansion and intensification of agriculture have led to increasing use of fertilizers and pesticides which has resulted in higher crop productivity. If not well managed, however, fertilizers and pesticides can degrade the water quality of rivers, lakes and marine water bodies. In addition, intensification of livestock farming systems is increasing pressure on water bodies. Section 2 reviews the chain: drivers, agriculture related pressures and state of water bodies at the global scale. In addition, remedial actions are proposed, including policy recommendations, that take the relevant socio-economic context into account.

Section 3 focuses on the use of marginal quality water, such as wastewater from urban areas or saline agricultural drainage water, as millions of farmers worldwide often have no other alternative but to irrigate with these waters. Minimizing risks and, at the same time, maximizing benefits when using such water is an enormous challenge that needs to be addressed. In addition, concerns about the use of arsenic-laden water in agriculture are growing and, therefore, this emerging issue needs special attention. Section 3 reviews the main factors driving the use of marginal quality water for agriculture and provides an overview of the use of such water worldwide. Moreover key considerations are outlined to guide policy.

2. Water quality impacts from agriculture

The main water quality problems associated with agriculture worldwide are salinization and nutrient and pesticide pollution. Salinization is commonly cited as the most widespread groundwater quality problem and as having the greatest environmental and economic impacts (Morris *et.al.,* 2003). On the other hand eutrophication, a result of high nutrient loads (mainly nitrogen and phosphorus), is considered to be the prevailing water quality problem for surface water (UN-Water, 2009). Other pollutants originating in agricultural activities include pesticides, oxygen-demanding substances and sediments.

2.1 Salinization of water resources in irrigated areas

2.1.1 Problem statement, concepts and definitions

Salinity is the most important criterion for evaluating irrigation water quality (Ghassemi, *et al.*, 1995). High salt concentrations prevent the uptake of water by plants causing crop–yield reductions. This occurs when salts accumulate in the root zone to such an extent that the crop is no longer able to extract sufficient water from the salty soil solution, resulting in water stress for a significant period (FAO, 1994). If water uptake is appreciably reduced, the plant slows its rate of growth. The plant symptoms are similar in appearance to those of drought.

Soil salinization in its early stages of development reduces soil productivity, but in advanced stages it kills all vegetation and consequently transforms fertile and productive land to barren land.

When speaking of water quality, sodicity is also a very important variable. The term refers to the presence of a high proportion of sodium (Na^+) ions relative to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in soil or water. Sodicity degrades soil structure by breaking down clay aggregates, which results in more easily eroded soil that is less permeable to water, which then reduces plant growth.

Irrigating with saline or sodic water generally results in enhanced salinity or sodicity in soil water unless proper irrigation measures are applied. These measures include applying irrigation water in excess of crop requirements to leach the salts from the soil (leaching factor) and favouring the drainage of saline water through well-designed drainage systems.

Waterlogging, which is one of the consequences of land sodicity and one of the precursors of land salinization, damages plant growth. There must be a balance between the amount of air and water in the soil for healthy growth of the plant. If the soil is waterlogged, the plant's growth will be damaged and its production will be adversely affected.

Environmental and agricultural damage caused by salinity, sodicity and waterlogging may imply very severe economic and social damage, therefore well designed policies need to be developed for prevention and remediation.

2.1.2 Causes and drivers of water salinization

There are different causes, both natural and human, that can induce accumulation of salt in soils and water resources. Natural salinity refers to the 'primary' salinity that was present prior to the development of land for agriculture, and human-induced salinity refers to the 'secondary' salinity often caused by land-use change.

Natural salinization of land and water is closely related to the long-term accumulation of salts in the soil profile and, subsequently, in groundwater, but it could occur as a result of the one-time submergence of soils under seawater (Ghassemi, *et al.*, 1995).

Salts accumulated in soils could be mobilized and cause salinization of water bodies. The main cause for this salt mobilization is irrigation. Application of leaching fractions for soil-clearing entails the discharge of saline effluents from drainage schemes in irrigated areas. In addition, excessive irrigation can raise water tables from saline aquifers and this can increase seepage of saline groundwater into water courses and increase their salinization. Intrusion of saline seawater into aquifers is another important cause of salinization of water resources in coastal areas. This intrusion is frequently the result of excessive groundwater extractions for agriculture. Excess mineral fertilization in agriculture also plays a role in the increase of salt content in water resources.

Other human factors that can be locally important for water salinization is the discharge of saline water to rivers from industries and mining activities. In addition, periodic application of de-icing agents in snow-belt regions of industrialized countries contributes to the accumulation of salt in the soil and water.

2.1.3 Extent of salinization: Global overview

In almost all countries where land salinization is a major problem, it is accompanied by water salinization. Table 1 shows the regional distribution of agricultural land salinized by irrigation and indicates that, globally, 34 Mha are now impacted.

Major problems have been reported in Pakistan, China, United States, India, Argentina, Sudan and many countries in Central and Western Asia. (AQUASTAT and Ghassemi, *et al*., 1995). Countries shown in Table 2 accumulate 90% of the area salinized by irrigation.

Figure 1 represents the spatial distribution of land under irrigation which is affected by some degree of salinization. It was produced by combining FAO AQUASTAT country statistics regarding irrigated areas affected by salinization with spatial information on irrigated areas where precipitation is not sufficient to leach away salt residues that are built up in the soil due to irrigation. It was assumed that the risk of salinization of irrigated areas can occur only in areas with an Aridity Index lower than 0.65 (where the Aridity Index is defined as Yearly Precipitation divided by Yearly Reference Evapotranspiration).

2.1.4 Actions to prevent water salinization from agriculture.

Leaching and drainage are required to maintain salt balance in the soil profile and to sustain crop yields in arid areas (FAO, 2007b). The salinity of drainage water might be up to 50 times higher than irrigation water and its disposal can increase the salinity of receiving water bodies. The challenge is to minimize environmental impacts on ecosystems linked to these water bodies, as well as the economic impacts on the subsequent activities (e.g. agriculture), using this water.

TABLE 1: AREA SALINIZED BY IRRIGATION PER REGION

Region	Million ha
South Asia	10.30
East Asia	6.70
Western Asia	6.12
Northern America	5.34
Central Asia	3.21
Southern America	0.95
Sub-Saharan Africa	0.68
Northern Africa	0.68
Australia and New Zealand	0.20
Total	34.19

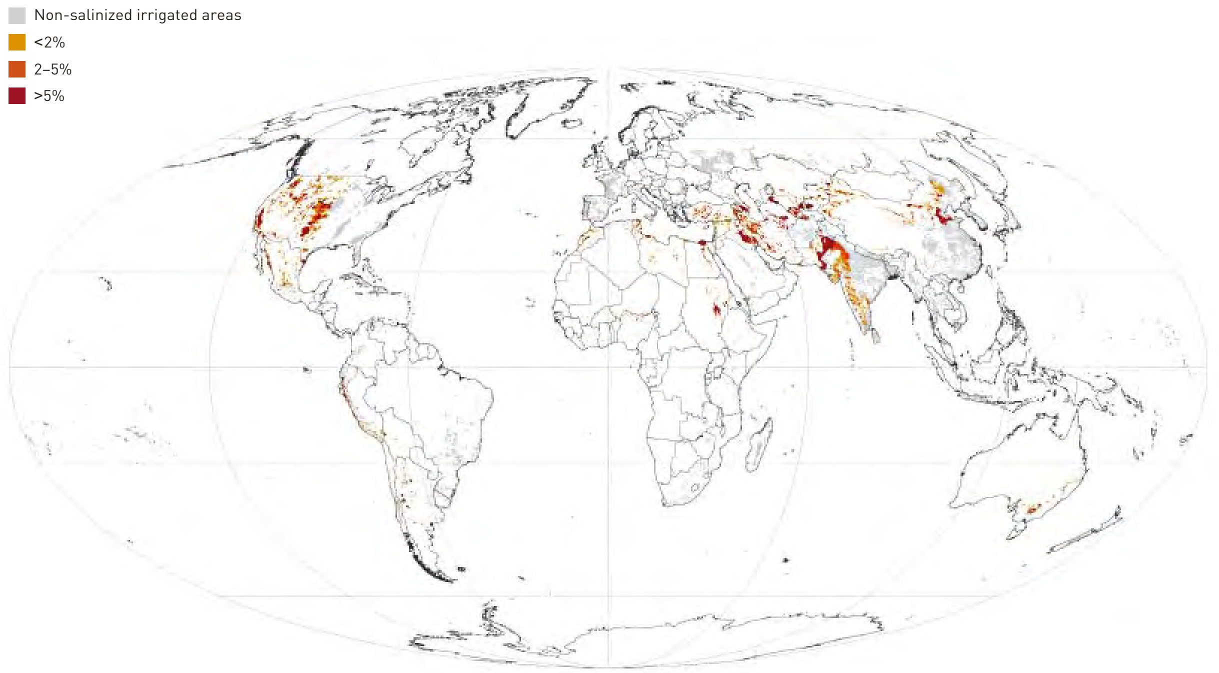
Source: AQUASTAT, different years.
** Regions based on country groupings used in SOLAW.*

TABLE 2: COUNTRIES WITH THE LARGEST AREAS SALINIZED BY IRRIGATION

Country	Million ha
Pakistan	7.00
China	6.70
United States	4.90
India	3.30
Uzbekistan	2.14
Iran (Islamic Republic of)	2.10
Iraq	1.75
Turkey	1.52

Source: AQUASTAT different years and Ghassemi 1995.

FIGURE 1: PROPORTION OF LAND SALINAZED DUE TO IRRIGATION



Source: FAO

Until 20 years ago there were few constraints to the disposal of drainage water from irrigated lands. One of the principal reasons for increased constraints on drainage disposal is to protect the quality of receiving waters for downstream uses and to protect the local environment and ecology. Now, many developed and developing countries carry out drainage water management practices. These practices can be grouped as follows:

- water conservation;
- drainage water reuse;
- drainage water disposal; and
- drainage water treatment.

Each of these options may impact hydrology and water quality in an area. Interactions and trade-offs occur when more than one option is applied.

Planners, decision-makers and engineers need a framework to help them select from among the various options and to evaluate their impact and contribution towards development goals. Moreover, technical expertise and guidelines on each of the options are required to enable improved assessment of the impact of the different options and to facilitate the preparation of drainage water management plans and designs. FAO provides guidelines to plan and design land drainage systems (FAO, 2007b and FAO 2005), at the same time, to protect water resources from the negative impacts of the disposal of agricultural drainage water (FAO, 2002).

The environmental and economic hazards must be considered carefully and, if necessary, mitigating measures taken. If possible, drainage must be limited to wet seasons only, when the salty effluent inflicts the least harm. In regions with pronounced dry and wet seasons, the drainage system may be operated in the wet season only and closed during the dry season. This practice of checked or controlled drainage saves irrigation water.

Another crucial issue in coastal plains and islands is the prevention of saline intrusion induced by groundwater pumping. Two main approaches taken to deal with this problem are: (i) reduction of water extraction from groundwater in coastal areas; and (ii) the creation of saltwater intrusion barriers by injecting water into aquifers.

2.2 Agriculture pollution of water resources

Agriculture is by far the greatest water user in the world and consequently a major cause of water pollution. Agricultural pollution is commonly non-point source, however, agricultural operations sometimes include identifiable point source discharges, particularly for concentrated livestock operations. The main pollutants from agriculture are excess nutrients and pesticides.

2.2.1 Problem statement, concepts and definitions.

Excess nutrients causing eutrophication, hypoxia and algal blooms in surface water bodies and coastal areas is the main water quality problem globally (UN-Water, 2009). It has been suggested that the planetary boundaries, or upper tolerable limit, for changes to the global nitrogen cycle (Rockstrom *et al*., 2011) and for freshwater eutrophication has been already crossed (Carpenter and Bennet, 2011). Major nutrient sources affecting water include agricultural runoff and domestic sewage, industrial and mining effluents as well as atmospheric inputs from the burning of fossil fuels. In a comparison of domestic, industrial, and agricultural sources of pollution from the coastal areas of Mediterranean countries, agriculture was the leading source of nutrients (UNEP, 1996). High-nutrient loads (mainly phosphorus and nitrogen) substantially harm beneficial uses of water.

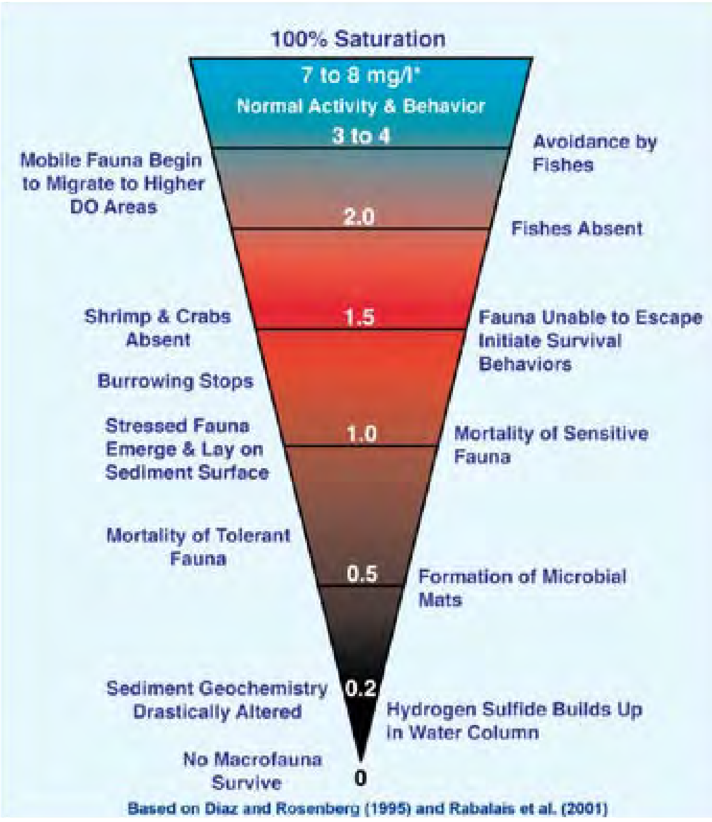
Nitrogen and phosphorus are factors that limit life in aquatic ecosystems. Eutrophication is excessive nutrient accumulation (e.g. nitrogen concentrations higher than 5 mg/litre), which generally promotes excessive plant growth and decay. Normally, simple algae and plankton are favoured over other more complicated plants and water becomes cloudy, shady and coloured.

The process of decay consumes dissolved oxygen in the water creating hypoxic conditions and harming oxygen-consuming fish and shellfish. These effects on fauna are shown in Figure 2. Excessive nutrient inputs can also cause harmful algal blooms. Cyanobacteria, also known as blue-green algae, have increased in fresh waters and coastal areas such as the East China Sea in recent decades (UN-Water, 2009). The toxins produced by the excessive algae can cause poisoning of fish, shellfish and even humans. Global warming may exacerbate this problem, since cyanobacteria have a competitive advantage over other types of algae at higher temperatures.

Excess nitrogen (N) driving accumulation of nitrates in groundwater is another crucial issue. Nitrate is a soluble compound that can be easily leached from soil by deep percolation to aquifers. In many irrigated areas concentrations of nitrate in underlying groundwater are greater than the World Health Organization (WHO) standards for drinking water (50 mg/litre). This is directly related to the intensive and improper use of mineral fertilizer and manure for agriculture, sometimes exceeding crop–nitrogen demand. This relation between agriculture intensification and nitrate pollution of groundwater is illustrated in Figure 3, which shows that nitrate in groundwater under intensive cash-crop cultivation was higher than under mixed farming areas, extensive coconut cultivation and uncultivated areas in Sri Lanka.

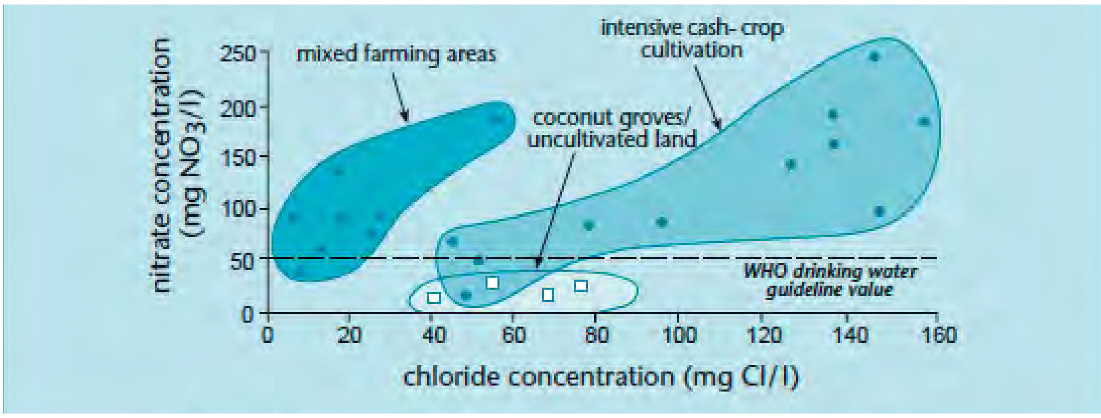
Pesticide accumulation in groundwater and surface water bodies, especially lakes and wetlands, is an increasing concern. All pesticides are designed to be sufficiently toxic and persistent to reduce populations of the weed, insect or fungal pest they are designed to control, but they can also be toxic (poisonous) to desirable plants and animals, including people. Some pesticides are so highly toxic that very small quantities can kill a person, while exposure to a sufficient amount of almost any pesticide can make a person ill. Prior to the 1980s, there was relatively little concern that water resources, especially groundwater, could be polluted by pesticides (Morris *et al.*, 2003). However, extensive monitoring campaigns in developed countries have shown an increasing presence off such compounds in surface water and groundwater.

FIGURE 2: CONE OF FAUNAL RESPONSE TO DECLINING OXYGEN CONCENTRATION



Source: Based on data from Díaz and Rosenberg (1995) and Rabalais et al. (2001).

FIGURE 3: RELATIONSHIP BETWEEN GROUNDWATER NITRATE CONCENTRATIONS AND CHLORIDE CONCENTRATIONS FOR DIFFERENT AGRICULTURAL LAND USES, KALPITIYA PENINSULA, SRI LANKA

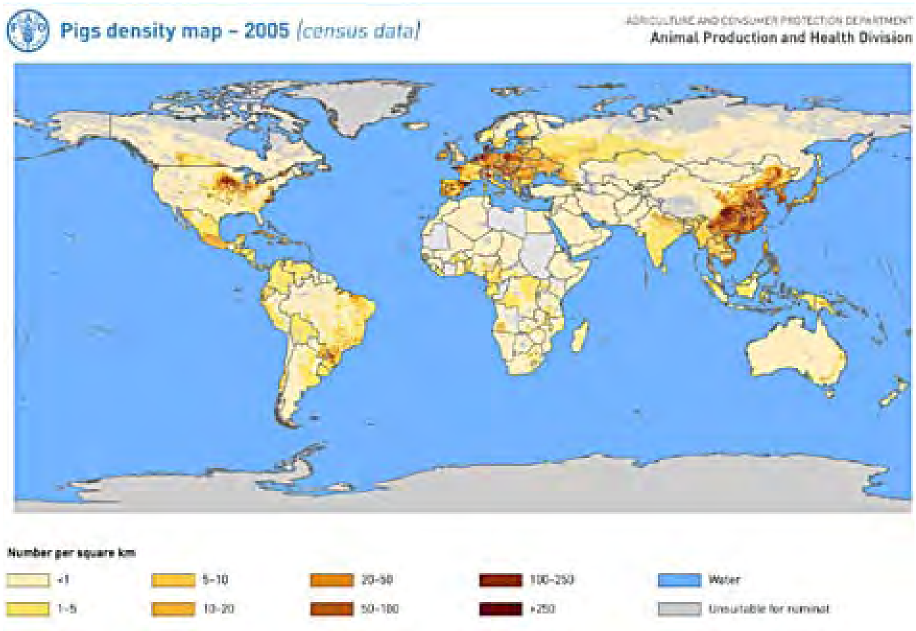


Source: from Mubarak et al., 1992

2.2.2 Drivers and causes of increasing agriculture pollution

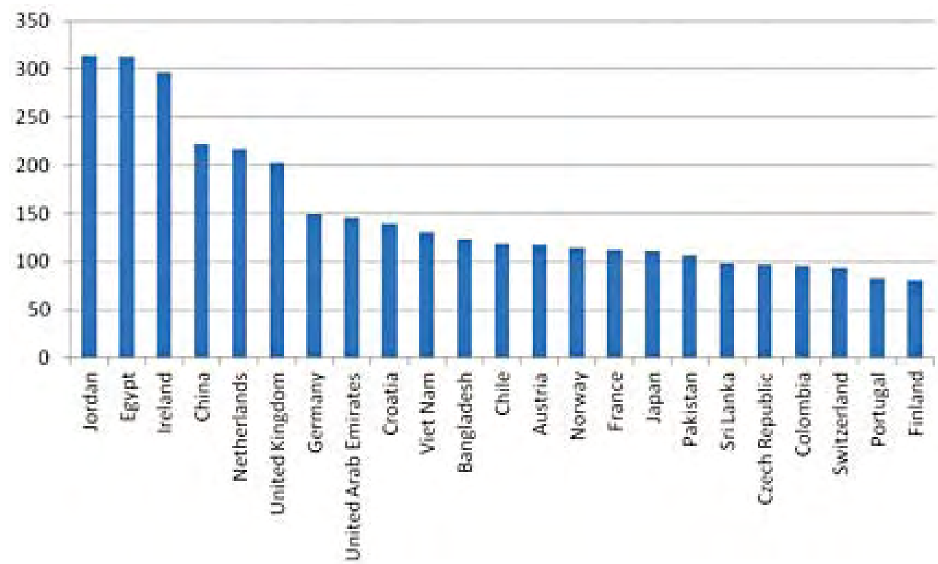
Intensification of agriculture during the second half of the twentieth century has brought enormous benefits to global food security. Agriculture productivity has been steadily increasing because of the rapid expansion of irrigation, fertilizer application and better pest control. However, intensified use of fertilizers and pesticides, and the growth of intensive livestock farming, have also had unanticipated adverse impacts on the quality of surface water resources and underlying groundwater. An indicator of this intensification process is the high concentration of pig breeding in East Asia and Europe (Figure 4) or the high consumption of mineral fertilizers per unit of cultivated area in some countries (Figure 5).

FIGURE 4: ESTIMATED PIG DENSITY WORLDWIDE (2005)



Source: FAO, 2007a

FIGURE 5: AVERAGE CONSUMPTION OF MINERAL NITROGEN FERTILIZERS PER CULTIVATED LAND (ARABLE LAND AND PERMANENT CROPS) IN SELECTED COUNTRIES IN 2002 (kgN/ha)



Source: FAOSTAT
Note: Organic fertilizers (e.g. manure) are not accounted for.

Intensified use of fertilizers has often come together with improper management and/or excessive application of nutrients. Today the link is clear between expanding and intensification of cultivated areas, increasing unit of fertilizer use and rising groundwater nitrate concentrations in developed countries. This is also of increasing concern in many emerging countries where agricultural expansion and intensification are taking place.

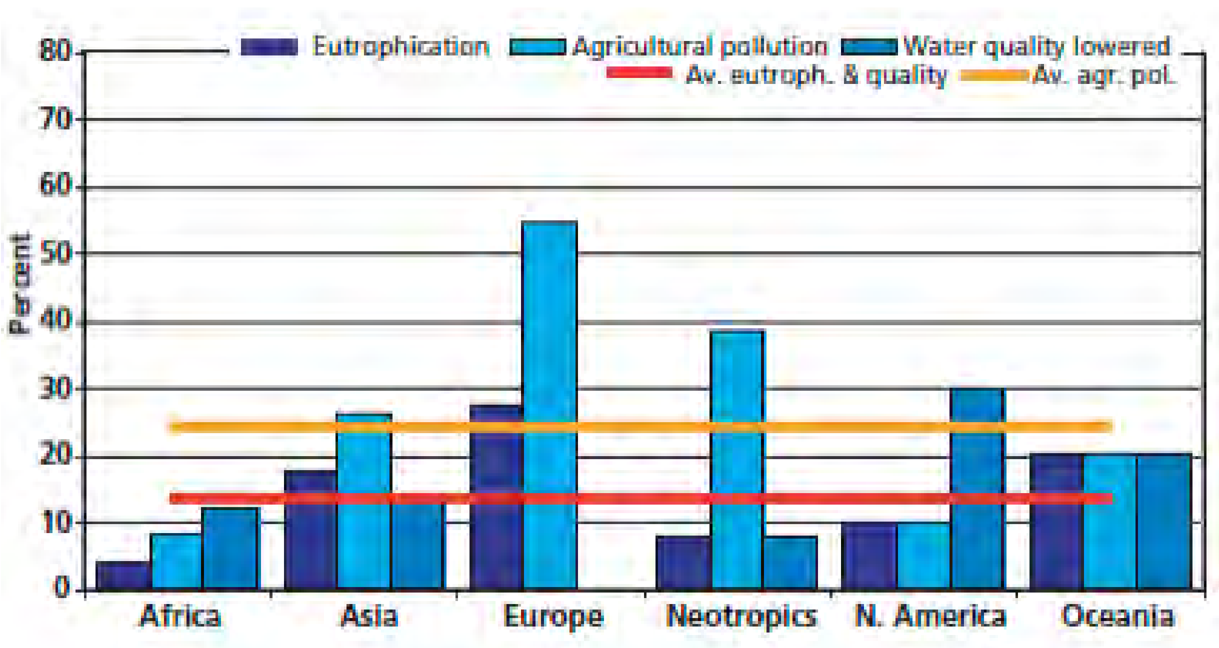
The use of pesticides has followed a similar pattern to that of nutrients with an intensified use often accompanied by improper management practices such as: (i) an improper selection of pesticides; (ii) poor pesticide storage; (iii) disposal of pesticide spray-tank washings; or (iv) landfill disposal of pesticide processing waste. So far this intensification and poor management of pesticides have primarily affected developed countries, but this is a problem that is gaining importance in developing countries, where a proper regulatory and control framework is often lacking.

2.2.3 Eutrophication and hypoxia in wetlands and coastal areas

The FAO Water Report: *Scoping agriculture-wetlands interactions* (2008b) reviewed 90 wetlands around the word and studied three different types of water quality degradation: (i) eutrophication, (ii) water quality lowered by agricultural pollution and (iii) overall lowered water quality (Figure 6). Eutrophication, regardless the driver, is a frequent trend in wetlands in Europe, Asia and Oceania. Pollution from agriculture is most severe (most frequent) in European wetlands, wetlands in Neotropics (Latin America) and Asian wetlands. Water quality degradation (regardless the source –agriculture or other-) is most pronounced for North America and Oceania. This general state change provides little insight into the origins or effects of water pollution (chemical or biochemical), however, it does indicate the presence of a water quality problem. The African cases list very few state changes for water quality/pollution, which is in line with what would be expected of the generally low (or lower) input agriculture systems.

Similarly, much of the hypoxia and anoxia in shallow coastal marine areas has developed within the last 50 years and is closely associated with anthropogenic activities. Díaz and Rabalais (2010) noted that no

FIGURE 6: PERCENTAGE OFF WETLANDS SUFFERING WATER QUALITY DEGRADATION PER REGION



Source: FAO, 2008b

other environmental variable of such ecological importance to estuarine and coastal marine ecosystems has changed so drastically in such a short period. Over time trends have been consistent for increasing severity of duration, intensity, or extent of hypoxia in areas with long-term data, for example the northern Adriatic Sea. Currently, there are over 500 hypoxia areas associated with anthropogenic activities in the world's coastal areas covering more than 245 000 km^2 of sea bottom (Figure 7).

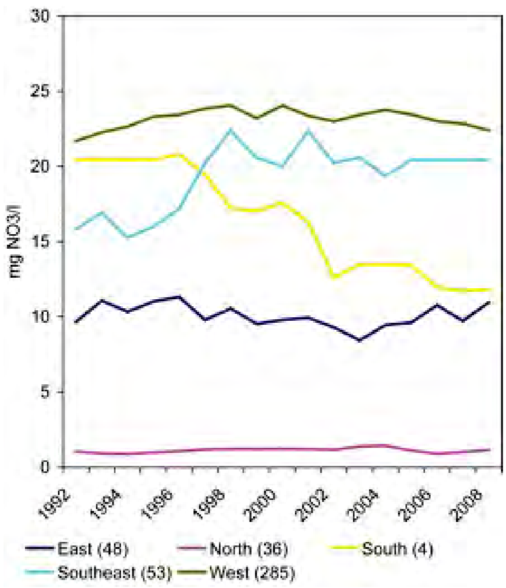
2.2.4 Nitrate in groundwater

Nitrate is the most common chemical contaminant in the world's groundwater aquifers. Nitrate in groundwater has been reported as a major problem in Europe, United States and South and East Asia. In Europe, even when mean concentrations of nitrate in groundwater have remain relatively stable in the last decades (Figure 8), nitrate drinking water limit values are exceeded in around one-third of the groundwater bodies for which

FIGURE 7: GLOBAL DISTRIBUTION OF DOCUMENTED CASES OF HYPOXIA IN COASTAL AREAS RELATED TO HUMAN ACTIVITIES, RED DOTS

Source: Rabalais et al., 2010

FIGURE 8: NITRATE CONCENTRATIONS IN GROUNDWATER BETWEEN 1992 AND 2008 IN DIFFERENT GEOGRAPHICAL REGIONS OF EUROPE.



Source EEA 2008

Note: The number of groundwater bodies included per country is given in parentheses.

information is currently available (EEA, 2008). In India the occurrence of nitrate in ground water beyond national permissible limit (45 mg nitrate/l) has been reported in hundreds of districts in 21 Indian states (CWWB, 2010). In China, according to the China Geological Survey, nitrate pollution of the shallow groundwater is widespread with almost 100% of water samples containing some level of nitrate, and with 30-60% of samples containing nitrates at levels above the national standard (20 mgN/l).

2.2.5 Pesticides pollution of water resources

According to available data in FAOSTAT, the United States is currently the country consuming the largest amount of pesticides, followed by China, Colombia and Brazil. In terms of use per unit area of cultivated area, Colombia, Costa Rica and Japan are the most intensive users of pesticides (Figure 9). Consumption and intensity of pesticides use serve as indicator of how pesticides stress water bodies. Even when pesticide consumption in developing countries represents only a small proportion of the global consumption, rates of increase in pesticide consumption are now greater in some of the more rapidly developing economies than in the developed world. This increase in the amount of pesticides consumed worldwide is counteracting the effective use of new pesticide compounds at lower dose rates.

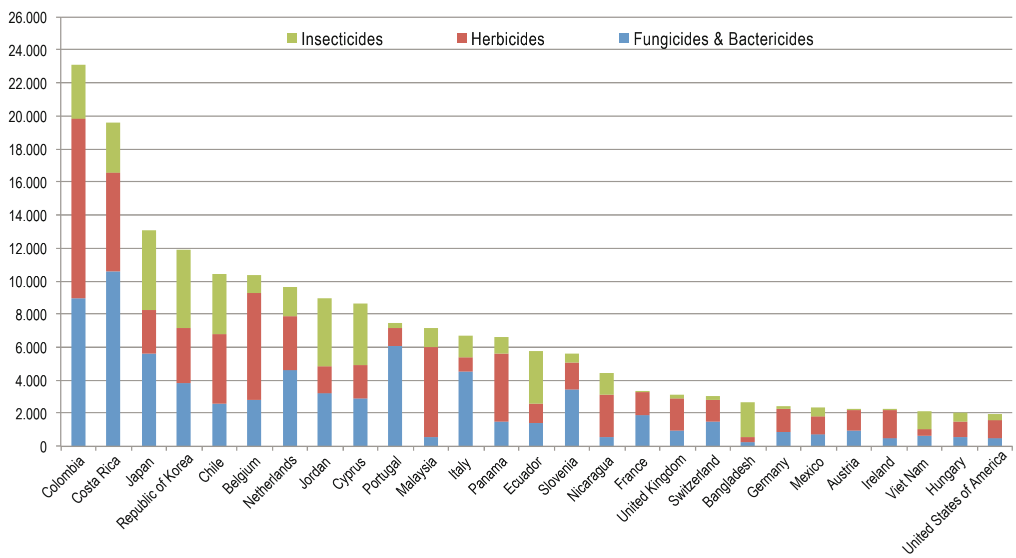
As a result of the expansion of water monitoring programmes in developed countries an increasing number of pesticides are being detected in water bodies in these countries. Table 3 shows a summary of pesticides occurring in groundwater.

2.2.6 Agriculture pollution trends

Livestock waste production and fertilizer and pesticide consumption have increased over the last 50 years worldwide, mainly because of the green revolution and especially in developed countries. Although, in the last two decades, the agrochemical consumption rate is stabilizing or even declining in some developed countries, the fast-growing developing countries are becoming the greatest users of agricultural inputs. Figure 10 shows mineral fertilizer consumption, giving trends for different regions of the world.

This increase in nutrient and pesticide loads on croplands has increased the transport through and accumulation in water systems. Figures 11 illustrates this evolution in nutrient transport taking nitrogen as an example.

FIGURE 9: CONSUMPTION OF INSECTICIDES, HERBICIDES, FUNGICIDES AND BACTERICIDES PER UNIT OF ARABLE LAND AND PERMANENT CROPS (G/HA). COUNTRIES WITH HIGHER INTENSITY USE OF PESTICIDES ARE SELECTED.



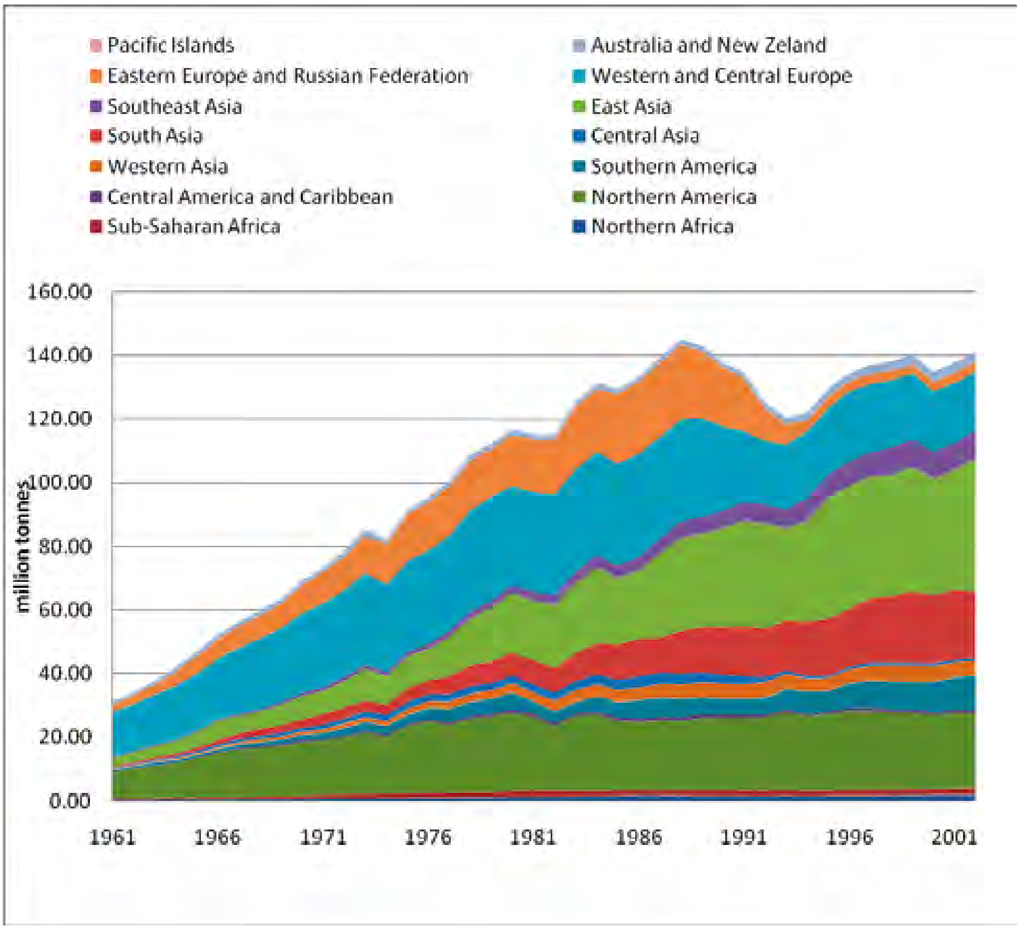
Source: FAOSTAT 2006, 2007 and other years for USA, Brazil and Malaysia.

TABLE 3: DOMINANT PESTICIDES USED AND TYPICAL COMPOUNDS DETECTED IN GROUNDWATER IN SELECTED REGIONS

Region	Dominant pesticide use	Typical compounds detected
United Kingdom	Pre- and post-emergent herbicides on cereals, triazine herbicides on maize and in orchards	Isoproturon, mecoprop, atrazine, simazine
Northern Europe	Cereal herbicides and triazines as above	As above
Southern Europe	Carbamate and chloropropane soil insecticides for soft fruit, triazines for maize	Atrazine, alachlor
Northern USA	Triazines on maize and carbamates on vegetables eg potatoes	Atrazine, aldicarb, metolachlor, alachlor and their metabolites
Southern & Western USA	On citrus and horticulture, and fumigants for fruit and crop storage	Aldicarb, alachlor and their metabolites, ethylene dibromide,
Central America & Caribbean	Fungicides for bananas, triazines for sugarcane, insecticides for cotton, and other plantation crops	Atrazine
South Asia	Organo-phosphorous & organo-chlorine insecticides in wide range of crops	Carbofuran, aldicarb, lindane,
Africa	Insect control in houses and for disease vectors	Little monitoring as yet

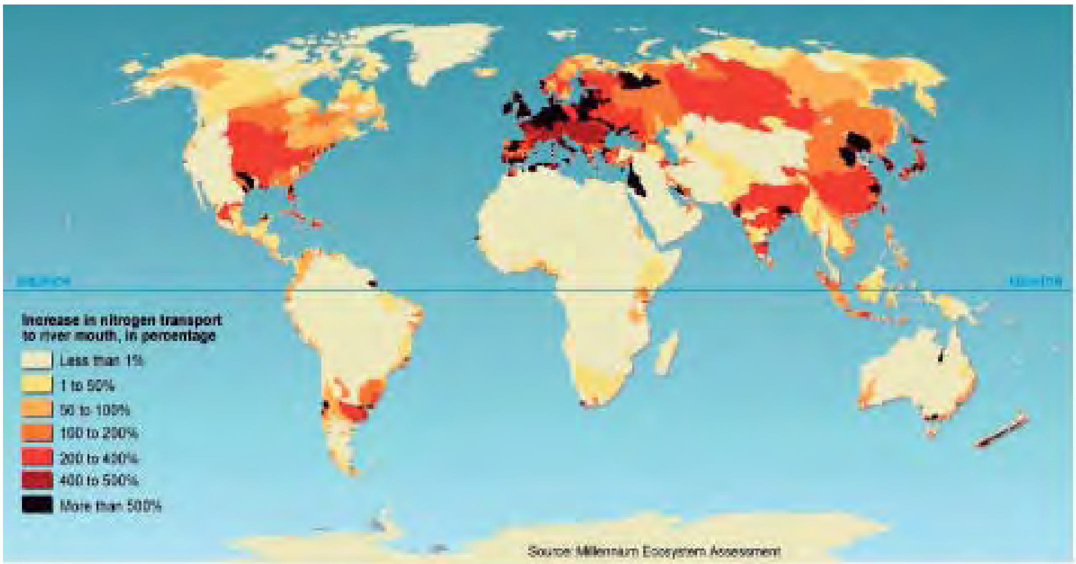
Source: Morris et al., 2003

FIGURE 10: CONSUMPTION OF MINERAL FERTILIZERS PER REGION FROM 1961 TO 2002



Source: FAOSTAT

FIGURE 11: CONTRAST BETWEEN CONTEMPORARY AND PRE-DISTURBANCE TRANSPORT OF TOTAL NITROGEN THROUGH INLAND AQUATIC SYSTEMS RESULTING FROM ANTHROPOGENIC ACCELERATION OF THIS NUTRIENT CYCLE.



Source: Millennium Ecosystem Assessment 2005

The excess of nutrient loads sometimes exceeds the capacity of natural systems to assimilate additional constituents. For example, in combination with increasing urban and industrial wastewater discharge, additional nutrient load has resulted in increasing cases of hypoxia related to human activities in coastal areas as shown in Figure 12.

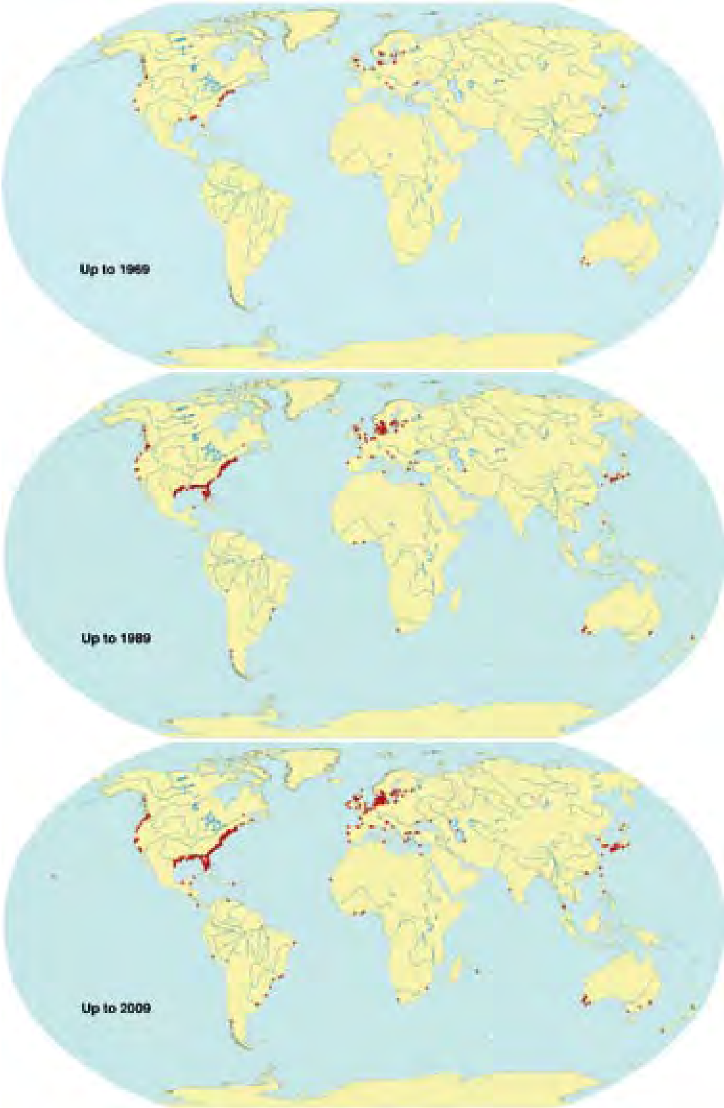
2.2.7 Remedial and preventing actions against agriculture pollution

Management to remedy pollution from agriculture should occur within broader integrated management frameworks such as Integrated Water Resource Management (IWRM) and Integrated River Basin Management (IRBM) that ensure a comprehensive overview of the problem, but specific actions need to be carried out by polluters and implemented at the relevant scales (e.g. national, regional, municipal, local, project-level).

In existing, or potential, areas that have been polluted by agriculture, strategies and action plans should include explicit analyses of a broad range of diagnosis, prevention and remedial options. The most important and comprehensive measure taken to minimize agriculture pollutant loads to water systems has been the implementation of good agricultural practices (GAP) including integrated plant nutrient management (IPNM) and integrated pest management (IPM) for the rational use of pesticides, fertilizers and proper livestock waste management practices. For these GAP to be adopted by farmers the proper policies need to be designed including regulations and education, dissemination and communication policies. FAO has produced extensive information (plant nutrition bulletins, irrigation and drainage papers, etc.) and offers important services for GAP and IPNM (available at: http://www.fao.org/prods/GAP/index_en.htm and http://www.fao.org/agriculture/crops/core-themes/theme/spi/it/). Prevention and disposal of obsolete pesticides deserves special attention since often stockpiles of old pesticides are poorly stored and toxic chemicals leak into the environment (more information in http://www.fao.org/ag/AGP/AGPP/Pesticid/Disposal/guides_en.htm).

Sustained monitoring programmes at all scales are essential. Agriculture pollution prevention policies require abundant and quality data. Water quality data are used to characterize waters, identify trends over

FIGURE 12: EVOLUTION OF DOCUMENTED CASES OF HYPOXIA RELATED TO HUMAN ACTIVITIES, RED DOTS. THE NUMBER OF HYPOXIC AREAS IS CUMULATIVE FOR THE SUCCESSIVE TIME PERIODS.



Source: Rabalais et al., 2010

time, identify emerging problems and help direct pollution control efforts to where they are most needed. In addition, where pollution control programmes are already taking place, data analysis allows assessment of the effectiveness of the programme. A good water quality monitoring programme should include a proper selection of: i) sampling sites; ii) sampling stations; iii) parameters to be monitored; and iv) the frequency and timing of sampling. Complete guidance on how to design and implement freshwater quality studies and monitoring programmes can be found in UNEP/WHO 1996. In addition, complementary information and statistics are needed on pressure indicators from agriculture such as type and extent of fertilizers and pesticides used.

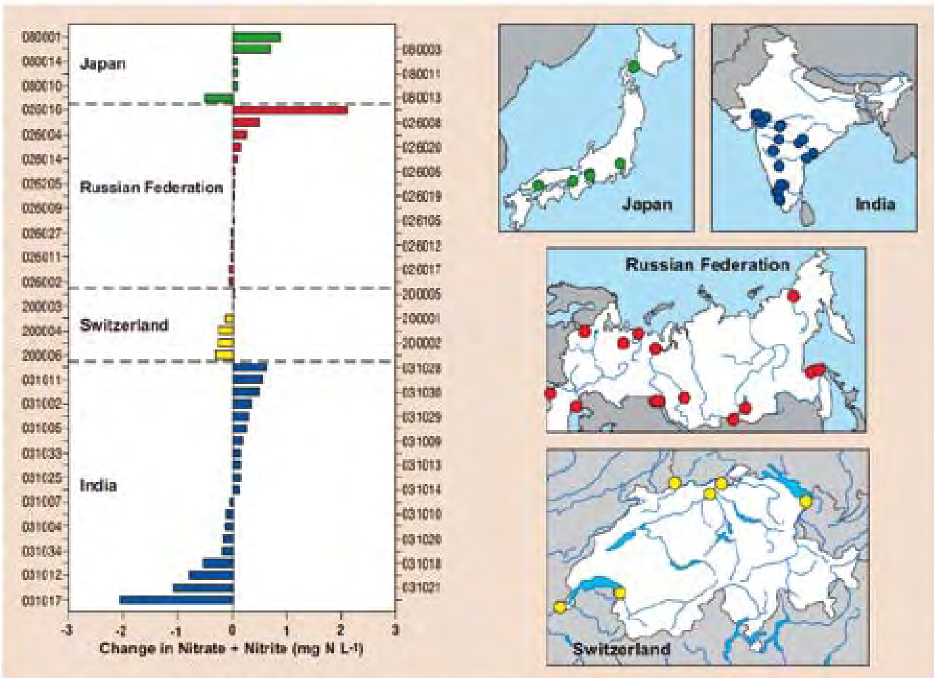
There are examples from around the world of successful policies that reduce pollution loads from agriculture. Rabalais *et al.* 2010 reported improvements in oxygen depletion conditions in many smaller systems worldwide and other examples of diminished symptoms of eutrophication through reductions in nutrient loadings (Figure 13). The UNEP-GEMS *Water quality outlook* showed changes in median nitrate concentrations in rivers between the early 1980s and the early 2000s in Japan, the Russian Federation, Switzerland and India

(Figure 14). Improvements (measured as decreases) in nitrate concentrations could be detected at most Swiss river monitoring stations and about half of the Indian river stations, whereas nitrate increased or remained the same in most Japanese and Russian river stations. The improvements in nitrate concentrations are likely to be the result of local and regional efforts to reduce pollutant loads into rivers and lakes (UNEP-GMES 2004).

FIGURE 13: LOCATION OF 38 SYSTEMS THAT HAVE RECOVERED FROM HYPOXIA (GREEN CIRCLES), PRIMARILY THROUGH MANAGEMENT AND REDUCTION OF NUTRIENT LOADS. ALL SITES ARE IN NORTHERN EUROPE AND THE UNITED STATES, EXCEPT THE BLACK SEA AND LAKE TUNIS IN THE MEDITERRANEAN SEA. BLACK DOTS ARE SYSTEMS THAT REMAIN HYPOXIC.

Source: Rabalais et al., 2010

FIGURE 14: CHANGE IN MEDIAN COMBINED NITRATE AND NITRITE CONCENTRATIONS AT RIVER MONITORING STATIONS BETWEEN 1980-1984 AND 2000-2004. POSITIVE VALUES INDICATE AN INCREASE AND NEGATIVE VALUES INDICATE A DECREASE IN COMBINED NITRATE AND NITRITE CONCENTRATIONS OVER TIME. STATION IDENTIFIERS ARE SHOWN ON THE VERTICAL AXIS.



Source: UNEP-GMES 2004

3. Marginal quality water use for agriculture

Currently, irrigation using marginal-quality water is a common practice for millions of farmers worldwide. Often these farmers do not have access to an alternative source of clean water. There are different types of marginal-quality water but the most important, in terms of number of users, are wastewater from domestic and other urban activities and saline or sodic agricultural drainage water and groundwater. Additionally, concerns about the use of arsenic-laden water in agriculture are growing. This emerging issue needs special attention.

3.1 Urban wastewater use in agriculture

3.1.1 Problem statement, concepts and definitions

As pressure on water resources intensifies, the conservation of fresh water through use of non-conventional waters, such us (treated) wastewater becomes an increasingly relevant option. Wastewater use for irrigated agriculture is especially important, particularly in urban and peri-urban areas (Figure 15). This section reviews the status and trends of wastewater use in agriculture and provides policy and management recommendations to maximize benefits and minimize the risks of such a use.

Even when no commonly shared terminology is used to refer to the different types of wastewaters and their use, Box 1 gives the definitions of terms used in this report, which are often used by many authors.

FIGURE 15: DIFFERENT SCHEMES OF DIRECT USE OF TREATED OR UNTREATED WASTEWATER

Source: FAO, 2010

BOX 1: DEFINITIONS

Types of wastewater

The term wastewater, as used in this report, include raw and diluted wastewater.

Urban wastewater is usually a combination of one or more of the following:

- Domestic effluent consisting of black water (excreta, urine and associated sludge) and grey water (kitchen and bathroom wastewater).
- Effluent from commercial establishments and institutions, including hospitals.
- Industrial effluent where present.
- Storm water and other urban runoff.

Treated wastewater is wastewater that has been processed by a wastewater treatment plant and that has been subjected to one or more physical, chemical, and biological processes to reduce its pollution or health hazard.

Reclaimed (waste) water or recycled water is treated wastewater that can officially be used under controlled conditions for beneficial purposes, such as irrigation.

Types of wastewater use in agriculture

- Direct use of untreated wastewater from a sewage outlet occurs when it is directly disposed of on land where it is used for cultivation.
- Indirect use of (un)treated urban wastewater occurs when water from a river receiving (un)treated urban wastewater is abstracted by farmers downstream of the urban centre for agriculture. This happens when cities do not have a comprehensive sewage collection network and drainage systems are discharging collected wastewater into rivers.
- Direct use of treated wastewater occurs when wastewater has undergone treatment before it is used for agriculture or other irrigation or recycling purposes.
- Planned use of wastewater refers to the conscious and controlled use of wastewater either raw (direct) or diluted (indirect). However, most indirect use happens without planning.

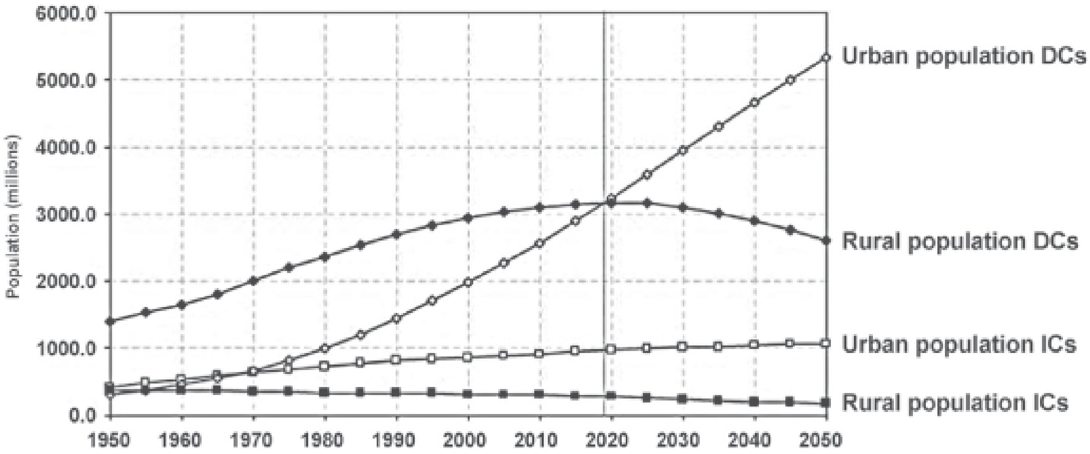
Source: Raschid Sally and Jayakody, 2008 and Jimenez and Asano, 2008

3.1.2 Factors driving wastewater use in irrigated agriculture

There are a variety of factors driving wastewater use in agriculture (physical, economic, social and political) but the main one is the lack of fresh water that, together with a high level of local water demand, leads to **water scarcity, stress and competition.** Wastewater is sometimes the only reliable available water source for agriculture as fresh water is allocated for industries and households. In arid and semi-arid regions freshwater availability is low by nature, but even in rainy regions pollution of water sources may reduce the amount of water that is safe to use. Population growth, especially in urban and peri-urban areas (Figure 16), is increasing pressure on water quality because of the growing amount of wastewater produced. Population growth is also increasing water demand both directly and indirectly through an increasing food and fibres demand. In addition, climate change is expected to lower water availability in certain areas and in certain periods. Together these factors are leading to an increasing use of wastewater in agriculture.

In developing countries direct use of untreated wastewater is also driven by **poverty**, which limits the 'coping capacity' of cities to respond to the infrastructure needs of urbanization, e.g. with comprehensive wastewater treatment. (Raschid.and Jayakody, 2008).

FIGURE 16: WORLD POPULATION FROM 1950, PROJECTED TO 2050 DCS = DEVELOPING COUNTRIES; ICS = INDUSTRIALIZED COUNTRIES



Source: United Nations (2008)

In industrialized countries and tourist areas **environmental protection and enhancement** in combination with **wastewater management needs** represent an emerging driver for direct use of reclaimed water. In areas with more stringent wastewater discharge standards, such as in Europe, United States, Australia and South Africa, water reclamation and reuse becomes a competitive alternative both from economic and environmental viewpoints.

3.1.3 Opportunities and risks

New source of fertilizers – Wastewater contains the macro and micro nutrients (e.g. nitrogen, phosphorus, potassium, calcium and magnesium) that plants need to grow. When safely used in agriculture it leads to eventual savings for fertilizer. In fact in some areas it may be the only affordable source of fertilizers for poor farmers. Therefore, the use of wastewater can be a reliable source of nutrients for urban and peri-urban agriculture, which can raise incomes, reduce poverty and improve food and nutritional security. Additionally, at the sight of the global phosphorus crisis, with a peak in global phosphate rock reserves foreseen by around 2030 (Cordell *et al* 2009), wastewater can become an alternative and relevant source of this essential nutrient.

Available all year round – Unlike rainwater or natural water courses, wastewater is a reliable source of water all year round, much less dependent on weather changes and climate variability. Urban and periurban farmers can benefit from a more reliable source of water which allows growing more crops per year resulting in increased yields and incomes for periurban farmers.

Low cost wastewater treatment – When wastewater treatment services are not provided, the use of wastewater for agriculture acts as a low-cost treatment method, taking advantage of the capacity of soil and plants to naturally remove contamination. Therefore, the use of wastewater for irrigation helps to reduce downstream health and environmental impacts that would otherwise result if wastewater was discharged directly into surface bodies.

Health risks - Wastewater often contains a variety of pollutants: salts, metals, metalloids, pathogens, residual drugs, organic compounds, endocrine disruptor compounds and active residues of personal care products. Any of these components can harm human health and the environment. (WHO/FAO/UNEP, 2006). Farmers can suffer harmful health effects from contact with wastewater, while consumers are at risk from eating vegetables and cereals irrigated with wastewater (typhoid, etc.).

Environmental risks - Wastewater use poses environmental risks, especially in relation to soil and groundwater pollution (salinization of soil, clogging, pollution of water resources, etc.). Generally, the use of domestic wastewater poses less risk to the environment than the use of industrial wastewater, especially where industries use or produce highly toxic chemicals. Industrial discharges containing toxic chemicals are mixed with domestic wastewater in many countries, creating serious environmental problems and, where the wastewater is used for crop irrigation, endangering the health of the farmers and product consumers. Efforts should be made to reduce or eliminate practices that entail the mixing of domestic and industrial wastewater, particularly where wastewater is used for agriculture.

The use of wastewater in agriculture may have both positive and negative impacts. With careful planning and management, the use of wastewater for agriculture can be beneficial to farmers, cities and the environment.

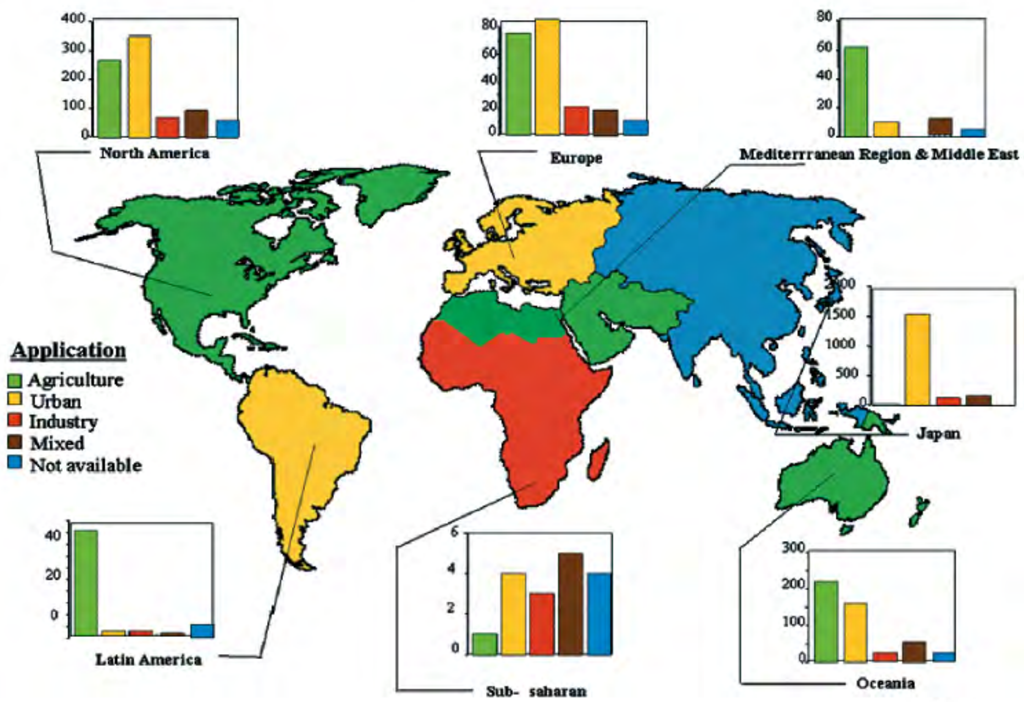
3.1.4 Regional overview

Planned versus unplanned reuse

Planned water reclamation and reuse is an already widespread strategy in developed regions and is expanding throughout the world. Figure 17 shows the results of a survey carried out during the European Commission project AQUAREC in 2003. The number of municipal water reuse schemes identified worldwide is sorted per type of reuse application. The types of application are split into five categories: 1) agricultural irrigation; 2) urban, recreational and environmental uses, including aquifer recharge; 3) processing water for industry; 4) (indirect) potable water production; and 5) combinations of the above (multipurpose).

Most of the 3 300 water reclamation facilities identified for planned water reuse are located in developed regions. For example over 1 800 were identified in Japan, over 800 in the United States, 450 in Australia and 230 in the European Union.

FIGURE 17: NUMBER OF IDENTIFIABLE PLANNED WATER REUSE SCHEMES IN SEVEN REGIONS OF THE WORLD PER TYPE OF REUSE APPLICATION



Source: European Commission, 2006

On the other hand, developing regions had fewer planned reclamation facilities: about 100 sites in North Africa and the Near East area, 50 in Latin America and 20 in sub-Saharan Africa. Those numbers are destined to become outdated quickly since many projects were identified in an advanced planning phase, and some countries such as China were not included in the survey.

Previous data do not include unplanned and indirect use of wastewater, which is a common practice in developing regions especially for agricultural purposes. This unplanned irrigation has been broadly reported in low-income countries in Africa, Latin America and Asia, but data on this regard is very scarce because of the unplanned nature of the wastewater use.

Developed and developing countries

Box 2 and Box 3 summarize the main characteristics of wastewater use for irrigation in both developing and developed regions. Information is presented on the main drivers behind wastewater use, type of guidelines followed and main approaches.

Agriculture represents an important demand on water and, as a consequence, is the biggest user of wastewater by volume among all the different uses of water. Overall, surface irrigated with untreated wastewater is substantially higher than that irrigated with treated wastewater. This is especially the case for developing and low-income countries (Jiménez and Asano, 2008).

BOX 2: OUTSTANDING CHARACTERISTICS IN DEVELOPING REGIONS

Near East and North Africa (low and middle income countries)

- The main driver of reuse is water scarcity
- Reuse performed with partially treated or untreated wastewater
- Agricultural irrigation is the main reuse activity
- WHO guidelines basically followed

Central and South Africa

- Little available information on reuse practices
- Water reuse is driven by water scarcity and a lack of sanitation
- Wastewater is appreciated as a reliable water resource and for its nutrient content
- Are starting to follow WHO guidelines but with problems

Central and South America

- Water reuse is driven by the interest in recycling nutrients contained in wastewater in poor soil areas, the lack of sanitation that make raw sewage available for irrigation, and water security in the Caribbean Islands, Mexico and Peru (water scarce countries).
- Wastewater is frequently used untreated and to irrigate crops directly or indirectly. Farmers appreciate this wastewater because it is a reliable water source, because of its nutrient content and because of its low or zero cost.
- Public policies tend to control unplanned reuse rather than promote planned use.
- Most of the countries follow WHO guidelines but have problems

Asia (middle and low income countries)

- Water reuse is driven by water scarcity, lack of sanitation and demand in high population density areas.
- Perform reuse for agriculture and aquaculture

Source: Adapted from Jimenez and Asano, 2008

BOX 3: OUTSTANDING CHARACTERISTICS IN DEVELOPED REGIONS

Europe

- Water is a scarce resource in Southern Europe (Mediterranean region) where agriculture is the main user of wastewater.
- Wastewater use in agriculture is driven by: a) water scarcity; and b) stringent effluent discharge regulations.
- European countries use either WHO Guidelines or California's Title 22 standards (see Box 4 and 5).

North America

- Reuse is only practiced in some states/provinces because of chronic and temporary water shortage, fast growing water demand in urbanized areas, stringent standards for wastewater discharge, the increased cost of mobilizing new water resources and environmental constraints.
- The first standards for water reuse in the world were established in the State of California in 1918. This legislation evolved into the Title 22 standards, which are stringent because of the high level of public health protection required by the State.
- 22 out of 50 States comprising the United States have water reuse standards. Some follow the style of Title 22 standards' but others do not
- In 2005 the United States Environmental Protection Agency released new water reuse criteria

Oceania

- Water reuse is driven by regional water scarcity and stringent effluent discharge conditions to protect ocean, coastal and surface water ecosystems.
- Australia is undertaking important water reuse programmes. It has developed a new water policy based on mandatory measures and incentives for promoting water reuse.
- Currently, reuse is increasing at a rate of 10-17 percent per year.
- Of reclaimed water used, 28 percent is for agricultural irrigation.
- Water reuse schemes have been developed with subsidies, where the recycled water cost has been set at 30 percent of the cost of potable water.

Near East and North Africa (high income countries)

- The main driver for reuse is water scarcity.
- There are water reuse schemes for agricultural and landscape irrigation.
- Use reclaimed water where there is a high demand for water (see Box 2).
- Wastewater use standards are inspired by the California Title 22.

Asia (high income countries)

- Water reuse is driven by water scarcity, demand in high population density areas, and in one case (Singapore) by international political pressure on water resources.
- Performing reuse for municipal and industrial purposes (like Japan and Korea)
- Municipal reuse is for activities requiring low quality water (like toilet flushing) but also for human consumption (only Korea)

Source: Adapted from Jimenez and Asano, 2008

BOX 4: CALIFORNIAN TITLE 22 REGULATION (STATE OF CALIFORNIA, 2000)

- Attempts to achieve near zero-risk, with relatively expensive compliance requirements.
- It is flexible: 43 uses, four treatment levels and alternative treatment is possible.
- Primarily developed in response to projects to eliminate public health risks.
- Criticized for not being a risk-based regulation and for being overly conservative.
- This approach may be applicable to countries with a strong domestic financial market like Israel, the European Union and Australia, but when a critical level of financing is not available this model cannot be considered to be of practical use.

Source: European Commission, 2006

BOX 5: WHO/FAO/UNEP GUIDELINES (WHO, 2006)

- Designed to facilitate reuse, recognizing that regulations should be realistic and able to be realized within the context they are to be applied.
- Standards criticized for being too low.
- This approach is valuable to countries with limited financial means and wastewater treatment infrastructure. In economies in transition, too strict standards would virtually ban the reuse practice but this does not necessarily stop the reuse of often even less treated or untreated wastewater.

Source: European Commission, 2006

Many high-income and water-scarce countries, especially in the Near East and the Mediterranean region, are intensively using treated wastewater for irrigation. In a number of these countries – Israel, Jordan, and Tunisia – water reuse provides the greatest share of irrigation water. Israel is the world's leader in this area, with over 70 percent of collected and treated wastewater re-used for agricultural purposes (Kanarek and Michail, 1996).

3.1.5 Common patterns

Even when use of wastewater in irrigation can be driven by many factors and the resulting schemes for wastewater use can be very heterogeneous, common patterns can be detected in different countries.

- Lack of quality water and poverty drive untreated wastewater use in urban and peri-urban agriculture.

This is a common pattern in sub-Saharan Africa and other poor regions where there is no economic capacity to afford conventional sanitation and wastewater treatment facilities. This poses health, environmental and agriculture risks if no additional measures are applied.

- Water scarcity and health and environment protection drive reclaimed wastewater use in high-income countries:

This is a common pattern in countries such as Israel, Spain, Australia or the United States (California and Florida) where highly effective sanitation and treatment technology is used in planned reclamation facilities. This is a costly approach but reduces risk almost to zero.

- Water scarcity drives treated wastewater use in emerging (middle income) countries.

This is a common pattern in areas were low cost technologies are applied providing partially treated wastewater for irrigation purposes. This approach poses moderate risks to health, environment and agriculture yield.

Different patterns and schemes for wastewater use for irrigation will require a specific approach to minimize the associated risks and maximize the potential benefits.

3.1.6 Policy and institutional framework

To maximize benefits and minimize risks related to the use of wastewater for irrigation a robust policy and institutional framework needs to be designed. In many countries, where wastewater use in agriculture takes place, these frameworks are lacking.

Policies for wastewater use can be implemented through several types of instruments: laws and regulations, economic measures, information and education programmes all focusing on treatment or non-treatment options depending on the local socio-economic conditions (Table 4).

The institutional framework on wastewater use in irrigation is especially complex since there may be a great number of institutions involved in dealing with: i) health protection; ii) agriculture; and iii) water management at different administrative levels: international, national, local. Responsibilities and the jurisdictions of the public institutions need to be clear and coordination mechanisms should be created to establish comprehensive and effective policies.

Policies on the use of wastewater for irrigation can have one or more objectives (conserve water and nutrients, maximize agricultural yields, protect public health, prevent environmental damage, meet produce quality standards for domestic and international trade...). Defining these objectives is important for developing a national policy framework. The right policies can facilitate the safe use of wastewater for agriculture.

An essential issue is to know the current institutional framework well and to identify and clarify the role (responsibilities and jurisdictions) of the different institutions (ministries, agencies…) at both national and local level.

3.1.7 Management strategies to reduce risks

Advanced treatment of wastewater before use is to eliminate health and environmental risks. This is the main approach used when planning wastewater reuse facilities in developed countries. In many developing countries, however, the cost of construction, operation and maintenance, and the lack of required skills, are the primary constraints to wastewater treatment capacity. In this situation it may be wiser to manage or minimize risk, rather than attempting to eliminate it through advanced wastewater treatment.

Minimizing health risks:

In most developing countries wastewater treatment is a long-term strategy. Interim solutions may be needed to protect farmers and public health (CA., 2007). In these countries, the focus has been on prioritizing afford-

TABLE 4: INSTRUMENTS TO IMPLEMENT POLICIES ON WASTEWATER USE IN IRRIGATION

	Laws and regulations	Plans and programmes	Economic framework	Education, social awareness and social marketing
Focus on treatment options	Especially middle to high income countries where promotion of planned use of treated wastewater is needed			
Focus on non-treatment options	Especially in low to middle income countries were controll of unplanned wastewater use is needed			

able and easily adoptable risk-management strategies. Adopting the multiple-barrier approach can reduce human and crop exposure to toxic compounds and pathogens. The 2006 WHO-FAO-UNEP 'Guidelines on the safe use of wastewater in agriculture', present a number of risk management strategies that can be implemented (Figure 18).

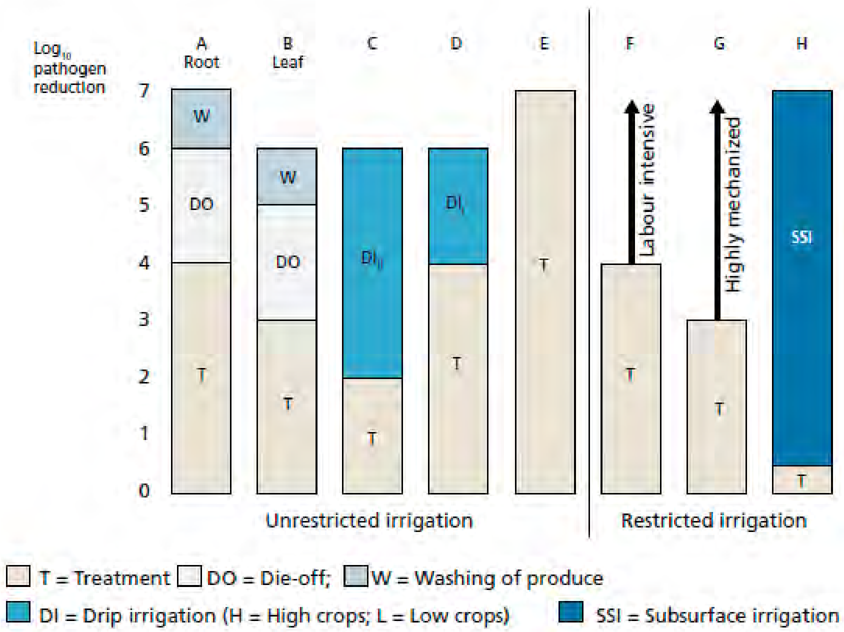
Though unpopular, *protective measures* such as wearing boots and gloves can reduce farmers' exposure. Farmers can wash their arms and legs after immersion in wastewater to prevent the spread of infection. Improvements in *irrigation methods* and in *personal and domestic hygiene* can be encouraged by public awareness campaigns. Drip irrigation can protect farmers and consumers by minimizing crop and human exposure, but pretreatment of wastewater is needed to avoid clogging of emitters. A combination of *farm-level and post-harvest* measures can be used to protect consumers, such as restricting crops to be used (industrial or inedible crops) or products that require cooking before consumption. Farmers can stop applying wastewater long before harvest, to reduce potential harm to consumers. Vegetables can be washed before sale or consumption and storage methods can be improved. Public agencies can implement child immunization campaigns against diseases that can be transmitted by wastewater use and target selected populations for periodic antihelminthic campaigns.

In many developing countries, where high-tech wastewater treatment is not feasible, treatment can be phased in by first introducing primary treatment facilities, particularly where wastewater is used directly for irrigation. Secondary treatment can be implemented in some areas by using low-cost options, such as waste-stabilization ponds, constructed wetlands and up-flow anaerobic sludge blanket reactors (Mara 2003).

Minimizing environmental risks:

Nutrients in municipal wastewater can contribute to crop growth, but periodic monitoring is needed to avoid imbalanced nutrient supply. *Periodic monitoring* is required to estimate the nutrient loads in wastewater and to adjust fertilizer applications.

FIGURE 18: OPTIONS TO REDUCE PATHOGENS ALONG THE FOOD CHAIN WITH DIFFERENT COMBINATION OF HEALTH PROTECTION MEASURES THAT ACHIEVE THE HEALTH-BASED TARGET OF (≤ 10^{-6} DALYS) PER PERSON PER YEAR.



Source: WHO/FAO/UNEP 2006

Salt levels in wastewater, even after most treatments, are often too high for unrestricted irrigation. To maintain a favourable salt balance, excess water must be able to drain from the root zone. *Good drainage* is particularly important in arid and semi-arid areas. The quality of drainage water should be controlled and must be disposed of properly.

3.1.8 Management strategies to maximize benefits

To maximize farmers' benefits several technical and market issues should be addressed:

- Selection of crops, agricultural practices and technologies:
  Raw, but also treated, wastewater has certain characteristics that might affect crop productivity and, consequently, farmers' income. For example wastewater, even after secondary treatment, typically has high salt concentration and therefore actions to prevent soil salinity and harmful effects on crops must be undertaken (see the Sections on *Actions to prevent water salinization from agriculture* and *Improving management of saline and sodic water*). Suspended solids in wastewater is another example of a constraint that needs to be managed. Suspended solids in wastewater may increase clogging of soil and of some types of drip-irrigation systems. To prevent this, the right irrigation technology and the right agricultural practice should be implemented. Especially relevant is the selection of crops and varieties that are resistant to low-quality water and salinity.
- Management of nutrients to meet crop requirements in different seasons:
  Often there is no control of the total amount of nutrients used for crop production. Farmers should periodically measure nutrient concentrations in applied wastewater or, at least should have an indication of the average nutrient content in the water being used. When farmers do not have the resources or capacity to implement this measurement they will need public support. When nutrient content in wastewater is known, farmers can better match crop requirements and the amount of nutrients applied by diluting wastewater or by adding extra fertilizer if feasible.
- Approach to market and consumers:
  Consumers are often reluctant to buy products that have been irrigated with wastewater, even when treated. Many countries using reused water for irrigation face exportation restrictions and their products have no access to more profitable markets. This is often because of a lack of confidence and cultural and religious barriers. Strengthening consumer confidence, and dismantling unjustified cultural and religious barriers, should be a priority. Certifying that crops were produced in a safe environment, with a special focus on the safe use of wastewater, would increase produce safety and the confidence of both consumers' and markets'. More information on how to create certification programmes is shown in FAO, 1997.

Farmers should be provided with specific guidelines on dealing with the above-mentioned issues and to support production and access to markets. In addition, proper dissemination and education campaigns need to be designed to facilitate the adoption of such guidelines by farmers.

3.1.9 Planning and implementation

National plans and programmes should be developed with the participation of the stakeholders involved: public agencies and ministries, farmers, service providers, NGOs, researchers and universities. This participation should include communication strategies and data collection from stakeholders to ensure their interests are covered.

Key factors such us religion, economic financial considerations, public perception, cultural barriers, psychological taboos, technical feasibility and institutional capacity needs to be considered to successfully implement wastewater use schemes.

3.1.10 Economic and financial considerations

Projects related to wastewater use for irrigation should be economically justified and financially feasible, otherwise they may fail over the long term.

The economic appraisal of a project should be from the viewpoint of the regional basin, comparing its economic costs and benefits. Although farmers may be net beneficiaries when using treated wastewater, compared with their previous and alternative sources of water, this depends very much on local circumstances and the scale of farming (smallholder farmers or large-scale commercial farming). In any event their net benefits are unlikely to offset the full cost of the scheme. On the other hand, the benefits to urban and industrial users could be sizeable and, in most cases, would be the principal justification for the project. The net impact of the project on the local and downstream environment will also be site specific, and there are likely to be both benefits and costs (FAO, 2010).

Once the basic economic justification for the project is established, the next step is to examine its financial feasibility. The distribution of the costs and benefits of the project among the different stakeholders is crucial to its feasibility. Its impact on the finances of the various stakeholders – national government, regional water authority, farmers, municipal utility and/or other major players should be assessed. Financial gainers and payers should be identified to gauge the incentives, or conversely the penalties, to be applied and the type of funding that would be appropriate. Water charges, taxes, subsidies, soft loans, environmental service payments, and other instruments could all form part of the financing proposals.

3.2 Saline, sodic and desalinated water use in agriculture

3.2.1 Problem statement

Surface runoff and subsurface drainage from agriculture systems often have higher salt content than the originally used irrigation water. This is because of excessive use of mineral fertilizers, inappropriate irrigation methods, irrigation of saline soils and leaching fractions applied. In addition, use of water resources that are considered saline or sodic is increasing worldwide as shown in Section 1.1. Salinized drainage water and groundwater are often used for irrigation purposes posing agriculture and environmental risks owing to soil salinization and water quality degradation downstream. Problems from soil salinization and sodicity are described in Section 1.1.

Desalination of salty groundwater and brackish drainage water is an available option for coping with the problem of water salinization. In addition, when seawater is desalinated, it is used to augment freshwater resources (FAO, 2006). Even if this technology is interesting the main constraint is the massive use of energy required and the associated costs.

3.2.2 Global overview

Use of saline and sodic water

Currently no overall and complete global or regional quantifications exist for saline and sodic drainage use for agriculture. Nevertheless, Figure 1 gives an idea of the extent of this practice.

The cases of Egypt and India illustrate the importance of the issue. Egypt uses approximately 5 billion m^3 of drainage water for irrigation in the Nile Delta, where drainage water and freshwater are mixed. In India, approximately 32 billion m^3 of saline and sodic groundwater are withdrawn annually for different uses, mainly for agriculture. The use of saline or sodic waters is a common practice in many other countries such as

Bangladesh, China, Iran, Pakistan, Syria, Spain or the United States, especially to irrigate salt-tolerant plants and trees, but also conventional grains and forage (CA, 2007).

Use of desalinated water in irrigation

Global desalination capacity has grown rapidly worldwide in the last 30 years (Figure 19). Figure 20 presents the share of the installed desalination capacity in terms of the process used. The multistage flash distillation process makes up the highest total production capacity of desalinated waters, followed closely by Reverse Osmosis (RO). Other processes are comparatively smaller in production capacity. Although thermal distillation plants make up about 21 percent of the world total of desalinating facilities, they produce more than half of the total desalinated waters because they are larger than RO facilities. RO is particularly appealing because recent advances in membrane technology allow for modular construction of desalinating facilities to meet small- to large-volume desalination needs (FAO, 2006). From an inventory by Wangnick (2000), seawater and brackish water make up about 59 percent and 41 percent, respectively, of the total water sources for desalination.

RO is the preferred desalination technology for agriculture uses because of the cost reductions driven by improvements in membranes in recent years.

Spain provides an important example of the application of desalinated water for irrigation. Spain has more than 300 treatment plants (about 40 percent of the total number of existing plants worldwide) and 22.4 percent of the total desalinated water is used for agriculture. Most of these plants process brackish water (only 10 percent of the total desalinated water for agriculture originates from seawater) and are located in coastal areas or within 60 km of the sea (FAO, 2003). In this country, small and medium-sized brackish-water desalination plants, with a capacity of less than 1 000 m^3/d (11.6 litres/s), are common because they adapt better to the requirements of individual farmers and to the existing hydraulic structures.

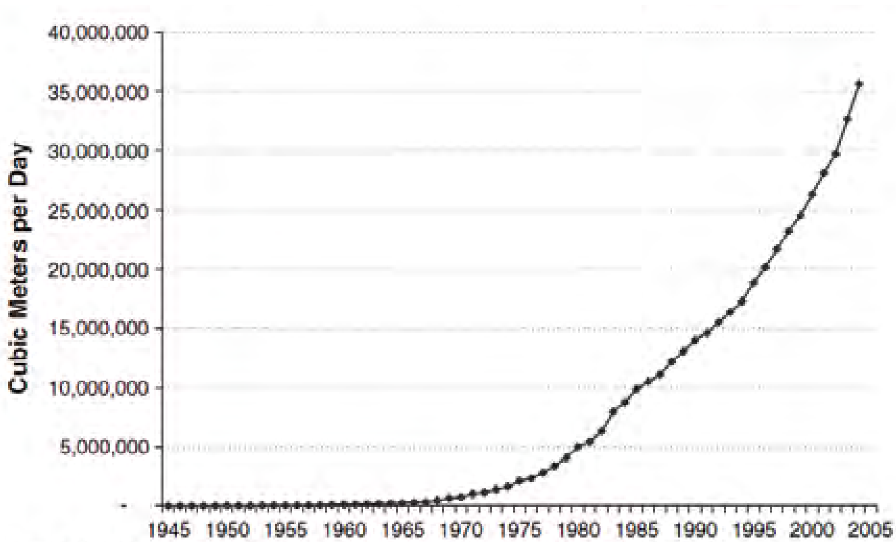
3.2.3 Improving management of saline and sodic water

When dealing with salinity it is important to bear in mind that many land and irrigation areas have varying levels of tolerance to increases in salinity. Therefore, salinity must be considered in the context of the particular asset at risk and the value of that asset. A salinity risk assessment should be carried out to determine the intensity of the actions to apply and the methods to follow. In areas identified as having a high hazard level a good salinity monitoring programme should be developed. In addition, actions to prevent farther salinization of land and water or to remedy saline or sodic soils need to be implemented.

The prevention of salinity, sodicity and waterlogging requires more efficient irrigated agriculture or effective drainage measures, or better still a combination of the two. Improved efficiency of water use has been the subject of much research by irrigation engineers and agronomists, and many techniques are now employed, of varying technical complexity and cost. An extensive description of these techniques is given by Ghassemi, *et al.*, 1995 with a detailed review of engineering options, biological options, policy options and a wide range of tools that can be used to manage and monitor salinization.

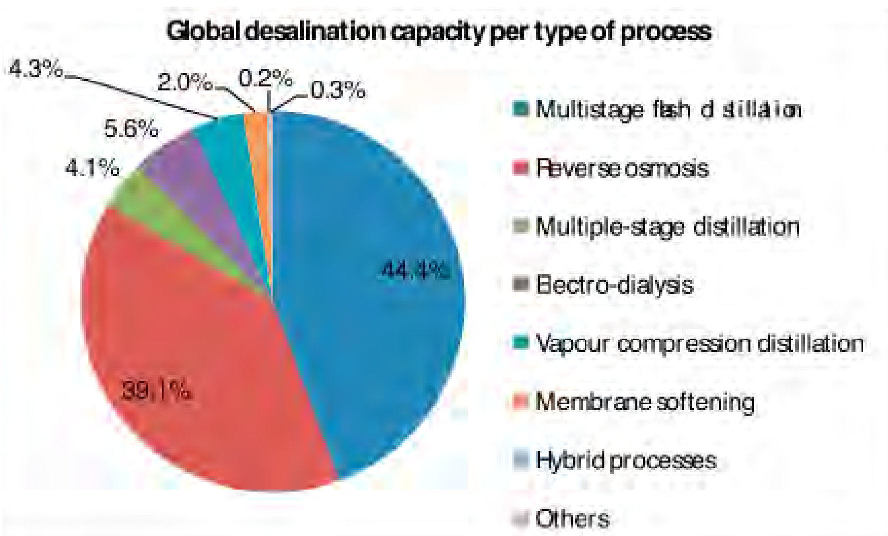
Drainage is the primary method of controlling soil salinity. A drainage system should permit a small fraction of the irrigation water (about 10 to 20 percent, the drainage or leaching fraction) to be drained and discharged out of the irrigation project. This can be achieved by open ditches, tile drains or pumping from boreholes. The choice depends on the permeability of the soil, subsoil and underlying aquifer material, on the funds available for the capital works, on the resources of local communities for operation and maintenance and the energy costs of pumping.

FIGURE 19: CUMULATIVE TOTAL CAPACITY OF DESALINATION PLANTS IN THE WORLD. 1945 TO 2004



Source: Wangnick/GWI, 2005

FIGURE 20: GLOBAL DESALINATION CAPACITY PER TYPE OF PROCESS

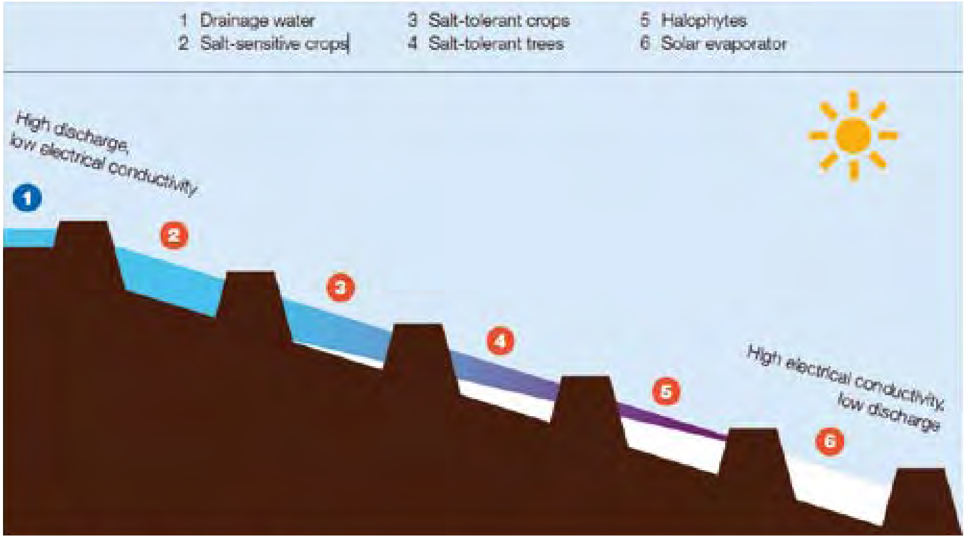


Source: Wangnick/GWI, 2000

Crop selection is another crucial issue related to salinity or sodicity management in agriculture. Crops vary considerably in their ability to tolerate saline conditions, for example durum wheat, triticale or barley tolerate higher salinity than rice or corn. Irrigation with saline water can even improve the quality of some vegetables, as the sugar content in tomatoes or melons can increase.

Saline drainage water can be reused downstream directly of blended with freshwater. These approaches would require planning at the watershed scale to adapt agriculture practices and crops to the increasing salt content after different cycles of reuse (Figure 21).

FIGURE 21: SEQUENTIAL REUSE OF DRAINAGE WATER



Source: CA, 2007

Reuse of saline water can require treatment before use. Desalination of salty groundwater, brackish drainage or even seawater is an option of increasing importance. In the past, the high cost of desalinating and the energy required have been major constraints to large-scale production of freshwater from brackish waters and seawater. However, desalinated water is becoming more competitive for urban uses because desalinating costs are declining (Table 5) and the costs of surface water and groundwater are increasing. In spite of this development, the costs of desalinated water are still too high for the full use of this resource for irrigated agriculture, except for intensive horticulture for high-value cash crops, such as vegetables and flowers (mainly in greenhouses) grown in coastal areas (where safe disposal is easier than in inland areas).

The discharge of salty drainage water may pose environmental problems to downstream areas. The environmental hazards should be considered carefully and, if necessary, mitigating measures taken (FAO, 2007b). If possible, drainage should be limited to wet seasons only, when the salty effluent inflicts the least harm. Constructed wetlands are a relatively low-cost option for protecting aquatic ecosystems and fisheries, either downstream of irrigated areas or in closed basins. The volume of drainage water requiring disposal can be reduced by treatment and cyclic reuse. Disposal options include direct discharge into rivers, streams, lakes, deserts, and oceans and discharge into evaporation basins.

3.3 Arsenic-laden water use in agriculture

3.3.1 Problem statement

Natural arsenic in groundwater at concentrations above the WHO drinking water standard of 10 µg/litre is not uncommon, and the realization that water resources can contain insidious toxic concentrations of naturally-occurring chemical constituents, such as arsenic, is fairly recent and increasingly urgent.

Sources of arsenic that have been created by people such as mineral extraction and processing wastes, poultry and swine feed additives, pesticides and highly soluble arsenic trioxide stockpiles are also not uncommon and have caused further contamination of soil and groundwater.

TABLE 5: ENERGY CONSUMPTION AND SEAWATER DESALINATION COSTS IN SPAIN

Year	Energy requirements (kWh/m³)	Costs (Euro/m³)
1970	22.0	2.103
1980	18.0	1.803
1985	15.0	1.112
1988	13.0	1.102
1990	8.5	0.961
1992	7.8	0.871
1994	6.2	0.751
1996	5.3	0.661
1998	4.8	0.528
1999	4.5	0.521
2000	4.0	0.504
2001	3.7	0.492
2002	3.5	0.428

Note: US$1 = Euro0.83 as at 27 April 2004.

Source: FAO 2003

The use of arsenic-polluted groundwater has increased considerably in the last decades, especially in Asia. In this period arsenic pollution of these water resources was unnoticed. The aim was to provide farmers with inexpensive sources of drinking and irrigation water. Thus, millions of shallow tube wells were constructed to withdraw groundwater. This had very positive effects providing farmers with water during the dry season and during periods of drought and offered an inexpensive source of drinking-water mostly free of waterborne diseases. It released, however, an enormous amount of arsenic that increased human exposure to this pollutant and posed significant health risks.

Estimates of arsenic toxicity (arsenosis) from drinking water, causing skin lesions and various types of cancers, indicate about 130 million people are impacted (Nordstrom, 2002).

Besides drinking water health risks, there is a concern about the potential levels of arsenic entering the food chain through absorption by crops from irrigated water. Widespread use of As-contaminated irrigation water ultimately leads to issues of food security, food safety and degradation of the environment through:

1. Reduced agricultural productivity resulting from As toxicity to crops (e.g. rice) and possibly to animals when high As crops (e.g. rice straw) are used for feed.
2. Constraints on land use because of arsenic build up in soils, toxicity to crops and/or unacceptable quality of agricultural products.
3. Creation of spatial variability in soil As, Fe and P levels that make agricultural management of land difficult.
4. Enhanced exposure of humans to As through agricultural products containing elevated levels of As, especially rice, and through food system and environmental pathways of arsenic, e.g. high As animal products, dermal absorption while weeding rice paddies, use of high As straw and manure as fuel.

3.3.2 Extent of the problem

Arsenic contamination in groundwater has been reported in more than twenty countries around the world (Nordstrom, 2002) and, in many, shallow groundwater is used for both drinking and irrigation, potentially exposing millions of people (Table 6).

TABLE 6: GLOBAL ARSENIC CONTAMINATION IN GROUNDWATER (NORDSTROM 2002)

Country/ region	Potential exposed population	As concentration in groundwater (µg /liter)	Environmental conditions
Bangladesh	30,000,000	<1 to 2,500	Natural; alluvial/deltaic sediments with high phosphate,* organics
West Bengal, India	6,000,000	<10 to 3,200	Similar to Bangladesh
Vietnam	>1,000,000	1 to 3,050	Natural; alluvial sediments
Thailand	15,000	1 to >5,000	Anthropogenic; mining and dredged alluvium
Taiwan	100,000 to 200,000	10 to 1,820	Natural; coastal zones, black shales
Inner Mongolia	100,000 to 600,000	<1 to 2,400	Natural; alluvial and lake sediments; high alkalinity
Xinjiang, Shanxi	>500	40 to 750	Natural; alluvial sediments
Argentina	2,000,000	>1 to 9,900	Natural; loess and volcanic rocks, thermal springs; high alkalinity
Chile	400,000	100 to 1,000	Natural and anthropogenic volcanogenic sediments; closed basin; lakes, thermal springs, mining
Bolivia	50,000	-	Natural; similar to Chile and parts of Argentina
Brazil	-	0.4 to 350	Gold mining
Mexico	400,000	8 to 620	Natural and anthropogenic; volcanic sediments, mining
Germany	-	<10 to 150	Natural: mineralized sandstone
Hungary, Romania	400,000	<2 to 176	Natural; alluvial sediments; organics
Spain	>50,000	<1 to 100	Natural; alluvial sediments
Greece	150,000	-	Natural and anthropogenic; thermal springs and mining
United Kingdom	-	<1 to 80	Mining; southwest England
Ghana	<100,000	<1 to 175	Anthropogenic and natural; gold mining
USA and Canada	-	<1 to >100,000	Natural and anthropogenic; mining, pesticides, As_2O_3 stockpiles, thermal springs, alluvial, closed basin lakes,various rocks

Source: Nordstrom 2002

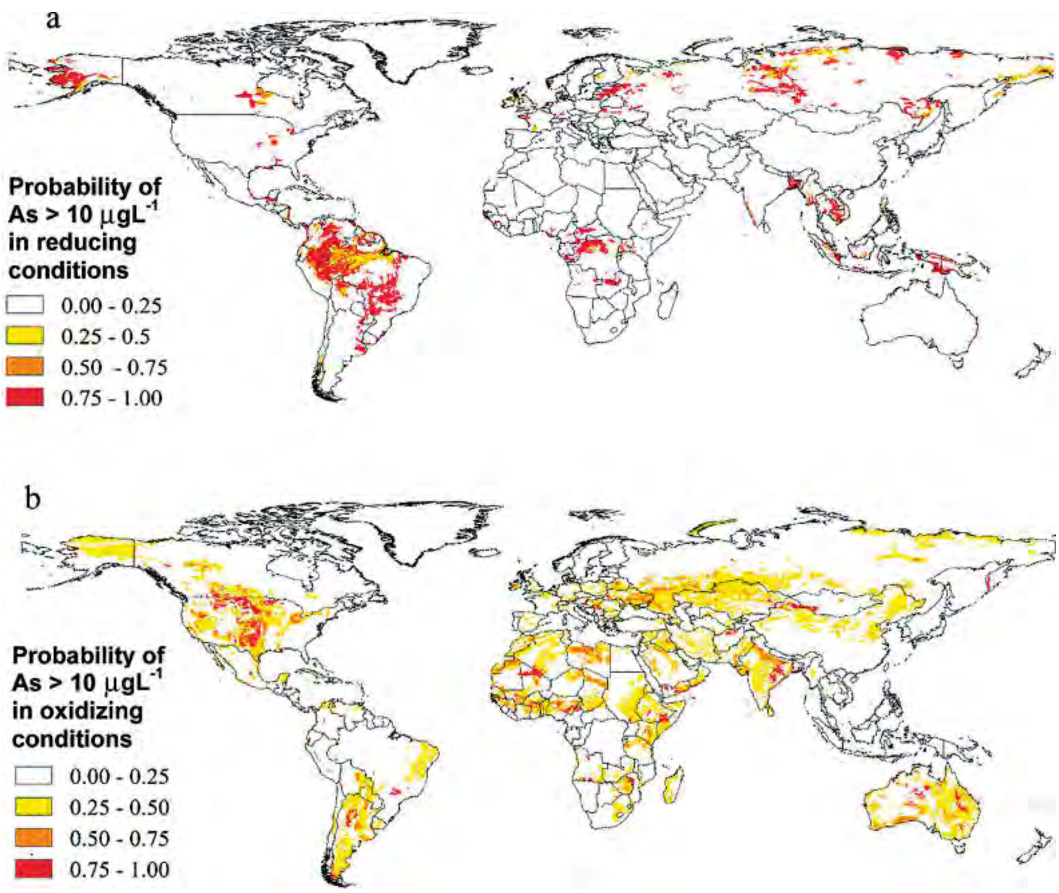
Although the main geochemical mechanisms of arsenic mobilization are well understood, and important cases have been reported around the world (Table 6) the real worldwide scale of affected regions is still unknown.

Amini *et al.*, (2008) conducted a study using a large database of measured arsenic concentrations in groundwater (around 20 000 data points) from around the world as well as digital maps of physical characteristics such as soil, geology, climate, and elevation to model probability maps of global arsenic contamination. (Figure 22). The probability maps based on modelling the above information correspond with the known contaminated regions around the world and delineate new untested areas that have a high probability of arsenic contamination. Notable among these regions are Southeast and Northwest China, central Australia, New Zealand, northern Afghanistan, and northern Mali and Zambia.

3.3.3 Knowledge gaps and remedial actions

Considerable effort has been made to study and develop practical and acceptable water treatment systems for rural households but remedial actions to reduce exposure to As through the food chain is less understood and controlled. This is an emerging issue and important knowledge gaps need to be filled (Box 6).

FIGURE 22: MODELED GLOBAL PROBABILITY OF GEOGENIC ARSENIC CONTAMINATION IN GROUNDWATER FOR (A) REDUCING GROUNDWATER CONDITIONS, AND (B) HIGH-pH/OXIDIZING CONDITIONS WHERE ARSENIC IS SOLUBLE IN ITS OXIDIZED STATE.



Source: Amini. et al., 2008

BOX 6: IDENTIFIED As KNOWLEDGE GAPS FOR ASIA

- The extent of using As-contaminated groundwater resources for irrigation in Asia has not been quantified.
- The scale of As accumulation in topsoils from As-contaminated irrigation water in Asia is unknown.
- The scale of land degradation caused by irrigation with As-contaminated water is unknown.
- Factors determining As accumulation in soils are not sufficiently understood and quantified.
- The relationship between As in water, soil and plants has not been quantified.
- Few management options have been developed to prevent and mitigate As-contamination of agricultural land.
- Uptake and toxicity of As in crops currently cannot be predicted.
- Limited knowledge is available about the differences between plant species and cultivars in As uptake, sensitivity, translocation and speciation.
- There is no plant toxicity data representative of the field situation.
- There is no insight into the risks of As in water and fodder for livestock and their food products.
- There are no policies concerning the use of As-contaminated groundwater for irrigation.
- Only limited data on inorganic As in rice, vegetables and other foods are available.
- The uptake efficiency/bio-availability of As in rice and other foods after consumption is largely unknown.
- The provisional tolerable daily intake for dietary inorganic As intake is still provisional 18 years after issuance, indicating uncertainties about the acceptable level.
- Globally, except for China, no food safety standards for inorganic As in foods have been found.
- A reliable and representative human health risk assessment for As in foods cannot be made at this stage.
- Data from countries other than Bangladesh for (inorganic) As in irrigation water, soil, crops and foods are very limited.
- Data on As in livestock and freshwater fisheries are so far insufficient to make any statement on the risks of As to animal health and the safety of food products from these sectors.

Source: Heikens, 2006

Most importantly, the scale of the problem needs to be better quantified. This should be based on scientifically justified methodologies resulting in reliable results, conclusions and recommendations. Close involvement of stakeholders from different sectors is necessary to optimize integrated and cross-sectoral programme coordination and implementation, which should include data sharing, human resources, funding and optimize the dissemination and integration of the outcomes in strategic planning and programming, thus ensuring sustainability.

Finally, it is worth mentioning that management options are being developed and successfully tested to prevent and mitigate As-contamination of agricultural land. For example, strategies to manage arsenic would enable rice production in Bangladesh to continue, which is so far the most arsenic exposed country (FAO, 2007c). Other strategies include:

1. Growing rice in an aerobic environment where As is adsorbed on oxidized Fe surfaces and is largely unavailable to rice.
2. Switching from As-contaminated shallow groundwater to uncontaminated surface or deep groundwater to avoid further build up of soil As. Unfortunately, the surface water option is limited and generally requires large irrigation development projects.
3. Identification or development of arsenic tolerant rice varieties, where arsenic uptake is also low.

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Review Article

A review of municipal solid waste environmental standards with a focus on incinerator residues

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Abstract

Environmental issues are often neglected until a lapse in the care for environment, which leads to serious human health problem, would then put regulation gaps in the spotlight. Environmental regulations and standards are important as they maintain balance among competing resources and help protect human health and the environment. One important environmental standard is related to municipal solid waste (MSW). Proper MSW management is crucial for urban public health. Meanwhile, the sustainability of landfills is also of concern as increasing volumes of MSW consume finite landfill space. The incineration of MSW and the reuse of incinerated residues help alleviate the burden on landfill space. However, the reuse of MSW incinerator residues must be regulated because they may expose the environment to toxic heavy metal elements. The study of environmental standards from different countries applicable to MSW is not widely published, much less those for incinerated MSW residue reuse. This paper compares extant waste classification and reuse standards pertinent to MSW, and explores the unique recent history and policy evolution in some countries exhibiting high environmental regard and rapid changes, so that policy makers can propose new or revise current MSW standards in other countries.

Keywords: Municipal solid waste; Environmental regulation; Incinerator residues; Leaching standard; Leaching criteria

Contents

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1. Introduction

An important purpose of environmental regulations is to regulate the use of resources to ensure minimal impact on the environment and human health. As the economy grows and income rises, the increased demand for natural resources and manufactured consumer goods has put strains on the environment (Swanson, 2008). Subsequently, the amount of solid waste generated increases in parallel to economic development, due to excessive consumerism. According to the United States Environmental Protection Agency (USEPA), solid waste that is not properly managed poses risk to human health and the environment by contaminating water, attracting insects and rodents, increasing flood due to blocked drainage of canals or gullies, among others (USEPA, 2002). Wastes can be classified as municipal solid waste (MSW), medical waste, hazardous waste, industrial waste, or radioactive waste (Links, 2006).

MSW is of particular concern in developing economies, as a significant portion of the population there does not have access to a waste collection service (Schübeler, 1996). Therefore, MSW management can have important consequences for public health, well-being, and sustainability. In the US, most of the MSW is handled in one of the three ways: landfilling (53.8%), recycling (34.5%), and incineration (11.7%) (USEPA, 2012). Although the incineration rate is still low in some countries, the reuse and recycle of incineration ash can greatly lower disposal burdens of MSW and provide valuable materials to countries that have limited natural resources (Huang et al., 2006). One of the benefits of incineration is volume reduction in waste, which alleviates limited landfill space, providing extra source of energy from combustion, and the potential recycling of incinerator residues. There are more than 200 waste-to-energy plants in 14 European countries, managing about 23% of MSW in these countries, and 89 waste-to-energy plants operating in 27 states in the US (Ornebjerg et al., 2006).

Generally, there are two types of MSW incineration ash, which are the remaining residues after burning: bottom ash (IBA) that remains after combustion on the grate and fly ash (IFA) that is removed from exhaust flue gases (Huang et al., 2006). Millions of tons of IBA are produced worldwide each year, and varying portions of them are recycled for structural applications. In Germany, over three million tons of IBA were generated, two million tons of which were reused in 2003 (Ornebjerg et al., 2006). On the other hand, Denmark, having recycled only slightly more than half a million tons of IBA in the same year, had a high IBA reuse rate of nearly 98% (Ornebjerg et al., 2006). These and other statistics are shown in Table 1. Numerous studies have been conducted on the assessment of reusing incineration ash (Chang et al., 1999; Erdem et al., 2011; Tang et al., 2014) and found it suitable as secondary construction material (Cai et al., 2004). IBA can also be reused as road bases and dye adsorbents (Lam et al., 2010). IFA is seldom reused due to its hazardous nature. In fact, IBA cannot be reused unless it meets the environmental regulations set out in individual countries.

The proper reuse of IBA as a new resource requires environmental regulations. The MSW environmental

Table 1
Incineration bottom ash quantities in selected countries (Ornebjerg et al., 2006).

Country	Tons of ash available per year (2003)	Tons of ash reused per year (2003)	Percent of ash reused (2003) (%)
Denmark	644,626	629,278	97.6
France	2,995,000	2,366,000	79.9
Germany	3,140,000	2,025,700	64.5
The Netherlands	1,075,000	950,000	88.4
United Kingdom	725,000	410,000	56.6
United States	9,000,000	500,000	5.6

standards covered in this review paper come from the European Union, the Netherlands, Denmark, the United States, Taiwan, and China. These countries either have advanced stages of waste management programs and policies, as in the case of European countries and the US, or the potential of growth in Asia as illustrated by Taiwan and China. The scope of coverage of environmental standards in this paper is limited to environmental standards pertaining to incinerated waste management. Specifically, inorganic contaminants in leaching limit criteria are discussed. As far as the authors of this paper know, there are no comprehensive, widely published evaluation criteria for the reuse of incinerated waste available. Furthermore, even when criteria are published, the rationales for the standard criteria are often not given (Barnett and O'Hagan, 1997). Huque and Watton (2009) attempt to explain environmental management policy differences in Canada and the United States by their different federal government structures and historical developments, but there is no analysis of such standards available. Compiling data and rationale from different countries is also difficult for researchers because primary sources of data are often not available in English. The objective of this paper is to compile environmental standards from countries with well-published environmental practices and standards, so as to be a source of reference for decision makers to formulate solid waste environmental standards. The standards presented in this paper may also become relevant in the future as incinerator residue treatment technology becomes more prevalent, and guidelines are needed to evaluate treatment effectiveness.

2. Environmental standards

2.1. Environmental standard principles

Decision makers face environmental, technological, economical, and political constraints in setting environmental standards (Blok and de Groot, 2004). Environmental standards are set to protect the environment from the negative effects of anthropogenic activities. However, other considerations must be taken into account to ensure successful implementation. For example, technology should be available to treat the waste as per the regulations and the standards should make economic sense for the industry to follow. Current environmental legislation in different countries is guided by their own set of principles (Streffer and Cansier, 2003). Table 2 summarizes the key features of some current guiding principles for setting environmental standards (Barnett and O'Hagan, 1997). The prudence avoidance principle has been adopted in Australia, Sweden, and several US states (Kheifets et al., 2001). The "As Low As Reasonably Achievable" (ALARA) principle plays an important part in the enforcement of environmental law in the Netherlands (Faure and Ruegg, 1994). At the European level, the "Best Available Technology Not Entailing Excessive Cost" (BATNEEC) principle is used (Faure and Ruegg, 1994).

2.2. Country statistics and environmental regulations overview

No two countries share identical circumstances in terms of political regime, industrial policy, major type of

Table 2
Different principles of setting environmental standards (Barnett and O'Hagan, 1997).

Principle	Features
"Safe" Levels	• Pollutant levels are set to levels deemed to be safe • Definition of "safe" not defined • Aspires to maximum safety benefit without regard to cost
Prudent Reduction	• A particular pollutant level is set at some "worthwhile" reduction from present levels • There is recognition that a "safe" level may not be identifiable
Precautionary Principle	• Broadly applied general principle • Recommendation to consider action to avoid possible harm even if it is not certain to occur (WHO) • High level of protection taking into account the diversity of situations in the various regions of the Community (under the context that the principle is formally a part of EU law) • Take action to avoid potentially damaging impacts of substances that are persistent, toxic and liable to bioaccumulate even where there is no scientific evidence to prove a causal link between emission and effects (definition given at the third North Sea Conference in 1990)
Best Available Technology Not Entailing Excessive Cost (BATNEEC)	• Recognizes that if a "safe" level exists it is likely to be too costly to achieve • The cost of standard is clear and reasonable • Technology should be "best" at preventing pollution and "available" to operator of activity concerned ("The effectiveness of policy instruments for energy-efficiency improvement")
As Low As Reasonably Achievable (ALARA)	• Broadly applied general principle • Any procedures for controlling pollutant levels should employ the latest and best technological aids to achieve outcomes that are ALARA • ALARA levels are implied to ensure safe or prudent levels and that more than this cannot be expected from the pollutant • Major application in radiation risk and protection

industries, geography, and the nature of their hazardous waste problem (Probst and Beierle, 1999). Similarly, they need different considerations for environmental standards. Countries with a high population density and a low percentage of arable land have the most to benefit from the reduction in landfill use, and the reuse and recycle of solid waste. For example, in the US, incineration tends to be the practice in land-scarce jurisdictions, and landfilling is the dominating practice in land-rich jurisdictions (U.S. International Trade Commission, 2004). This also tends to be the pattern in the countries listed in Table 3. Japan and South Korea both have high population densities (persons per square kilometer), at the same time they have a low arable land as a percentage of total land. Japan and South Korea also have high incineration plant densities, as measured by the number of incineration plants per one million people. Meanwhile, Taiwan has the second highest MSW incineration rate and the second highest population density as shown in Table 3. Another factor is a country's openness to trade; developing countries that are more open to trade are, for competitiveness reasons, significantly more reluctant to ratify international environmental agreements (Spilker, 2012). Countries listed in Table 3 are mostly developed countries, but China, still considered as a developing country, ranks 57 out of 75 by its Open Markets Index. A country can also be characterized by its environmental regulatory performance. The Environmental Regulatory Regime Index (ERRI) represents a summary of performance measure of the quality of the environmental regulatory system in a country. It comprises measures of various aspects of the regulatory system, including standards, implementation and enforcement mechanisms, and associated institutions. The greater the ERRI in a particular country, the more the concern that country has for environmental quality. Moosa et al. (2014) use the EERI to see the correlation between economic freedom and environmental performance. Among the countries examined here, the Netherlands, Germany, and Singapore have high environmental regulatory systems in place. These examples illustrate that it is worthwhile to learn about the unique situations of a country when analyzing a country's environmental policies and regulations.

Each country's national legislative and regulatory framework for solid waste management delineates roles and responsibilities in its respective levels of government (Hoornweg et al., 2005). In addition, studying how and to what extent regulations are derived from laws can give insights to policy analysts into effectiveness of environmental programs and where inefficiencies lie, and can provide lessons for countries wishing to start or review their environmental regulations. The development of a legal framework comprises two regulatory actions: the enactment of a formal legal instrument e.g. an act, ordinance, or decree, and the development of regulations, rules, and orders by the authority designated in the formal legal instrument (World Health Organization, 1987). Table 4 lists formal legal instruments and subsidiary regulations for environmental protection for some major countries. The listed legal instruments represent significant legal efforts to protect environmental and public health within their respective country, and some of them will be highlighted in Sections 2.3.2–2.3.6. It is also interesting to note that, from Table 4, significant formal legal instruments had been effective in Denmark, the US, Taiwan, and Japan since the 1970s, when environmental awareness became more prevalent.

2.3. Compilation of solid waste environmental standards and discussion

2.3.1. European Union waste acceptance criteria

2.3.1.1. Background information. The European Union (EU) has a clear and defined objective in waste management. Its long-term goal is to become a recycling society, avoiding waste, and using unavoidable waste as a resource wherever possible (European Commission, 2010). Through a combination of member state politics, regulatory politics, and international market competitiveness, the EU attempts at legitimizing the precautionary principle, and establishing international credibility, which contributes to its progression in environmental protection policies (Kelemen, 2007).

In the 1970s, the EU adopted the Waste Framework Directive and the Hazardous Waste Directive as a response to individual Member States that were taking action to control and manage waste (European Commission, 2005). Then in 1989, international outrage as a result of uncontrolled shipping of hazardous waste to developing countries and to Eastern Europe led to the adoption of the Basel Convention (European Commission, 2005). The Basel Convention aims to, among other objectives, reduce hazardous waste generation and restrict transboundary movements of hazardous wastes (Secretariat of the Basel Convention, 2011). In 2001, the Landfill Directive was adopted to address problems of pollution from incinerators, landfills, and recycling plants (European Commission, 2005). Today, the Waste Framework Directive, the Hazardous Waste Directive, and the Waste Shipment Regulation (adopted in 2006) form the basis of the regulatory structure on waste in the EU (European Commission, 2005). Since EU legislative power derives from the European Economic Community treaty, and as a supranational organization to which member states have ceded special administrative and legislative powers, the waste regulatory structure basis applies to Member States (Neumann, 2010). This has helped protect the environment and human health across the European Community (European Commission, 2005). Fig. 1 summarizes the historical trend on waste directives in the EU.

As for the reuse of solid waste in construction applications, the waste acceptance criteria (WAC) have been established in Europe, but there are no European limits especially for construction products. While the recycling of MSW incineration ash is widely practiced, management practices for incinerator residues vary in different

Table 3
Country statistics (top 3 extreme values bolded).

Country	Population (millions)	Population Density (persons per km^2)	Arable Land (% of total land area)	Incineration Plants/ Incineration Plant Density Per 1 Million People	MSW Incineration Rate	MSW Recycling Rate	Open Market Index Ranking (out of 75)	ERRI	Source
The Netherlands	16.8	498	30.0%	10/0.60	38%	51%	**6**	**1.747**	The World Bank (2015) Johnke (2002) Confederation of European Waste-to-Energy Plants (2013) European Environment Agency (2013) International chamber of Commerce (2013)
Denmark	5.6	132	57.0%	29/**5.15**	**54%**	42%	**15**	1.384	The World Bank (2015) Rambøll (2006) Confederation of European Waste-to-Energy Plants (2013) European Environment Agency (2013) International chamber of Commerce (2013)
Germany	81.3	231	34.0%	59/0.73	37%	**62%**	22	**1.522**	The World Bank (2015) Johnke (2002) Confederation of European Waste-to-Energy Plants (2013) European Environment Agency (2013) International chamber of Commerce (2013)
United States	319.0	35	17.0%	112/0.35	11.7%	34.5%	38	1.184	The World Bank (2015) Tangri (2003) USEPA (2012) International chamber of Commerce (2013)
Taiwan	23.4	**649**	24%	24/1.03	**55.8%**	42.5%	27	Not available	CIA (2014) Tsai (2014) Tsai and Kuo (2010) International chamber of Commerce (2013)
Japan	126.1	349	**11.6%**	1,320/**10.47**	**77%**	19.6%	39	1.057	The World Bank (2015) Kawamoto (2008) Tanaka et al. (2005) United Nations Environment Programme (2010) International chamber of Commerce (2013)

South Korea	50.3	**516**	15.6%	712/**14.14**	20%	**60.5%**	45	−0.121	The World Bank (2015) Ng (2013) International chamber of Commerce (2013) Legislative Council of Hong Kong (2013)
Singapore	5.5	**7,713**	**0.9%**	4/0.73	36%	**54%**	**2**	**1.771**	The World Bank (2015) Ryu and Shin (2013) International chamber of Commerce (2013)
China	1,357	145	**11.3%**	0.087	20%	3%	57	−0.348	The World Bank (2015) National Development and Reform Commission of the People's Republic of China (2012) International chamber of Commerce (2013)

jurisdictions, and there is still need for legislation on recycling of waste incinerator residues at the EU level (Van Garven et al., 2006).

2.3.1.2. EU WAC standard. The Landfill Directive of 1999 defines the different categories of waste, among other matters. It is a minimum directive, and EU member states can set stricter criteria nationally. The European Council Decision 2003/33/EC (published in January 2003 and taking effect in July 2004), on the other hand, lists the WAC for the different categories of waste: inert wastes, non-hazardous wastes, hazardous wastes acceptable in non-hazardous landfills, and hazardous wastes acceptable in hazardous waste landfills, pursuant to the Directive of 1999. These criteria are listed in Table 5.

The concept behind the WAC is that leaching should not result in an unacceptable increase in key pollutant concentrations in the groundwater downstream the landfill. The procedure for setting the WAC consisted of several consecutive steps. First, the point of compliance (POC) was set to be the groundwater quality 20 meters downstream the landfill (Hjelmar et al., 2005; Christensen, 2010). Quality criteria were then set for the peak concentrations of contaminants in the groundwater based on existing European groundwater or drinking water legislation. The release of contaminants from the source can be expressed as a function of liquid-to-solid ratio (L/S), and the transport of contaminants from the landfill through soil and into the groundwater can be modeled based on contaminant-subsoil sorption. Using the contaminant release and transport models, forward calculations could be done for the concentration at the POC for each contaminant. An attenuation ratio, $\frac{\text{source peak concentration}}{\text{forward-calculated peak POC concentration}}$, was used to back calculate permissible values at the source from the groundwater quality criteria at the POC for each contaminant. The source term criteria could then be transformed into limit values for a specific leaching test and L/S value (Christensen, 2010).

As shown in Table 6, the implementation of EU requirements related to acceptance criteria area is achieved in the majority of EU-15 Member States. In the Netherlands, Portugal, and the England and Wales parts of the UK, the inorganic leaching criteria are identical to the EU WAC, while in the Flanders part of Belgium, France, Germany, and the Northern Ireland part of the UK the inorganic leaching criteria are identical to or even more stringent than the EU WAC.

2.3.2. Denmark

2.3.2.1. Background information. Denmark's history of waste management goes back to as early as 1903, when incineration was introduced for waste treatment (Kleis and Dalager, 2004). However, it was not until the 1960s that environmental awareness became pervasive in the Danish general public (Kleis and Dalager, 2004). Not much later, Denmark had its first Minister of the Environ-

Table 4
Significant formal legal instruments and regulations related to solid waste management in different countries.

Country	Significant formal legal instruments	Selected Regulations	Reference
The Netherlands	Soil Protection Act (1987, revised 2008)	Decree No. 39 of 1995 concerning the discharge of water for purposes of soil protection Decree No. 649 of 1997 relative to the discharge of liquid substances into the soil Decree No. 469 of 2007 containing rules relative to quality of soil	Food and Agriculture Organization of the United Nations
Denmark	Environmental Protection Act (effective 1974, Consolidated Act No. 879, 2010)	Order No. 99 on reports of environmental supervision and approvals Order No. 1022 on environmental quality standards for water and requirements for discharges of pollutants into rivers, lakes or the sea Order No. 231 on quality requirements for environmental measurements	Food and Agriculture Organization of the United Nations
Germany	Basic Law (Grundgesetz) Article 74 Number 24 (promulgation in 1949)	Federal Waste Prevention and Disposal Act Packaging Ordinance Hazardous Substances Control Act Federal Nature Conservation Act	Neumann (2010)
United States	Resource Conservation and Recovery Act (1976)	40 CFR Part 256: Guidelines for Development and Implementation of State Solid Waste Management Plans 40 CFR Part 258: Criteria for Municipal Solid Waste Landfills 40 CFR Part 260: Hazardous Waste Management System 40 CFR Part 268: Land Disposal Restrictions	US EPA US Government Publishing Office
Taiwan	Waste Disposal Act (effective 1974, latest revision 2013)	Method for Normal Waste Cleaning, Treatment, and Recycling Standard for Hazardous Waste Identification	Taiwan Environmental Protection Administration
Japan	Waste Management and Public Cleansing Law (1970)	Standards on Transfer of Municipal Solid Waste Technical Standards on Municipal Solid Waste Disposal Facility Standards of Facilities for Recycling	Ministry of the Environment of Japan
South Korea	Wastes Control Act (enacted 1986, amended 2007)	Volume–Rate Wastes Disposal System Reporting System for the Import and Export of Waste	Ng (2013) Ministry of Environment of the Republic of Korea Pariatamby and Tanaka (2013)
Singapore	Environmental Protection and Management Act (enactment in 1999, revised 2002)	Hazardous Substances Regulations Trade Effluent Regulations	Food and Agriculture Organization of the United Nations
China	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Wastes (1996)	GB 5085.3-2007: Identification Standards for Hazardous Wastes – Identification for Extraction Toxicity GB 16889-2008: Standard for Pollution Control on the Landfill Site of Municipal Solid Waste GB 18485-2014: Standard for Pollution Control on the Municipal Solid Waste Incineration	Ministry of Environmental Protection, People's Republic of China

ment, and the Danish Environmental Protection Agency (EPA) was established in 1971 and 1972, respectively. A year later, in 1973, Denmark became the first country in the world to pass an environmental protection law (Copenhagen Cleantech Cluster, 2012). Yet around the same time, landfilling of waste was a common practice in Denmark. A point was reached such that landfill capacity was saturated in the Copenhagen region, and waste became a problem for human health. In the 1980s, the government took action to require counties and municipalities to meet recycling targets. Also in the 1980s, waste incineration and composting became the primary waste treatment solution, alleviating landfills (Copenhagen Cleantech Cluster, 2012). Eventually, the incineration tax and landfill tax were introduced and helped incentivize recycling. In 1997, Denmark became the first country to completely ban

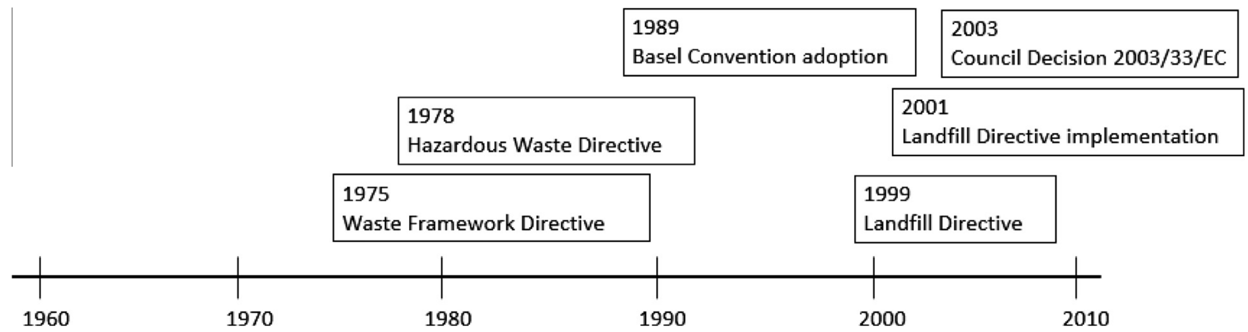

Figure 1. The EU's timeline on waste directives.

landfilling of combustible waste. The EU Landfill Directive in 1999 further helped shift the waste treatment paradigm from landfilling to recycling (Wong, 2014a).

In Denmark, there is extensive legislation for the application of IBA. From 1974 onward, IBA had to be disposed of in special sanitary landfills or recycled (Kleis and Dalager, 2004). While MSW IBA utilization is preferred over landfilling, the utilization must be done in an environmentally acceptable manner. Therefore, regulation of MSW IBA utilization has been in place since 1983 (Ornebjerg et al., 2006). The government provided impetus for a more wide spread use of IBA by imposing a State tax on IBA disposal in 1987 (Ornebjerg et al., 2006). Fig. 2 summarizes Denmark's historical timeline on waste regulations.

2.3.2.2. Denmark WAC, Statutory Order No. 252, and Statutory Order No. 1662. The EU WAC Decision has been implemented in Danish regulation by the Statutory Order No. 252 of 2009 (European Commission, 2009b). The Danish EPA decided to use a similar modeling methodology employed for the EU landfill directive, but adjusted for Danish conditions (Hjelmar et al., 2005). Denmark relies heavily on groundwater as a source for drinking water, and therefore has a strong incentive to strictly protect groundwater quality. Because of this, the Danish acceptance criteria should be more stringent than those set by the EU. Other differences are that the Danish POC is located 100 meters downstream of the landfill, and the K_d values, used to describe the contaminant-subsoil interaction in the transport modeling, have been adjusted for Denmark (Hjelmar et al., 2005). In Denmark, landfills that are located inland and those located near the seacoast are distinguished. Also, three subcategories of landfills for non-hazardous waste are defined: landfills for mineral waste, mixed waste, and non-reactive hazardous waste. Furthermore, mineral waste landfills are divided into three types: inland mineral waste landfills (MA0), seacoast mineral waste landfills with higher dilution potential by the nearby sea (MA1), and seacoast mineral waste landfills with lower dilution potential by the nearby sea (MA2) (Hjelmar et al., 2009). Table 7 lists the leaching limit values for non-hazardous mineral waste.

Beyond the characterization of waste for different landfills, Denmark's Statutory Order No. 1662 (2010), "Utilization of Residual Waste Materials and Soil for Construction Works and Utilization of Sorted, Unpolluted C&D Waste," sets leaching criteria that apply to residual products (MSWI BA, BA and FA from coal fired power plants) and soil. The criteria are listed in Table 8. Soil and residues to be utilized are classified into three different categories, based on the determination of trace element content after partial digestion with 7 M nitric acid (Saveyn et al., 2014), with different applications. Category 1 may be used for certain specified purposes, i.e. construction of roads, paths, parking lots, noise reduction walls, ramps, dikes, dams, railway embankments, pipe/cable trenches, landscaping, marine constructions, refilling floors and foundations. Categories 2 and 3 are for the reuse of contaminated waste for geotechnical purposes (Kirkland et al., 2012). Moreover, Category 2 is for roads, paths, cable graves, floors and foundations, noise banks, and ramps, whereas Category 3 is for roads, paths, cable graves, and floors and foundations. Both Category 2 and Category 3 residues and soil may be recycled under increasingly more stringent conditions concerning the type of application, thickness, and top cover. If the analysis result from the leachate meets the criteria for the category, the use is suitable for that category.

2.3.3. The Netherlands

2.3.3.1. Background information. The Dutch waste management system is well respected around the world. To some extent, Dutch national waste management policy has even influenced some European policies in recent years (Milios, 2013). Furthermore, some have estimated that more than half of Dutch legislation on the environment is derived from EU legislation (Andeweg and Irwin, 2014). Therefore, there is an intertwining relationship between EU and Dutch environmental legislation. Similar to some other developed countries, the Netherlands has faced challenges of increasing material consumption, lack of physical space, and environmental deterioration in the past decades. As a result, the government decided to reduce landfilling of waste (Wong, 2014b). Therefore, the Netherlands's standing in waste management can be attributed to

Table 5
Leaching limits as set out in Council Decision 2003/33/EC (EUR-Lex, 2003).

Element or substance	Inert wastes			Non-hazardous wastes			Hazardous waste acceptable at non-hazardous waste landfills			Hazardous waste acceptable at hazardous waste landfills		
	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 percolation test mg/L	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 percolation test mg/L	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 percolation test mg/L	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 percolation test mg/L
As	0.1	0.5	0.06	0.4	2	0.3	0.4	2	0.3	6	25	3
Ba	7	20	4	30	100	20	30	100	20	100	300	60
Cd	0.03	0.04	0.02	0.6	1	0.3	0.6	1	0.3	3	5	1.7
Cr (total)	–	–	–	4	10	2.5	4	10	2.5	25	70	15
Cu	0.9	2	0.6	25	50	30	25	50	30	50	100	60
Hg	0.003	0.01	0.002	0.05	0.2	0.03	0.05	0.2	0.03	0.5	2	0.3
Mo	0.3	0.5	0.2	5	10	3.5	5	10	3.5	20	30	10
Ni	0.2	0.4	0.12	5	10	3	5	10	3	20	40	12
Pb	0.2	0.5	0.15	5	10	3	5	10	3	25	50	15
Sb	0.02	0.06	0.1	0.2	0.7	0.15	0.2	0.7	0.15	2	5	1
Se	0.06	0.1	0.04	0.3	0.5	0.2	0.3	0.5	0.2	4	7	3
Sn	–	–	–	–	–	–	–	50	–	–	–	–
Zn	2	4	1.2	25	50	15	25	50	15	90	200	60
Cl^-	550	880	450	10000	15,000	8500	10,000	15,000	8500	17,000	25,000	15,000
F^-	4	10	2.5	60	150	40	60	150	40	200	500	120
SO_4^{2-}	560	1000	1500	10,000	20,000	7000	10,000	20,000	7000	25,000	50,000	17,000
Phenol index	0.5	1	0.3	–	–	–	–	–	–	–	–	

Table 6
Implementation of Decision 2003/33/EC; black = more stringent, gray = identical, white = slight differences (European Commission, 2009a).

	Austria	Belgium Brussels	Belgium Flanders	Belgium Wallopia	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Luxembourg	Netherlands	Portugal	Spain	Sweden	UK England/Wales	UK Northern Ireland	UK Scotland
Inert waste landfill leaching limit values	black	white	gray	white	black	gray	gray	gray	white	white	gray	white	gray	gray	white	gray	gray	gray	gray
Non-hazardous waste landfill leaching limit values	white	white	gray	white	white	white	black	black	white	white	white	white	gray	gray	white	white	gray	black	white
Non-hazardous waste landfill for hazardous waste leaching limit values	gray	white	black	white	white	white	black	gray	white	white	white	white	gray	gray	white	white	gray	gray	gray
Hazardous waste landfill leaching limit values	gray	white	black	white	white	white	gray	gray	white	white	white	white	gray	gray	white	white	gray	black	gray

nation-wide efforts to establish well-defined national waste management policy with quantitative targets, as well as comprehensive waste processing infrastructure.

The first piece of Dutch legislation that dealt explicitly with waste was the Waste Substances Act 1977, which covered discrete sectors of the environment separately, such as surface water, air, chemical waste, and noise. However, regulators found this sector-wise approach to be inadequate, and an integrated approach was required. The integrated approach was realized in the Environmental Management Act 1993. The Act covers a wide range of aspects such as waste collection, hazardous waste disposal, air quality, noise nuisance, environmental permits, and setting of environmental management strategies. At present, the Environmental Management Act is the central piece of legislation that governs the planning framework for environmental authorities, integrated permitting, compliance monitoring activities, and harmonization with other environmental laws (OECD, 2009). In 1995, a waste decree was issued to institute a landfill ban for 35 waste categories including all combustible and biodegradable wastes. At around the same time, the government also enacted a landfill tax to reduce waste generation to discourage landfill disposals. In 1997, the responsibility for waste management was passed from the provincial to the central government level in an effort to centralize waste

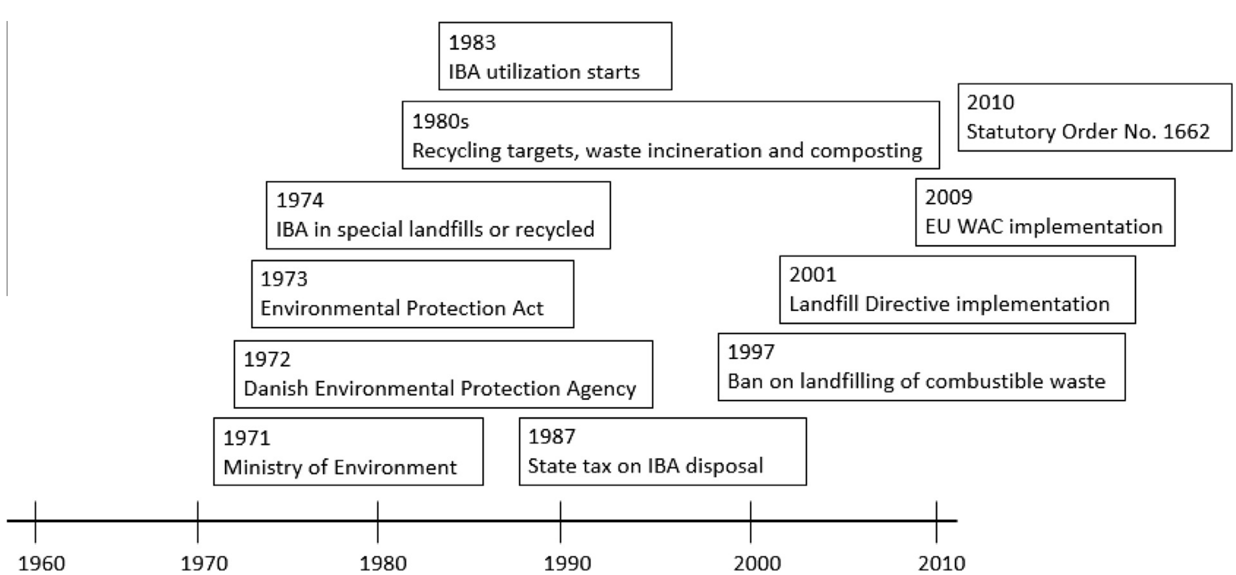

Figure 2. Denmark's timeline on waste regulations.

Table 7
Waste acceptance criteria for non-hazardous mineral waste in Denmark (Hjelmar et al., 2009).

Waste category	MA0: Mineral waste landfills located inland			MA1: Mineral waste landfills located near the seacoast			MA2: Mineral waste landfills located near the seacoast with lower dilution factor		
Contaminant	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 mg/L	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 mg/L	L/S = 2 L/kg mg/kg	L/S = 10 L/kg mg/kg	C_0 mg/L
As	0.082	0.37	0.040	0.40	2.0	0.30	0.40	2.0	0.30
Ba	9.5	28	5.5	30	100	20	10	30	6.0
Cd	0.072	0.11	0.060	0.60	1.0	0.30	0.60	1.0	0.30
Cr (total)	0.36	1.0	0.20	4	10	2.5	1.5	4.0	1.0
Cu	5.9	13	4.0	25	50	30	15	35	10
Hg	0.012	0.050	0.0063	0.050	0.20	0.030	0.050	0.20	0.030
Mo	0.44	0.90	0.31	5.0	10	3.5	5.0	10	3.5
Ni	0.22	0.50	0.14	5.0	10	3.0	5.0	10	3.0
Pb	0.28	0.60	0.18	5.0	10	3.0	5.0	10	3.0
Sb	0.022	0.080	0.012	0.20	0.70	0.15	0.20	0.70	0.15
Se	0.17	0.31	0.12	0.30	0.50	0.20	0.30	0.50	0.20
Zn	2.1	5.0	1.4	25	50	15	25	50	15
Cl^-	2,000	2,900	1,700	10,000	15,000	8,500	10,000	15,000	8,500
F^-	13	33	8	60	150	40	60	150	40
SO_4^{2-}	2,600	5,200	1,800	10,000	20,000	7,000	10,000	20,000	7,000
Testing method	EN 12457-1	EN 12457-2 or CEN/TS 14405	CEN/TS 14405	EN 12457-1	EN 12457-2 or CEN/TS 14405	CEN/TS 14405	EN 12457-1	EN 12457-2 or CEN/TS 14405	CEN/TS 14405

management, perhaps in an attempt to formulate policy in a more universal manner.

As per an amendment to the Environmental Management Act in 2002, the Ministry for Housing, Spatial Planning, and the Environment must draw up a Waste Management Plan every six years. The first National Waste Management Plan came into force in 2003, and was reviewed in 2009, resulting in the second National Waste Management Plan. The first National Waste Management Plan set out the framework for the Netherlands's future waste management, introduced the control of waste policies under a national perspective, banned direct disposal of mixed municipal waste to landfills, and called for the increase in waste utilization to 86% in 2012. The second National Waste Management Plan introduces initiatives to further enhance the waste management policy. Fig. 3 summarizes the historical timeline on waste regulation in the Netherlands.

2.3.3.2. Dutch soil quality decree. The overall Dutch approach to waste management, also known as the "Lansink's Ladder," is to: avoid as much waste as possible in the first place, recover reusable resources from wastes, generate energy through waste incineration, and then dispose the remaining waste into landfills (Zimring and Rathje, 2012). In keeping with the practice of recovering reusable resources from wastes, stony wastes can be reused in construction applications. For solid waste to be reused as construction material, the solid waste must meet the criteria as stipulated in the Dutch Building Materials Decree. From 1995 to 2008, the Dutch Building Materials Decree regulated the potential impact of construction materials on the environment. It specified the environmental quality criteria for the use of stony materials in construction, and did not distinguish between primary, secondary, and waste materials. The regulations were updated in 2007 into the Soil Quality Decree (came into force in July 2008). The reason for the revised decree was to develop a simplified and more transparent regulation containing a consistent set of emission limit values (van der Sloot et al., 2012).

There are limit values for monolithic and granular construction products in the Soil Quality Decree (Table 9). In general, these values are derived from impact modeling of groundwater and soil quality, which are determined by ecotoxicological criteria (Sloot et al., 2012). The emission limit values for granular construction products were calculated in six steps, using leaching results from tank leaching test carried out over 64 days (Saveyn et al., 2014). A generic average release pattern (in mg/m^2) for each inorganic substance based on a large collection of quality control data for construction products was determined using the percolation test NEN 7343. Geochemical modeling was then used to calculate how the substance concentrations varied with time and depth of the soil. These substance concentrations were compared with established compliance values at the POC. The source release was then adjusted to match exactly the compliance values in the soil and groundwater

Table 8
Limit values for content and leached amounts in Statutory Order 1662/2010 (Saveyn et al., 2014).

Substance	Category 1 (mg/kg)	Category 2 (mg/kg)	Category 3 (mg/kg)
	Total element content in dry matter[a]		
As	⩽20	>20	>20
Cd	⩽0.5	>0.5	>0.5
Cr (total)	⩽500	>500	>500
Cr (VI)[b]	⩽20	>20	>20
Cu	⩽500	>500	>500
Hg	⩽1	>1	>1
Ni	⩽30	>30	>30
Pb	⩽40	>40	>40
Zn	⩽500	>500	>500
	Leached amount at L/S = 2 L/kg		
Chloride	⩽300	⩽300	300–6,000
Sulfate	⩽500	⩽500	500–8,000
Na	⩽200	⩽200	200–3,000
As	⩽0.016	⩽0.016	0.016–0.1
Ba	⩽0.6	⩽0.6	0.60–8.0
Cd	⩽0.004	⩽0.004	0.004–0.080
Cr	⩽0.02	⩽0.02	0.020–1.0
Cu	⩽0.09	⩽0.09	0.090–4.0
Hg	⩽0.0002	⩽0.0002	0.0002–0.002
Mn[b]	⩽0.30	⩽0.30	0.30–2.0
Ni	⩽0.02	⩽0.02	0.020–0.14
Pb	⩽0.02	⩽0.02	0.02–0.20
Se	⩽0.02	⩽0.02	0.020–0.060
Zn	⩽0.2	⩽0.2	0.20–3.0
Testing method	EN 12457-1, L/S = 2 L/kg		

[a] Digestion is required for analysis.
[b] The content of Cr (VI) and the leached amount of Mn do not apply for IBA.

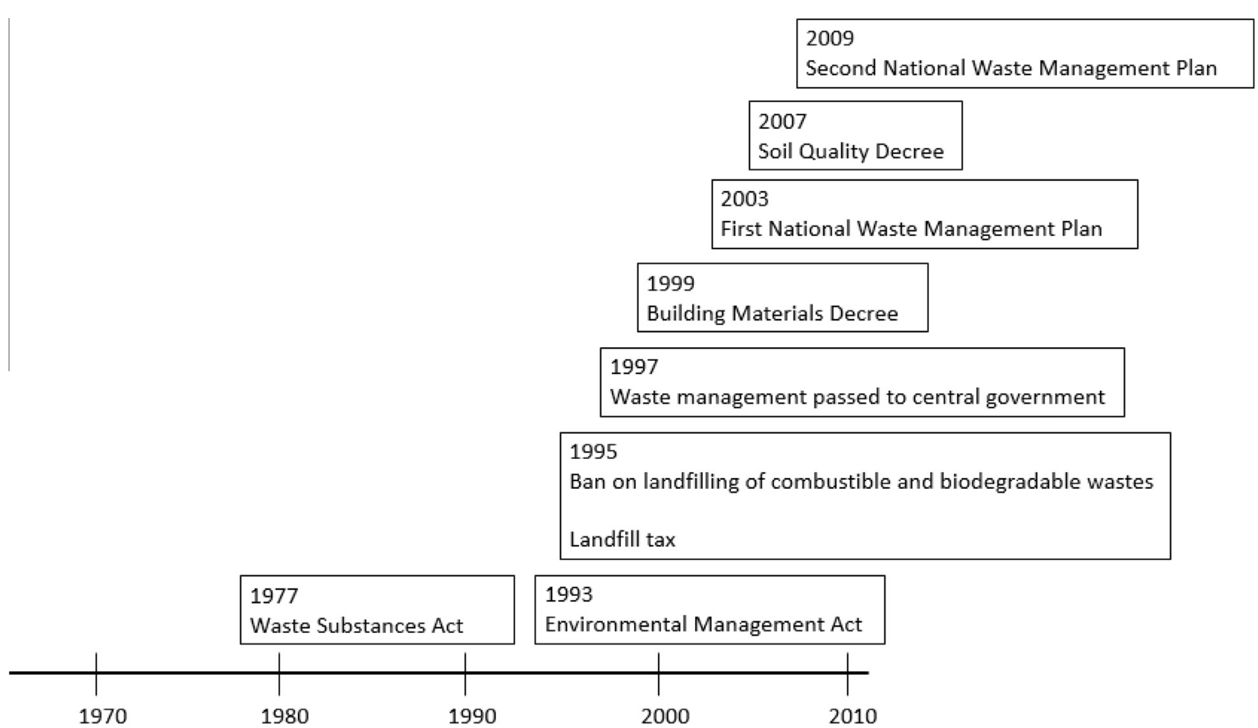

Figure 3. The Dutch timeline on waste regulation.

at the POC. The adjusted substance releases from the source were then transformed into emission limit values (in mg/kg). The more stringent emission limit value of the soil or the groundwater was selected, for being protective of both the soil and groundwater.

2.3.4. The US

2.3.4.1. Background information. In the immediate post-war period, new consumer products provided unprecedented convenience to the general population: air conditioners and central heating helped give comfort in the house, electric refrigeration increased the demand for pre-packaged food, television started a new era of home entertainment, cars enabled travel in the newly built highway system, and factories manufactured ever increasing consumable goods (Roberts, 2011). The consumer society and population increase escalated the generation of solid waste, and the management and control of waste were therefore necessary. Initially, collection and disposal of waste fell under the responsibility of local governments, however city populations, consumerism, and industry grew so much that waste generation proved to be too much to handle for cities (Roberts, 2011). This was evident in open dumps, where fires, odors, and vermin were common occurrences. In response, national guidelines on sanitary fill methods were published.

The Solid Waste Disposal Act, passed in 1965, was designed to assist state and local governments with the technical and financial aspects of developing and managing waste disposal programs, and to promote the development of guidelines for waste collection, transportation, recovery, and disposal. The Solid Waste Disposal Act was followed by the Resource Recovery Act of 1970, which shifted the emphasis of federal involvement from disposal to recycling, resource recovery, and conversion of waste to energy. Waste management was made more comprehensive with the Resource Conservation and Recovery Act of 1976; it is the primary law governing the disposal of solid and hazardous waste in the US. Broadly speaking, the law sets national goals to protect human health and the environment from waste hazards, conserve resources, reduce waste generation, and better manage wastes. In addition, the Act bans all open dumping of waste and encourages recycling. The Act also gives the EPA authority to promulgate criteria to differentiate between hazardous and non-hazardous wastes (Bricka et al., 1992) and regulations for the management of hazardous waste. The Resource Conservation and Recovery Act was amended and strengthened in 1984 with the Hazardous and Solid Waste amendments, which phased out land disposal of hazardous waste, increased enforcement authority of the Environmental Protection Agency, and set more stringent hazardous waste management standards. Fig. 4 shows the major legislations dealing with hazardous waste in the US.

Table 9
Emission limits from the Dutch regulation as part of the Soil Quality Decree (Saveyn et al., 2014; Muchová, 2010); limit values are specified for monolithic products (in mg/m^2), granular construction materials in "open" applications (infiltration rate of 300 mm/year), and in applications with isolating measures (infiltration rate of 6 mm/year).

Element	Monolithic (mg/m^2)	Granular, open (300 mm, mg/kg)	Granular, isolated (6 mm, mg/kg)
As	260	0.9	2
Ba	1,500	22	100
Cd	3.8	0.04	0.06
Cr	120	0.63	7
Co	60	0.54	2.4
Cu	98	0.9	10
Hg	1.4	0.02	0.08
Mo	144	1	15
Ni	81	0.44	2.1
Pb	400	2.3	8.3
Sb	8.7	0.16	0.7
Se	4.8	0.15	3
Sn	50	0.4	2.3
V	320	1.8	20
Zn	800	4.5	14
Br^-	670	20	34
Cl^-	110,000	616	8,800
F^-	2,500	55	1,500
SO_4^{2-}	165,000	1,730	20,000
Testing method	NEN 7375	CEN/TS 14405	

2.3.4.2. Waste characterization and landfill requirements. Unlike in the Netherlands, there is no relevant or equivalent standard for cumulative release from diffusion testing in the US to be used for the reuse of construction materials (van der Sloot et al., 2012). Perhaps this is one reason why little incineration ash is reused in the US. Another reason against reuse could be legal liabilities: if mixtures of fly and bottom ashes are determined to be hazardous by EPA standards, anyone connected with the distribution of those products may be held legally responsible (ASTM, 1989). Currently, mixed waste-to-energy ash is mostly disposed of in landfills (Oehmig et al., 2007; An et al., 2014). For testing, the Toxicity Characteristic Leaching Procedure (TCLP) test applies to ash from municipal waste incinerators that manage hazardous solid wastes (Simmons, 1991). Nevertheless, there are regulatory levels for identifying hazardous waste. By the TCLP test Method 1311, if any of the contaminant level from an extract of a representative solid waste is at or exceeds the regulatory level (Table 10), the solid waste is considered to exhibit toxicity characteristics, and is classified as a hazardous waste.

The approach for the derivation of the TCLP regulatory level takes into account three key determinations: acceptable level at the groundwater consumption point based on risk, the dilution/attenuation factor between the disposal unit and the receptor, and the leachate concentration from the waste that would be permitted (Simmons, 1991). In addition, explicit determination of allowed concentration from risks of exposure to the leached constituents is needed. Particularly, the risks are based on risk-specific doses for carcinogenic compounds that result in an incidence of cancer equal to or less than 10^{-5}, reference doses for non-carcinogenic constituents based on an estimate of

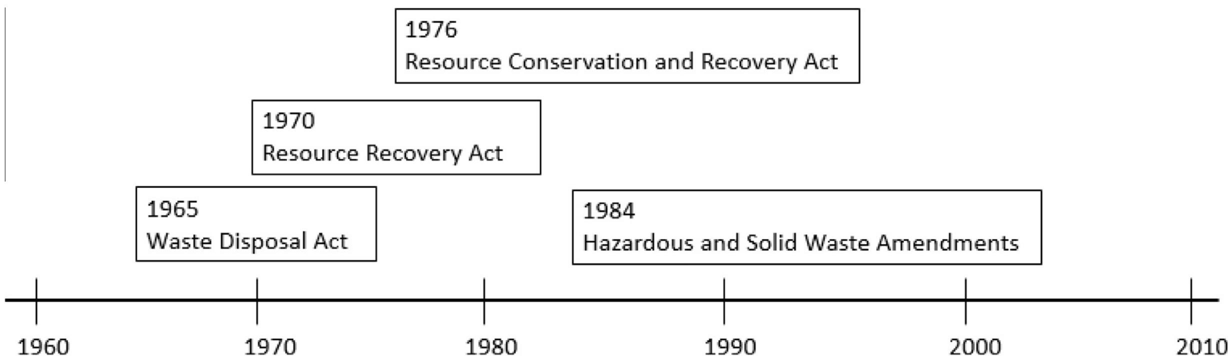

Figure 4. The US timeline on waste regulation.

Table 10
Maximum concentration of contaminants for toxicity characteristics (U.S. Government Publishing Office, 2011).

Contaminant	Regulatory level (mg/L)
Ag	5.0
As	5.0
Ba	100.0
Cd	1.0
Cr	5.0
Hg	0.2
Pb	5.0
Se	1.0
Testing method	TCLP Method 1311

the daily dose of a substance that will result in no adverse effect even after a lifetime of such exposure, and the proposed maximum contaminant levels in drinking water (Simmons, 1991).

Criteria for wastes from different industries are listed in 40 CFR 268.40. A restricted waste, as identified in 40 CFR 268.40, cannot be land disposed if a TCLP extract of the waste or a TCLP extract of the treated residue of the waste exceeds the value in 40 CFR 268.40 (shown in Table 11). In the latter case, the treatment standard has not been met, and further treatment is required prior to land disposal.

2.3.5. Taiwan

2.3.5.1. Background information. Taiwan is a densely populated mountainous island, and responsible waste management is an issue of crucial importance, because finding new sites for waste landfills is a challenge (Huang et al., 2006; Tsai and Chou, 2006). Similar to some European countries, Taiwan is active in tackling the challenges brought on by waste generation, and following the general international trend of valuing sustainable resources (Pariatamby and Tanaka, 2013). Taiwan's commitment to waste reduction is evident in its mandatory recycling system, which requires residents to recycle certain waste materials. In addition, there is a strict schedule of recyclables collection, where fines are imposed on mixing of recyclables and other trash (Ross, 2008). As can be illustrated in the following paragraphs, in Taiwan, solid waste management initially focused on waste disposal technology, then on resource recycling, and then on waste source reduction.

Prior to 1968, MSW were stored in public collection boxes, and waste personnel would collect and transport the waste to disposal sites. The public collection boxes were abolished in 1971, however. Also, before 1984, there was no proper treatment of MSW in Taiwan; most of the MSW were disposed in facilities with no intentional design for environmental protection (Ho et al., 2006). The construction of sanitary landfills began in 1984, and of incinerators later in 1991.

In 1991, incineration technology was introduced as an alternative to landfills, as the latter were approaching their capacity (Ross, 2008). However, environmentalist groups, citing community health concerns arising from waste incineration, led a strong opposition to the incineration practice as a permanent solution. The government later adopted a "zero waste policy" instead in 2003 as a central tenet of a waste reduction strategy (Fillingham, 2013).

In 1997, in order to stop dumping of garbage in public areas, which posed significant health risks, citizens were required to meet trash collectors and throw their household waste directly into the garbage truck (Ross, 2008). This "Keep Trash off the Ground Policy" is still in practice today in all parts of Taiwan except for specific remote areas (Pariatamby and Tanaka, 2013).

Table 11
Inorganic hazardous constituents in hazardous waste leachates from 40 CRF 268.40 (U.S. Government Publishing Office, 2015).

Contaminant	Non-wastewater concentration limit (mg/L)
As	5.0
Ba	21
Cd	0.11
Cr (total)	0.60
Pb	0.75
Hg	0.25
Se	5.7
Ag	0.14
Ni	11
Sb	1.15
CN^-	590
Testing method	TCLP Method 1311

In 2001, the government introduced a trash bag collection fee, which is levied by requiring citizens to purchase government-issued trash bags in stores and markets. Trash collectors in the island only accept waste in city-approved bags, and the fee helps discourage unnecessary discarding of garbage (Ross, 2008).

In 2002, as a result of Taiwan's Waste Disposal Act, which puts higher priority on waste reutilization, industries have been encouraged to reuse and conserve resources in manufacturing processes (Pariatamby and Tanaka, 2013). To combat the problem of discarded plastic bags clogging drainage ditches and creating floods, the Taiwan Environmental Protection Administration (Taiwan EPA) began to promote the "Plastic Shopping Bags, and Disposal Plastics (Styrofoam Included) Tableware Limitation Policy," which also began in 2002 (Pariatamby and Tanaka, 2013). Fig. 5 shows Taiwan's timeline on waste management practices, programs, and policies.

Two notable waste management approaches in Taiwan are its Zero Waste Policy and its Cradle-to-Cradle principle. What is significant about the Zero Waste Policy, initiated by the Taiwan EPA in 2003, is that it marked a turning point from end-of-pipe treatment to source reduction and resource reutilization in the waste management philosophy (Ho et al., 2006). There are four strategies to the Taiwan Zero Waste Policy: source reduction, reuse, recycling, and green consumption. Source reduction targets the minimization of toxicity and generation of wastes. Initial efforts were aimed at plastic shopping bags, disposal tableware, and non-rechargeable batteries, as well as "eco-design" considerations for products (Ho et al., 2006). The reuse of retired furniture was promoted by the Taiwan EPA, and will be followed by small appliances. The reuse strategy provides economic incentive to furniture refurbishing firms, since resale of renewed furniture can generate profit. Taiwan places much of its recycling effort on its citizens. For example, waste producers have to sort garbage into recyclables, kitchen wastes, and trash. On the industrial side, recycling of IBA is also supported by the Taiwan EPA. Greater acceptance of green consumption and demand for "green products," encouraged by the Government Green Procurement program began in 2002; the program sets minimum procurement level for government agencies to buy "eco-certified" products and promotes consumer product purchase by private enterprises (Ho et al., 2006). Taiwan is the first country-level jurisdiction in Asia to apply cradle-to-cradle in the planning of resource circulation strategies (Pariatamby and Tanaka, 2013). The cradle-to-cradle design concept would keep materials cycling in nature. In the ecological aspect, biodegradable raw materials are used in product design and returned to the ecological cycle, while in the industrial aspect non-toxic materials are continually cycled back (Taiwan EPA, 2012).

What is unique about Taiwan's case is that there is a civic dimension to waste management. This is a positive development to Taiwan's waste management because developing a culture of compliance is crucial (Probst and Beierle, 1999). The government invites citizens to actively participate in waste source reduction. For example, in 1996 the "Environmental Tableware Package Design Contest" asked people to prepare their own tableware, and in 2001 the "Use Less Plastic Bags" activity asked restaurants to use less plastic tableware. Government agencies and schools in Taiwan believed in the promotion of waste source reduction to young generations, and as a result,

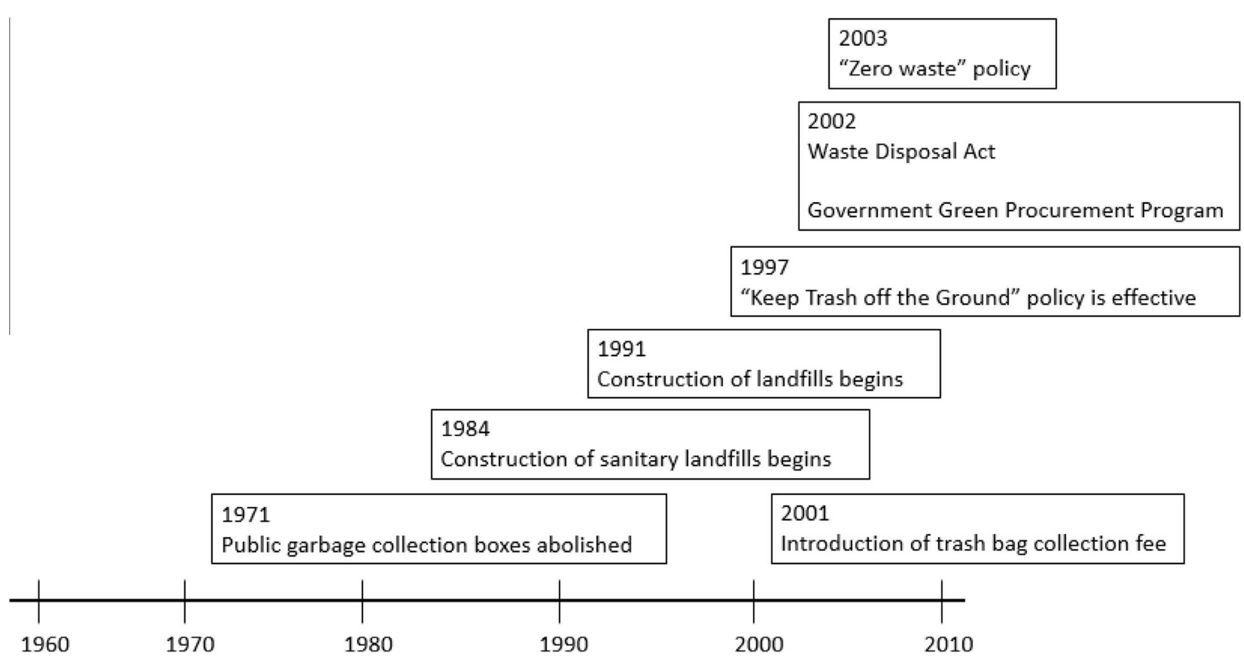

Figure 5. Taiwan's timeline on waste regulation.

government departments and schools stopped providing any disposal tableware in 2006. The government set up reward programs for sustainable behavior in private citizens. In 2011, as a result of the "Regulations on Rewards for Disposal Take-Out Cup Source Reduction and Collection," customers were offered discounts from fast food and convenience stores for self-prepared dining utensils (Pariatamby and Tanaka, 2013).

2.3.5.2. Waste characterization and incinerator residue reuse. Taiwan draws upon the experiences of other developed nations in promoting the reuse of incineration ash in building materials. In fact, the Taiwan EPA adopts similar regulatory limits (Table 12) as the US EPA for identifying hazardous waste by the TCLP method, which is equivalent to Taiwan's indigenous NIEA R201.14C method (Chang et al., 2012). In addition, leaching results from studies on IBA are often compared to TCLP limits when evaluating its utilization (Wang et al., 1998; Yang et al., 2012).

There is a high reuse rate of IBA in Taiwan. Leaching limit criteria for IBA reuse are divided into three categories (Table 13), although there is little variation across the different categories for each contaminant. Categories 1 and 2 are for applications mainly in concrete aggregates, while Category 3 is for foundation and road fill that must be used in quantities of at least 10,000 tons. The criteria for Categories 1 and 2 are identical, except that there is no limit for chloride ions in Category 2.

Table 12
Hazardous waste identification in Taiwan (Taiwan EPA, 2006).

Contaminant	Regulatory level (mg/L)
Ag	5
As	5
Ba	100
Cd	1
Cr (total)	5
Cr (VI)	2.5
Cu	15
Hg	0.2
Pb	5
Se	1
Testing method	TCLP or NIEA R201.14C

Table 13
Criteria for bottom ash reuse in Taiwan (Taiwan EPA, 2010).

Contaminant	Category 1 (mg/L)	Category 2 (mg/L)	Category 3 (mg/L)
Cl^-	0.024	NA	NA
As (total)	0.5	0.5	5
Ba	100	100	100
Cd	1	1	1
Cr (total)	5	5	5
Cr (VI)	0.25	0.25	2.5
Cu	15	15	15
Hg (total)	0.02	0.02	0.2
Pb	5	5	5
Se	1	1	1
Testing method	TCLP		

2.3.6. China

2.3.6.1. Background information. China is in the midst of rapid urbanization, which corresponds to huge generation of MSW (Zhang et al., 2010). In fact, China surpassed the US as the world's largest waste generator in 2004 (Hoornweg et al., 2005; Vanacore, 2012). From the end of the 1950s through the end of the Cultural Revolution (1966–1976), environmental issues were not factored in China's economic and industrialization plans (Pariatamby and Tanaka, 2013). Though China began to realize the importance of environmental protection at the 1972 Stockholm Conference on Human and Environment, environmental awareness was weak then at lower-level government authorities and the public. After the late 1970s, as China opened its economy and environmental deterioration worsened, the government took notice and borrowed the environmental experience from Western countries (Pariatamby and Tanaka, 2013). Three government-issued documents formed the basis for environmental protection practices in the early stage in China: Certain Regulations on Environmental Protection and Improvement, the Provisional Environmental Protection Law of the People's Republic of China, and the Articles on environmental protection that were added to the 1982 National Constitution of the People's Republic of China (Pariatamby and Tanaka, 2013). In the 1980s, there was a sudden industrial and economic boom, even while the environmental condition was largely neglected. As a response, in the Second National Meeting on Environmental Protection in 1983, the government announced environmental protection to be a state fundamental policy, which meant that economic growth and environmental protection were to be planned, implemented, and developed simultaneously (Pariatamby and Tanaka, 2013). Since the 1990s, China has opened its MSW management market to private and foreign (especially French, Japanese, German, and American) owners (Pariatamby and Tanaka, 2013). The first law to regulate the management of MSW was the Law on Prevention and Control of Environmental Pollution Caused by Solid Waste of the People's Republic of China, effective in 1996 (Hoornweg et al., 2005). After that, a series of laws and regulations on MSW was issued to promote cleaner production in manufacturing, require more government approvals in construction, set standards for MSW treatment technologies, and attract private and foreign investment to waste treatment industries (Hoornweg et al., 2005). Fig. 6 summarizes China's major laws on waste management.

Outside of official state regulations, there exists an informal waste collection sector where private individuals save recyclable consumables, especially electrical and electronic equipment, and sell them for extra income (Hicks et al., 2005; Zhang et al., 2010). Another interesting aspect is, unlike other industrialized countries, in China nearly all solid waste management expenditure comes from local government financing, which has contributed the lag of MSW treatment behind economic development.

There are no government-mandated standard criteria for the use of incinerated waste materials. According to the Standard for Pollution Control on the Municipal Solid Waste Incineration (GB16485 2014), IBA can be landfilled directly. In addition, IBA that have lower leachability of heavy metals than China's leaching standard and TCLP can be treated as non-hazardous waste for use as building materials. Also, according to GB16485 (2014) IFA is to be managed as hazardous waste, but if it needs to be landfilled it must meet the requirements of GB16889 (2008). On the other hand, if IFA is to be treated in a cement kiln, it must meet the requirements of GB 30485 (2013).

2.3.6.2. Hazardous waste identification and landfill waste requirements. Table 14 shows the leaching limit criteria for the purpose of identifying hazardous waste in China, similar to the function of TCLP regulatory limits in the US. The criteria are identical for the elements that the two countries share in common (i.e. Ag, As, Ba, Cd, Cr, Hg, Pb, Se). In China, if wastes meet the criteria as listed in Table 15, they can be landfilled. Unlike the EU waste acceptance criteria, the GB 16889 criteria do not distinguish between inert, non-hazardous, and hazardous waste landfills.

Table 14
Hazardous waste identification in China (Ministry of Environmental Protection of the People's Republic of China, 2007).

Contaminant	Regulatory level (mg/L)
Ag	5
As	5
Ba	100
Be	0.02
Cd	1
Cr (total)	15
Cr (VI)	5
Cu	100
Hg	0.1
Ni	5
Pb	5
Zn	100
Testing method	HJ/T 299-2007

2.3.7. Solid waste environmental standard international comparison and discussion

In the earlier sections, waste leaching criteria from different places are surveyed by individual countries. In this section, a comparison of these criteria is made at the international level. The waste criteria presented in this paper can be divided into two groups, hazardous waste characterization criteria, and solid waste reuse criteria. Comparison of criteria allows for the assessment of where a particular country's criteria stand in relation to other countries. If substantial deviations exist among different countries, researchers may take the opportunity to learn different, perhaps updated, methodologies of deriving the standard values.

2.3.7.1. Hazardous waste characterization. Figs. 7a and b compare the hazardous waste characterization criteria for the US, Taiwan, China, and the EU. The criteria are split up into two figures because different units are used, mg/L in 7a and mg/kg in 7b. The values are the same as those listed in Sections 2.3.1 and 2.3.4–2.3.6, but only the hazardous waste criteria are shown for comparison. The US, Taiwan, and China all use leaching methods similar to the TCLP to characterize waste toxicity, and their criteria are expressed in mg/L, which makes the leaching criteria comparable. Between the US and Taiwan, the leaching limits are identical in all the inorganic contaminants that they have in common. In Taiwan, there are criteria for two

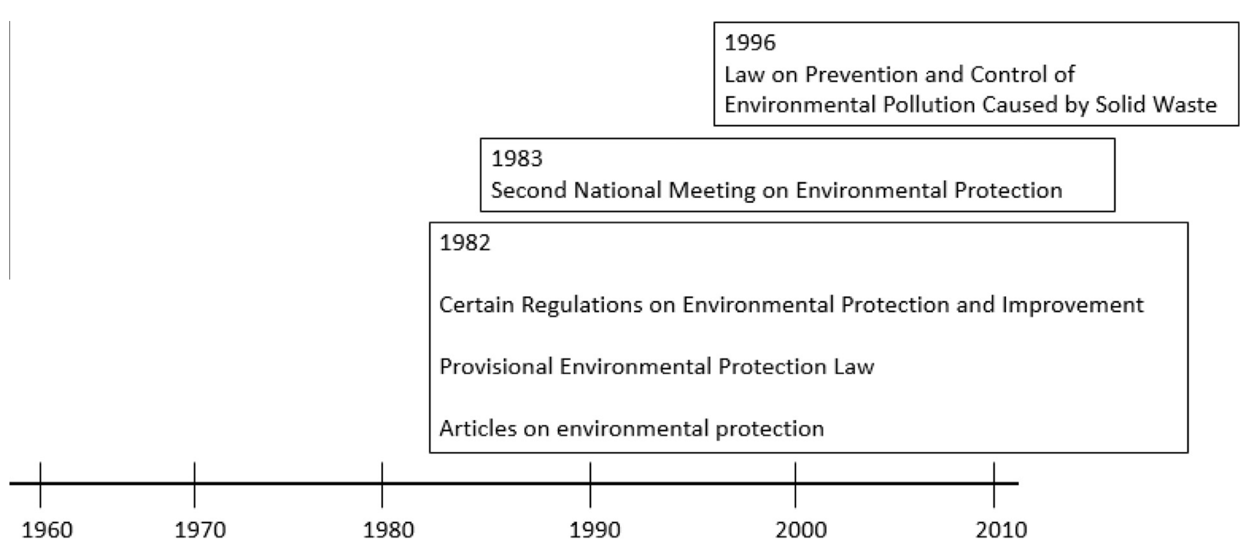

Figure 6. China's timeline on waste regulation.

Table 15
Landfill waste requirement in China (Ministry of Environmental Protection, 2008).

Contaminant	Regulatory level (mg/L)
As	0.3
Ba	25
Be	0.02
Cd	0.15
Cr (total)	4.5
Cr (VI)	1.5
Cu	40
Hg	0.05
Ni	0.5
Pb	0.25
Se	0.1
Zn	100
Testing method	HJ/T 300-2007

additional inorganic contaminants, hexavalent chromium and copper, which are not in the US limits. Between the US and China, the leaching limits are identical in inorganic contaminants that they have in common except for total chromium and mercury, in which case total chromium limit value for the Chinese criteria is higher and the mercury limit value is lower. Also, the Chinese criteria have more elements – beryllium, hexavalent chromium, copper, nickel, zinc, and fluoride. Both Taiwan and China use the TCLP method or similar for waste characterization, but they both have included extra inorganic contaminants to the list of leaching criteria, and for a couple of the inorganic contaminants, China has either loosened (Ag, 0.14–5 mg/L; Ba, 21–100 mg/L; Cd, from 0.11 to 1 mg/L; Cr total, from 0.60 to 15 mg/L; Pb, 0.75–5 mg/L) or tightened (Hg, 0.25–0.1 mg/L; Ni, 11–5 mg/L) limit values as compared to the US leaching criteria for hazardous waste characterization.

In order to compare the US criteria for hazardous waste characterization and the EU waste acceptance criteria, the US criteria are converted to mg/kg. These values are compared to the EU criteria values for hazardous landfill wastes at L/S ratios of 2 and 10, as shown in Fig. 7b. Between the US and the EU, the US criteria are higher in all of the inorganic contaminants that they have in common. However, the US results are derived from the TCLP method at an L/S ratio of 20, while those for the EU are derived at L/S ratios of 2 and 10. More importantly, it is also worth noting that deionized water is the leachant in the EN 12457 method while acetic acid is the leachant in TCLP. Therefore, the results from the two different leaching methods are expected to differ.

Comparing the three most stringent limit values in the US and Taiwan, they belong to criteria for cadmium, mercury, and selenium. In China, they belong to those for beryllium, cadmium, mercury, selenium (cadmium and selenium are tied). In the EU, they belong to those for cadmium, mercury, and strontium. In all cases, cadmium and mercury have the most stringent values, indicating the countries' agreement of the high degree of harmfulness of cadmium and mercury to the environment.

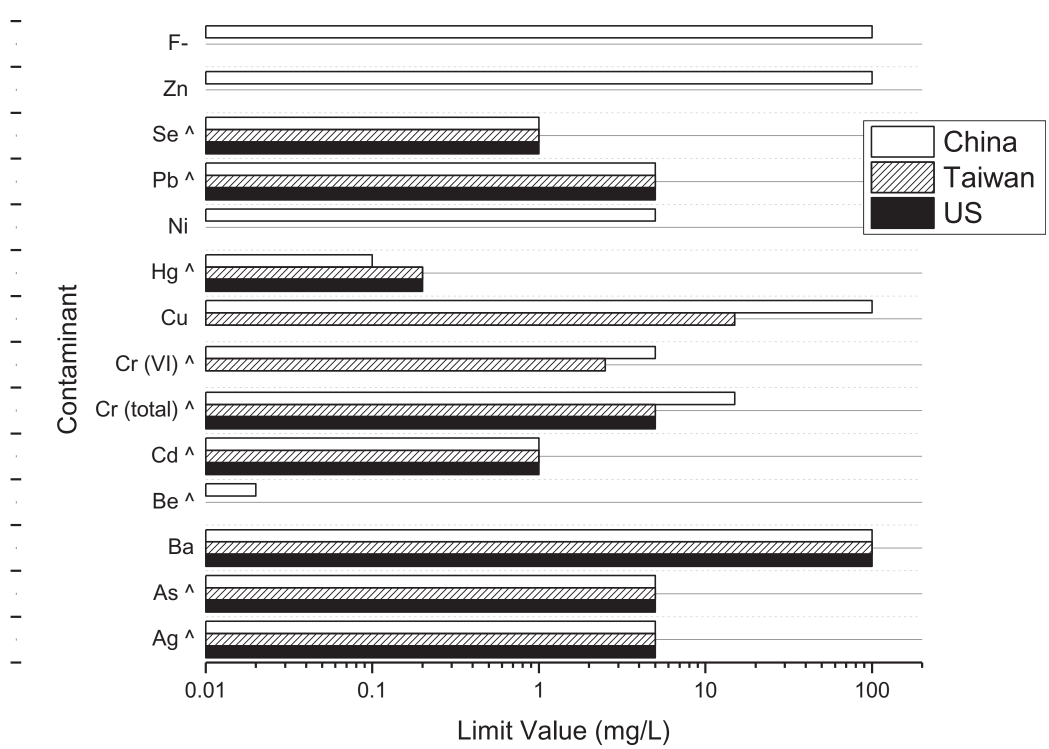

Figure 7a. Comparison of hazardous waste characterization criteria in the US, Taiwan, and China. ^ indicates a contaminant belonging to one of the top three most stringent limit values for at least one country.

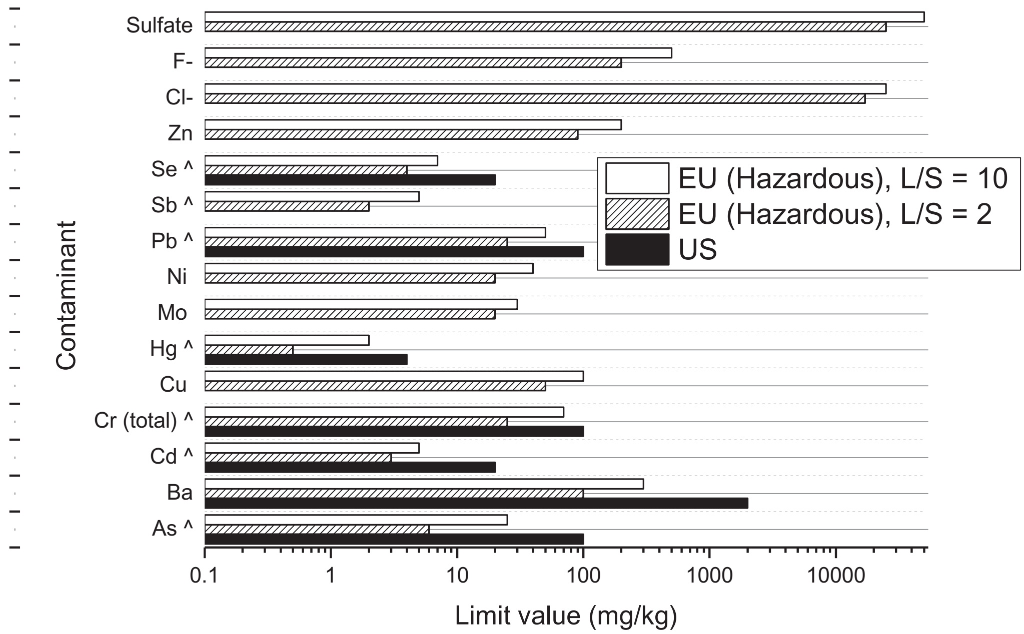

Figure 7b. Comparison of hazardous waste characterization criteria in the US and EU. ^ indicates a contaminant belonging to one of the top three most stringent limit values for at least one country.

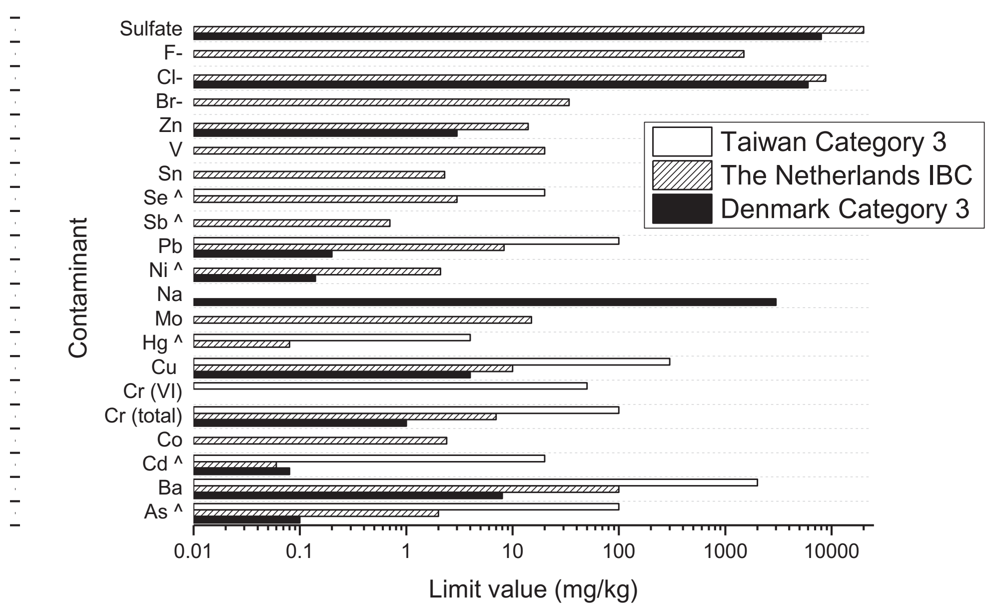

Figure 8a. Comparison of the less stringent set of waste reuse criteria in Denmark, the Netherlands, and Taiwan. ^ indicates a contaminant belonging to one of the top three most stringent limit values for at least one country.

"Metals and Alloys Used in Food Contact Materials and Articles," (European Directorate for the Quality of Medicines & HealthCare, 2013) published by the European Directorate for the Quality of Medicines & HealthCare, describe in detail metal, including cadmium and mercury, levels toxic to human health. Briefly, cadmium is a relatively rare element, and present at low concentrations in the environment. However, it is toxic to humans at low dosages and the biological half-life is long. The methyl form of mercury is the most toxic form of organic mercury. Methyl mercury is also listed as one of the six most dangerous chemicals in the environment, while inorganic mercury is classified as a carcinogen.

2.3.7.2. Reuse of solid wastes. Figs. 8a and b show the limit criteria for the reuse of solid wastes for Denmark, the Netherlands, and Taiwan, and the top three most stringent criteria are indicated within each country. The data are split into two figures for comparison of more lenient criteria across the countries (Fig. 8a), and for more stringent

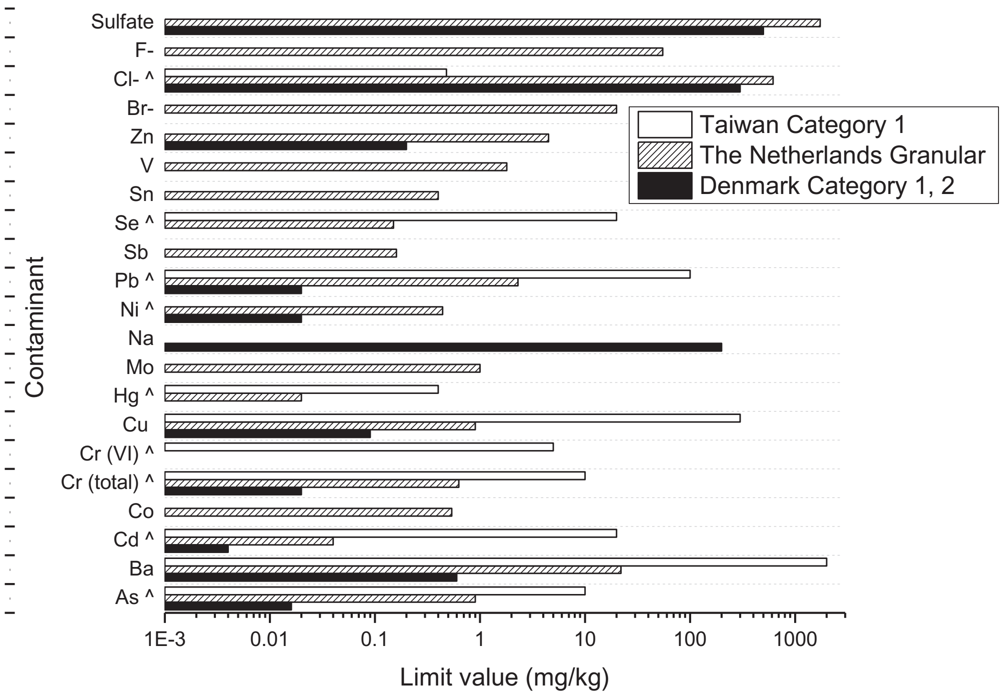

Figure 8b. Comparison of the more stringent set of waste reuse criteria in Denmark, the Netherlands, and Taiwan. ^ indicates a contaminant belonging to one of the top three most stringent limit values for at least one country.

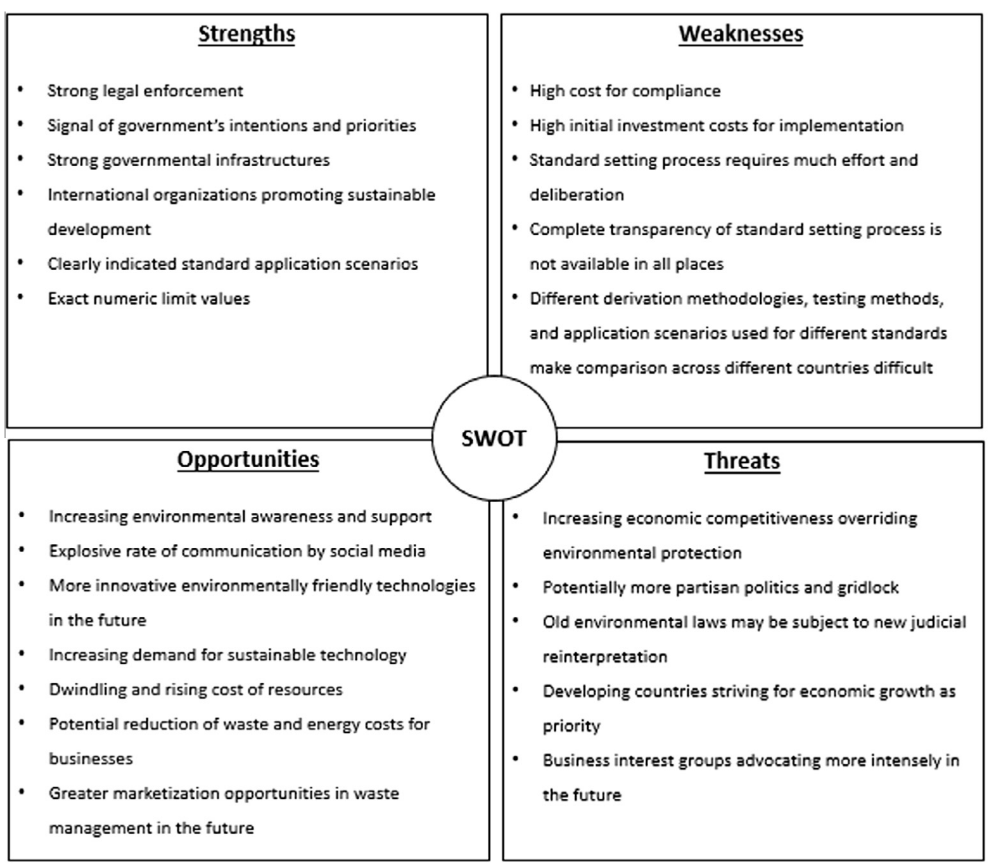

Figure 9. SWOT analysis of MSW standards.

criteria across the countries (Fig. 8b). The inorganic contaminants that fall into the top three most stringent criteria across the different countries include arsenic, cadmium, chromium (total), mercury, nickel, lead, selenium, and chloride ions. The inorganic contaminants that most frequently fall into the top three most stringent criteria are cadmium and mercury, further highlighting the importance and potential danger of these contaminants to public health and the environment. Similar to the waste characterization criteria, the Taiwan criteria in Figs. 8a and b are converted into mg/kg for comparison. It is observed that the criteria are generally more stringent in Denmark as compared to other countries in the table.

3. Conclusion

Environmental standards and regulations are integral to protecting and improving environmental quality. A subset of these standards deals with MSW and incinerated MSW. Through examining the environmental regulation history of various countries and their MSW leaching criteria, one can make the following generalizations:

- Countries with limited natural resources should have an interest in resource reuse.
- A country's uniqueness, for example historical, social, and/or economic aspects, plays a role in setting environmental policies.
- Between developed and developing economies, more developed ones tend to have greater environmental concerns, and waste management focus priorities in developing economies generally follow similar paths as those in developed ones.
- Standard setting is a science that takes into account the natural environment setting that needs protection, the transport phenomena of contaminants through different media, and the contamination source.
- For some countries, it may be practical to follow standards established in other countries, especially if those countries face similar challenges.

These generalizations may serve as implications that will help decision makers in governments that are looking to begin to set MSW leaching criteria standards initiate proposals. It is hoped that, with more standards in place, there is a greater degree of resource reuse and preservation.

The future of MSW standards remains uncertain, as shown in a SWOT analysis in Fig. 9. Setting environmental standards has the benefits of setting legally enforceable regulations, enjoying the strong infrastructures already in place for their ease of implementation, and being understandable for the public to comply. However, as environmental technologies become more sophisticated the cost for compliance and initial investment costs may increase, much scientific work and deliberation by policymakers are needed to finalize standards, and tracing the origins of limit values in standards may not be possible. For future research studies in MSW standards, investigators could look into opportunities and threats. Increasing popular support for standards in general propagated by social media and open innovation, increasing demand for sustainable technology brought on by the dwindling and rising cost of resources, and aligning business interests with waste and energy cost reduction goals may increase standards' importance and availability. Meanwhile, perceived economic priority over environmental concerns, partisan political paralysis from gridlock in governments, judicial reinterpretation of past environmental statutes, and business groups' lobbying efforts may hamper standards promulgation. For future research studies, analyzing the relationship between these new trends and MSW environmental standards would be worthwhile.

Acknowledgment

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Appendix A

Term	Explanation
ALARA	As Low As Reasonably Achievable principle, initially a radiation safety principle of keeping radiation doses and amount of radioactive material releases to the environment as low as can be achieved
Attenuation ratio	General term used for the reduction of magnitude of a numerical term
BATNEEC	Best Available Technology But Not Entailing Excessive Costs, a principle that allows for modification of the best available technology requirement if its costs are excessive in relation to their effectiveness in achieving environmental objectives or to the capabilities of the industry
CEN	European Committee for Standardization
CFR	United States Code of Federal Regulations
EN	European standards
ERRI	Environmental Regulatory Regime Index, an index representing a summary of performance measure of the quality of the environmental regulatory system in a country
NEN	Dutch Standards Institute, center for standards in the Netherlands
OECD	Organization for Economic Cooperation and Development

(*continued on next page*)

Appendix A (*continued*)

Peak concentration	The maximum amount of a substance, such as the highest concentration of a contaminant at a specific point
POC	Point of compliance, a location at some distance from a potential source of pollution where some enforcement limit is set, measured, and shall not be exceeded
Reference dose	An estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime
Source release	The release of a contaminant from its original source
TCLP	Toxicity Characteristic Leaching Procedure
USEPA	United States Environmental Protection Agency
WAC	Waste Acceptance Criteria, European Union criteria for the acceptance of waste at each landfill class as specified
WHO	World Health Organization

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Environmental, economic and social impacts of the use of sewage sludge on land

Final Report

Part I: Overview Report

This report has been prepared by Milieu Ltd, WRc and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r.

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List of abbreviations

AD	Anaerobic digestion
AOX	Total adsorbable organo-halogen
APD	Acid phase digestion processes
BAT	Best available techniques
BOD, BOD5	Biochemical oxygen demand
CBA	Cost-benefit analysis
CEN	Comité Européen de Normalisation
CHP	Combined heat and power plant
COD	Chemical oxygen demand
CoGP	Code of good practice
DEHP	Bis(2-ethylhexyl)phthalate
DG ENV	Directorate General Environment of the European Commission
DM	Dry matter, or dry solids, or total solids
DS	Dry solids, dry matter, total solids
ECJ	European Court of Justice
EEA	European Environment Agency
EoW	End-of-waste
EPA	Environmental Protection Agency
EQS	environmental quality standards
EU 12	The 12 Member States that joined the EU in 2004 and 2008
EU 15	The 15 Member States that joined the EU before 2004
EU 27	All 27 Member States since 2008
FAO	Food and Agriculture Organization
FWD	Food waste disposal
GHG	Green house gas
GWP	Global warming potential
HACCP	Hazard analysis and critical control point
IA	Impact Assessment
IPPC	Integrated pollution prevention and control
LAS	Linear alkylbenzene sulfonate
LCA	Life-cycle analysis
MAD	Mesophilic anaerobic digestion
MBT	Mechanical biological treatment
MS	Member State of the European Union
MSW	Municipal solid waste
Mt	Million tonnes
ND	Nitrate Directive
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
OC	Organic compounds / Organic contaminants
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCDD/F	Polychlorinated dibenzodioxins and polychlorinated dibenzofurans
pe	population equivalent
PPP	Public private partnerships
PTE	Potentially toxic elements; refers to heavy metals
QA	Quality assurance
QMRA	Quantitative microbial risk assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive

SEPA	Scottish Environmental Protection Agency
SSM	Safe sludge matrix
TD	Thermal Destruction
tDS	Tonnes of dry solids
THP	Thermal hydrolysis process
TOC	Total organic content/carbon
TRF	Toxicological reference value
TS	Total Solids, dry matter, dry solids
TSP	Total sludge production
UBA	Umweltbundesamt
UWWTD	Urban waste-water treatment
VOSL	Value of statistical life
WFD	Water Framework Directive
WI	Waste incineration
WWTP	Wastewater treatment plant

The Sewage Sludge Directive (86/278/EEC) was adopted more than 20 years ago with a view to encourage the application of sewage sludge in agriculture and to regulate its use as to prevent harmful effects on soil, vegetation, animals and humans. In the light of the increased production of sewage sludge across the European Union with the implementation of the Urban Wastewater Treatment Directive, and recognising the need to assess recent scientific research on the reuse of sludge in agricultural soils, the European Commission is currently considering whether the current Directive should be revised.

The European Commission (DG Environment) awarded a contract to Milieu Ltd, together with its partners WRc and Risk & Policy Analysts Ltd (RPA), to prepare a *Study on the environmental, economic and social impacts of the use of sewage sludge on land* (DG ENV.G.4/ETU/2008/0076r).

The aim of the study was to provide the Commission with the necessary elements for assessing the environmental, economic and social impacts, including health impacts, of present practices of sewage sludge use on land, provide an overview of prospective risks and opportunities and identify policy options related to the use of sewage sludge on land. This study thus provides background information for a decision whether or not a revision of the directive is needed and lays the basis for a possible revision.

This final report presents the overall results of the study and it compiles the detailed reports prepared over the course of the project, incorporating the results of two open consultations held in the course of the project.

- This overview report summarises the main project results and forms **Part I** of the final report.
- **Part II** is the **Report on Options and Impacts**, which describes the main options identified for the revision of the directive and presents the cost-benefit analysis of these options: it thus provides the final, detailed analysis of the study and it incorporates the results of the second open consultation.
- **Part III** presents the other project reports:
    - The **Assessment of Existing Knowledge** describes current levels of sewage sludge production, the concentration limits on pollutants in sewage in place in Member States and provides an overview of key EU legislation influencing sewage sludge, of sludge treatment technologies and their prospects and of current scientific literature on risks to human health and the environment.
    - The **Baseline Scenario and Analysis of Risk and Opportunities** estimates sludge production and application levels to 2020 and describes the forces influencing these levels
    - The project **Interim report on the first consultation** compiles the results of the first open, web-based consultation, summarising the comments and additional information provided by public bodies and stakeholders regarding the first two reports.

The two consultations held over the course of the project provided information and comments that were assessed and used where appropriate in the work. The first, from 24 June to 27 July, was an open, web-based consultation on reports 1 and 2. In total, 40 responses were received (including comments received after the deadline): 19 from governmental bodies, and 21 from industry and other stakeholders.[1] (Key information from these responses is compiled in the project's Interim Report – and thus the first two reports should be read together with this one for an overview of information gathered, all of which is used in the cost-benefit analysis.) The second consultation reviewed the draft version of the Report on Options and Impacts and its preliminary cost-benefit analysis. Here, an open web-based consultation was held from 17 December to 13 January, and 39 comments were received (including those sent after the deadline). It was followed by a workshop at the European Commission on 29 January, attended by over 40 Member State officials and industry stakeholders. The comments and new information provided in this second consultation were used to revise the cost-benefit analysis and the Report on Options and Impacts.

Key findings and results of the study are summarised in the following sections.

[1] Of the industry and other responses, 19 were from the private sector and commercial organisations or from associations with commercial interests, 1 from an NGO and 1 from an individual citizen with specialist knowledge. Some were joint responses and some originated from different organisations but reiterated some of the comments.

Review of existing practices and knowledge

The first stage of work involved the collection and assessment of existing information concerning possible risks to health and the environment stemming from the application of sewage sludge on land, as well as the potential economic opportunities.

The Directive was based on the knowledge available at the time, including an evaluation of risks prepared by the COST 68 programme in the early 1980s. Since then, new scientific evidence has been generated relating to the human health and environmental impacts and the soil quality and fertility aspects of recycling sewage sludge to agricultural soil. A number of reports and risk assessments have also been published recently.

Benefits

There is scientific evidence that the application of sewage sludge to agriculture provides a series of agronomic benefits, in particular the recycling of plant nutrients such as nitrogen and phosphorus, and thus sludge is an effective replacement for chemical fertilisers. Indeed, one of the most commonly recognised environmental benefits is the recycling of phosphorus (P) in the food chain. This contributes to the conservation of mineral phosphorus reserves and also reduces external inputs of cadmium (Cd) present in phosphate rocks. Sludge also provides other plant macronutrients, such as potassium and sulphur, and micronutrients such as copper and zinc. The beneficial effects of sludge application on soil organic matter status, structural properties and soil moisture retention are also well documented.

In addition to its use on agricultural land, sewage sludge has been employed successfully for forestry and in land reclamation operations, such as for disused mines or closed landfills.

Some researchers claim benefits in terms of climate change and greenhouse gases emissions from sewage sludge recycled to agriculture, in particular that a portion of the carbon in sludge used in agriculture will be sequestered in the soil. However, this has not been fully scientifically substantiated and it is not believed that any national inventories of greenhouse gas emissions consider sequestered carbon from sludge used in agriculture.

In terms of air pollution, although replacing the use of chemical fertiliser by sewage sludge reduces the nitrous oxide emissions associated with that fertiliser, as little as 20% of the nitrogen in digested sludge cake is considered to be readily available to plants so the emissions of N_2O from its spreading are greater than the reduction in N_2O from the displaced fertiliser.

Current levels of sludge production

The total quantities (i.e. production) of sludge in the EU27 are currently estimated at 10.13 million tons (dry solids), as shown in the Table 1 on the next page.

Of this total, nearly 40% is estimated to be spread on land for agricultural use. The recycling of sludge to agriculture varies greatly among Member States. In a few EU15 countries – Denmark, France, Ireland, Spain and the UK – more than half of all sludge production is used in agriculture. In three of the EU27 Member States, however, no sludge is recycled to agriculture, and in four others the amounts are less than 5% of total sludge production.

Table 1: Recent sewage sludge production and quantities recycled to agriculture in the EU

Member State	Year	Sludge production (t DS)	Agriculture	
			(t DS)	(%)
Austria (a)	2006	252,800	38,400	16
Belgium				
• Brussels region	2006	2,967	0	0
• Flemish region	2006	101,913	0	0
• Walloon region (b)	2007	31,380	10,927	35
Denmark	2002	140,021	82,029	59
Finland (c)	2005	147,000	4,200	3
France	2007	1,125,000	787,500	70
Germany (d)	2007	2,056,486	592,552	29
Greece	2006	125,977	56.4	<1
Ireland	2003	42,147	26,743	63
Italy	2006	1,070,080	189,554	18
Luxembourg (e)	2005	8,200	3,780	46
Netherlands	2003	550,000	34	<1
Portugal	2006	401,000	225,300	56
Spain	2006	1,064,972	687,037	65
Sweden	2006	210,000	30,000	14
United Kingdom	2006	1,544,919	1,050,526	68
Sub-total EU 15		***8,874862***	***3,728638***	***42***
Bulgaria	2006	29,987	11,856	40
Cyprus	2006	7,586	3,116	41
Czech republic (f)	2007	231,000	59,983	26
Estonia (g)	2005	26,800	3,316	12
Hungary	2006	128,380	32,813	26
Latvia	2006	23,942	8,936	37
Lithuania (h)	2007	76,450	24,716	32
Malta (i))		Nd	Nd	nd
Poland	2006	523,674	88,501	17
Romania	2006	137,145	0	0
Slovakia	2006	54,780	33,630	62
Slovenia	2007	21,139	18	<1
Sub-total EU 12		***1,260,883***	***266,885***	***21***
Total		**10,135,745**	**3,995,523**	**39**

Sources: EC, 2006; EC, personal communication, 2009; Member State responses to the project consultations, 2009

Notes:

a) Austria: in addition in 2006, 177,000 t DM of industrial sludge (mainly from cellulose and paper industry) were produced and 3% of this was recycled to agriculture.
b) Wallonia: in addition in 2007, 48,000 tds of industrial sludge (mainly from paper industry,) were also recycled to agriculture.
c) Finland: the remaining is recycled in landscaping operations including landfill cover.
d) Germany: in 2007, 18% were also recycled in landscaping operations.
e) Luxembourg: in 2005, in addition 32% were reported to be composted – no final outlet provided
f) Czech republic: it is reported that up to 2/3 of sewage sludge is ultimately recycled to agriculture mainly after composting
g) Estonia: estimate based on 20 kg/pe and 90% collection and treatment as no figures were reported for total sludge production.
h) Lithuania: in addition in 2007, 11% were recycled on other land
i) No data for Malta, assumed zero

Although the overall proportion of sludge recycled to agriculture across the EU has increased slightly since 1995, the situation in some Member States has changed dramatically: the Netherlands, for example, has stopped the recycling of sludge to land, while the UK and some other Member States have significantly increased the amounts used on land.

More than 40% of sludge production is spread on land in the EU15, compared to less than 20% in the EU12. Moreover, the EU15 have a much higher level of sludge production, due both to higher populations as well as higher connection rates to urban waste water treatment (UWWT) plants. In the EU15, incineration is at present the main alternative to spreading on land; in the EU12, it is still landfilling. In both groups, however, the variation among individual countries is quite large.

To put these figures – as well as the overall analysis – in perspective, it should be noted that the use of sewage sludge in the EU is relatively small compared to other organic and inorganic fertilisers: sludge contributes less than 5% of the total amount of organic manure used on land (most of which is of farm animal origin), and sludge is applied to less than 5% of agricultural land in the EU.

Contaminants and pathogens

While sewage sludge contains nutrients and organic matter that are beneficial for the soil, it also contains contaminants such as heavy metals, organic compounds and pathogens. There is clear evidence that, since the mid 80s, concentrations of heavy metals in sewage sludge have steadily declined in the EU15 due to regulatory controls on the use and discharge of dangerous substances, voluntary agreements and improved industrial practices. These measures have led to the cessation or reduction of discharges, emissions and losses of these heavy metals to the environment.

The current Sewage Sludge Directive addresses both pathogen reduction and the potential for accumulation of persistent pollutants in soils but sets no limits for organic contaminants. The Directive sets limit values for seven heavy metals (cadmium, copper, nickel, lead, zinc, mercury and chromium), both in soil and in sludge itself. It specifies general land use, harvesting and grazing restrictions to provide protection against health risks from residual pathogens. The Directive requires all sludge to be treated before being applied to agricultural land, but allows the injection of untreated sludge into the soil under specific conditions.. While it calls for the use of treated sludge, the Directive does not specify treatment processes.

Most MS have adopted stricter standards and management practices than those specified in the Directive, either through binding rules or via codes or practice and other voluntary agreements. While the standards for the level of potentially toxic elements (PTEs) in soil in these Member State requirements are similar to the ones specified in the Directive, the majority of MS have introduced more stringent standards for sludge quality including stricter limits for most PTEs. Some have introduced limits for additional parameters such pathogens, organic contaminants and other elements. In general, untreated sludge is no longer applied and in several MS it is prohibited. However, these national (and in some case regional) requirements vary across the EU. In some cases, including the Netherlands, the Flemish region in Belgium and Bavaria in Germany, stringent standards have resulted in an effective ban on use of sludge for agriculture. (Details on Member State requirements can be found in Part III of this report.)

Current risks to human health and the environment

Significant environment or health risks linked to the use of sewage sludge on land in the EU have not been documented in scientific literature since the Directive took effect. It is, however, difficult to establish whether this is because the provisions of the Directive are sufficient or is due to the fact that more stringent national requirements have been put in place.

The presence of human pathogens in sewage sludge has led to a considerable amount of research to assess the health risks associated with the land applications of sludge. Significant environment or health risks linked to the use of sewage sludge on land in the EU have not been widely demonstrated by observations or risk assessments in scientific literature since the directive has taken effect, although there continue to be authoritative studies that identify and assess concerns. It is difficult to establish if the lack of evidence for adverse effects is because the provisions of the Directive are sufficient or is due to more stringent national requirements in some Member States.

Epidemiological and risk assessment studies on the risks to health from microbial pathogens in sewage sludge for workers and populations in the vicinity of sludge operations have not generally found the risks to be significantly greater than background risks.[2] Overall the health risks from indirect exposure to pathogens have also been found to be low, with no clearly identified public infections from the use of food grown on land where sludge was applied in accordance with the provisions in the Directive. [3]

In terms of other impacts on human health, recent risk assessments indicate that the exposure resulting from organic compounds in sewage sludge applied to land have not found an adverse effect on human health.[4] For risks posed by the wide range of potential organic contaminants, including pharmaceuticals, antibiotics, metabolically active substances, consumer and industrial substances, and for microbial pathogens, stringent precautionary controls are advocated by some authorities to deal with the risks found in some assessments. [5]

Environmental issues related to the recycling of sewage sludge on land include the risk of nutrient leaching, impacts on soil biodiversity and greenhouse gas emissions. Methane and nitrous oxide, both potent greenhouse gases, are both produced after sludge and other bio-wastes and recycled into agricultural land. Procedures and means to minimise their uncontrolled production and emission during treatment and recycling are necessary. In assessments of the global warming potential (GWP) of different treatment, recycling or disposal routes, efficient treatment and recycling to agricultural land can usually be demonstrated to have a lower GWP than other processes. There are some local circumstances, such as the location of the land or the nature of the sludge, in which the overall environmental impacts, either in terms of greenhouse gas emissions alone or in conjunction with other environmental factors, result in assessments that suggest non-agricultural routes may be more beneficial.

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[2] Tanner *et al 2008*, *Estimated Occupational Risk from Bioaerosols Generated during Land Application of Class B Biosolids*, J Environ Qual.2008; 37: 2311-2321

[3] Gale *et al.* 2003, *Pathogens in biosolids. Microbiological Risk Assessment. UKWIR,* London, UK. ISBN: 1-84057-294-9

[4] Smith SC (2008)), *The implications for human health and the environment of recycling biosolids on agricultural land*. Imperial College London Centre for Environmental Control and Waste Management. Available at: http:/www3.imperial.ac.uk/ewre

[5] See for example: Barkowski, D. *Et al* (2005) *Characterization and assessment of organic pollutants in Sewage Sludge from Municipal Wastewater Treatment Plants in the State of North Rhine-Westphalia*. Ministry of the Environment, Conservation, Agriculture and Consumer Protection of the State of North Rhine-Westfalia. Düsseldorf, June 2005. In addition, the conclusions of a recent risk assessment study (*Méthodologie d'évaluation des risques sanitaires des filières d'épandage des boues urbaines et industrielles*, 2007) carried out by the French institute INERIS together with other government bodies suggested that**:**

- The more stringent limits proposed in the Commission in 2003 (CEC 2003) are acceptable apart from
- Zinc limit value should be decreased from 750 mg t 500 mg/kg DM to reach an acceptable level of risk
- DEHP value of 100 mg/kg DM
- Benzo(a) pyrene separately from other PAHs

In terms of public concerns, odour can be an important issue prompting opposition to the use of sewage sludge on land, either due to the odour itself or to a public perception that substances adverse to health may be present. Despite a number of studies on possible adverse health effects to the public in the vicinity of sludge spreading operations there have been no unambiguously demonstrated adverse consequences to the public as a result of aerosols from properly conducted treatment and recycling operations.

Part III of this final report provides further details on the health and environmental risks and on the literature reviewed. It includes a summary of the information and comments provided by Member State officials and stakeholder representatives on this topic: here it should be noted that there was no clear consensus, with some respondents calling for stricter limits for precautionary reasons and others noting that health and environmental problems have not been identified and calling a continuation of the current requirements or for more relaxed approaches.

A baseline scenario for the future

The study developed a baseline scenario for the period 2010 to 2020: this scenario assumes that no change is made to the Sewage Sludge Directive, and it extrapolates from the current situation and current developments at EU level and in the Member States for its forecasts of future sludge production and sludge use on land. This baseline or reference scenario is an important element of the cost-benefit analysis, which measures the impacts of possible revisions to the Directive against it.

The development of the baseline involves a series of assumptions concerning key forces and trends as well as risks and opportunities that will affect the production of sewage sludge in the EU and its application to land.

In terms of overall sludge production, the following trends were identified for the EU27:

- The population of the EU will grow slowly, from about 499 million in 2010 to just under 514 million in 2020 (according to Eurostat projections)
- While industrial production will grow, process improvements, pollution prevention and improved on-site treatment will reduce sludge coming from industry
- Continued increased level of sewer connection and wastewater treatment across the EU27 which means more sewage sludge being produced which will need proper management.
- Increased industrial water pre-treatment and pollution prevention, reducing or eliminating discharge of toxic substances (heavy metals, chemicals) and improving sludge quality.

A broad range of EU, national and sub-national legislation could influence the spreading of sludge on land in the coming decade. The analysis gave highest importance to: the Landfill Directive, which will restrict the amount of sludge and other organic waste sent to landfills, and possible future local controls on pathogen content to ensure public acceptability. Many other pieces of legislation will be important, from REACH – whose restrictions on chemicals may reduce contaminants in sludge and increase public confidence – to the new Directive on renewable energy,[6] which could encourage the use of sludge for biogas and other forms of energy recover. Member States efforts to meet the requirements of the Nitrates Directives as well as the Water Framework Directive may restrict the use of sludge on land in local areas.

On the basis of this analysis of EU legislation, together with a review of possible developments in the Member States, the following major trends are expected to influence the spreading of sludge on land:

[6] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

- There will be a general phasing out of sludge being sent to landfill, due to EC restrictions on organic waste going to landfill as well as public disapproval: by 2010 the overall proportion of sludge going to landfill will be lower than currently reported, and it is estimated that by 2020 there will be no significant amounts of sludge going regularly to landfill in the EU27.
- Increased treatment of sludge before recycling to land through anaerobic digestion and other biological treatments, like composting. The use of raw sludge will no longer be acceptable.
- Potential increased restrictions on types of crops being allowed to receive treated sludge. Introduction of semi-voluntary and voluntary quality management programs such as the ones in place in England and Sweden to increase the safety of sludge use on food chain crops
- Increased attention to recovery of organic nutrients, including those in sludge.
- The main alternative to spreading sludge on land is likely to be incineration with energy recovery for sludge produced at sites where land suitable for recycling is unavailable. This will be the case in particular where population densities are high and public opposition, e.g. to odour problems, make it more difficult to recycle to land; it will be seen also where animal manures are over-abundant.

Developments related to climate change policy and renewable energy will also influence sludge management:

- Increased attention to climate change and mitigation of greenhouse gas emissions and thus recognised additional benefits of sludge applications to soils.
- There will be increased treatment of sludge with energy recovery through anaerobic digestion, incineration or other thermal treatment, with recycling of the ash. There may be increased production and utilisation of biogas from sewage sludge, as well as some production of alcohols and other fuels directly from sewage sludge using pyrolysis and gasification.
- Increased application of sludge to fuel crops such as miscanthus, hybrid poplars and other non-food energy crops.

On the basis of these trends, it is estimated that sludge production in the EU27 will reach about 11.5 million tons (dry solids) in 2010 and rise to just under 13.0 million tons in 2020 (see Table 2, above). Based on these EU-wide trends as well as analysis of individual Member States, estimates of future sludge production have been made for each Member State (some responses in the first consultation provided further information for these estimates).

Overall, in the baseline scenario the proportion of treated sludge recycled to agriculture across the EU will remain more or less the same, at 42% in 2010 and 44% in 2020 (see the Table below). The share used in incineration will rise slightly, while the share going to landfills will be halved.

Overall, the analysis considers that the use of sludge on land in the EU15 will not change dramatically over the next 5 years. While national, regional and local legislation may impose some restrictions here, the analysis suggests that the use of sludge on agricultural land will increase in the EU12, in particular in some Member States where it is currently little practiced.

Many of the factors that will influence future levels of sludge production and of sludge use on land are uncertain. The analysis identified among the key uncertainties the following factors: the development of treatment technologies for sludge; public perceptions of sludge recycling to land; future demand and supply of mineral fertilisers; and future risk assessments related to sludge (as well as public and political reactions to their results).

Table 2: Estimates of annual sewage sludge production and disposal routes, 2010 and 2020

Member State	2010					2020				
	Total Sludge	Recycled to land	Incineration	Landfill	Other	Total Sludge	Recycled to land	Incineration	Landfill	Other
	tds/a	%	%	%	%	tds/a	%	%	%	%
EU12										
Bulgaria	47,000	50	0	30	20	151,000	60	10	10	20
Cyprus	10,800	50	0	40	10	17,620	50	10	30	10
Czech Republic	260,000	55	25	10	25	260,000	75	20	5	5
Estonia	33,000	15			85	33,000	15			85
Hungary	175,000	75	5	10	5	200,000	60	30	5	5
Latvia	30,000	30		40	30	50,000	30	10	20	30
Lithuania	80,000	30	0	5	65	80,000	55	15	5	25
Malta	10,000			100		10,000	10		90	
Poland	520,000	40	5	45	10	950,000	25	10	20	45
Romania	165,000	0	5	95		520,000	20	10	30	40
Slovakia	55,000	50	5	5	10	135,000	50	40	5	5
Slovenia	25,000	5	25	40	30	50,000	15	70	10	5
EU12 Total	1,411,000	41	8	35	17	2,457,000	37	16	17	31
EU15										
Austria	273,000	15	40	>1	45	280,000	5	85	>1	10
Belgium	170,000	10	90			170,000	10	90		
Denmark	140,000	50	45			140,000	50	45		
Finland	155,000	5			95	155,000	5	5		90
France	1,300,000	65	15	5	15	1,400,000	75	15	5	5
Germany	2,000,000	30	50	0	20	2,000,000	25	50	0	25
Greece	260,000	5		95		260,000	5	40	55	
Ireland	135,000	75		15	10	135,000	70	10	5	10
Italy	1,500,000	25	20	25	30	1,500,000	35	30	5	30
Luxembourg	10,000	90	5		5	10,000	80	20		
Netherland	560,000	0	100			560,000	0	100		
Portugal	420,000	50	30	20		750,000	50	40	5	5
Spain	1,280,000	65	10	20		1,280,000	70	25	5	
Sweden	250,000	15	5	1	75	250,000	15	5	1	75
UK	1,640,000	70	20	1	10	1,640,000	65	25	1	10
EU15 total	10,153,000	43	29	11	17	10,530,000	44	37	4	15
EU27 total	**11,564,000**	**42**	**27**	**14**	**16**	**13,047,000**	**44**	**32**	**7**	**16**
EU12 (% of EU27 total)	*88*	*5*	*1*	*5*	*1*	*81*	*8*	*3*	*4*	*4*
EU15 (% of EU27 total)	*12*	*38*	*26*	*9*	*15*	*19*	*36*	*30*	*3*	*12*

Source: Based on consultant estimates and information from the consultations; see the annexes to the Report on the Baseline Scenario and Analysis of Risk and Opportunities

Notes: As working estimates, 2010 production rates have been taken to be the same as 2020 production for Member States expected to be in full compliance in 2010. For non-compliant states, rounded 2006 production rates have been used – see Annex 2 of Report 2 for details. The estimate for Belgium includes 110,000 t ds for the Flemish region; 50,500 t ds for the Walloon Region and 5,000 t ds for the Brussels region.

Options for the revision of the Sewage sludge directive

The project team developed a long list of options, based on the review of literature and of regulations in Member States as well as comments received from Member States and stakeholders in the first consultation for this study and the first workshop. This was reviewed with the European Commission. The original list included options which were deemed technically unfeasible or out of the scope of this study (for instance extending the boundary of the Directive to include uses such as reclamation, recreational and energy crops as the Directive is focused on agricultural land only).

As a result of analysis and discussion with the Commission, five options were developed. The options are as follows:

- **Option 1**: do-nothing: keeping the Directive as it is (i.e. the baseline scenario described above);
- **Option 2**: introduce certain more stringent standards, especially for heavy metals, standards for some organics and pathogens, and more stringent requirements on the application, sampling and monitoring of sludge;
- **Option 3**: introduce more stringent standards across all substances and bans on application of sludge to some crops;
- **Option 4**: total ban on the use of sludge on land; and
- **Option 5**: repeal of the Directive.

Table 7 at the end of this report provides a detailed overview of the components of these options.

Analysis of the economic, social and environmental impacts of the proposed options

The analysis of impacts followed the approach recommended in the European Commission's Impact Assessment Guidelines.[7]

The first step was a qualitative screening of the options to identify key impacts. The most important impacts identified in this screening were carried forward for detailed assessment. Table 3 below sets out the results of this qualitative assessment of the Options (the results here and in the following tables include information provided in the consultation on the preliminary version of the impact assessment).

It should be noted that the original screening list was longer: those impacts whose magnitude is considered to be quite limited are not included. This is the case, for example, for impacts on agricultural production. (Here too, these results incorporate the comments on the preliminary version of the analysis.)

A cost-benefit analysis was then prepared for the key impacts. It is important to underline that not all impacts identified in the qualitative analysis as potentially significant could be valued. Table 4 lists the impacts categories where valuations were made in this assessment, and those where valuation was not possible.

It should be noted that Option 1 is the baseline: the costs and benefits of the other options are assessed, in both qualitative and quantitative terms, in comparison with this one.

[7] Available at: http://ec.europa.eu/governance/impact/commission_guidelines/commission_guidelines_en.htm

Table 3: Initial qualitative assessment

Option	Economic Impacts	Environmental Impacts	Social Impacts
Option 1 - Baseline Scenario	0	0	0
Option 2 – "moderate changes"	Costs of alternative disposal (-) Obligation of treatment (-) Changes to regulation: including costs of consultation (-) Policy implementation and control (-) Benefits/costs if meeting other related legislation requirements (i.e. WFD, Waste Directive) (?) Loss of use of sludge as a fertiliser and fertiliser replacement costs (-/?)	Environmental benefits from reduced application (?/+) Environmental benefits/costs from alternative routes of disposal including climate change impacts from incineration, landfilling (-)	Human health benefits from reduced application (?/+) Human health costs from alternative routes of disposal, e.g. air pollution from incineration (-) Odour/amenity impacts (-/?)
Option 3 – more significant changes	As above but greater in magnitude		
Option 4 - Total Ban	Fertiliser replacement costs (--) Alternative routes of disposal for all sludge arisings (--)	Environmental benefits from reduced application (?/+) Environmental benefits/costs from alternative routes of disposal including climate change impacts (--)	Human health benefits from reduced application (?/+) Human health from alternative routes of disposal including climate change impacts (--) Odour/amenity impacts from increased landfilling and incineration (-/?)
Option 5 - Repeal of the Directive	Benefits from reduced policy monitoring and compliance (+)	Environmental benefits/costs from alternative routes of disposal including climate change (?) Potential environmental risks if a MS abandons all sludge regulation (?/--)	Human health from alternative routes of disposal including climate change (?) Potential risks to human health if a MS abandons all sludge regulation (?/--) Odour/amenity impacts from increased landfilling and incineration (-/?)
0: impact expected to be negligible; - : low/moderate negative impacts expected --: significant negative impacts expected +: low/moderate positive impacts ++: significant impacts expected			

Options 2, 3 and 4 will reduce potential environmental and health impacts from spreading sewage sludge to land, but increase impacts from alternative disposal paths. While some of these impacts – e.g. climate change and air pollution impacts from greater incineration – can be and have been assessed in monetary terms, this is not true for all. In particular, Options 2, 3 and 4 can reduce the environmental and health risks and impacts from spreading sludge on land. Here, however, neither the literature reviewed for the project nor the responses to the first consultation provided a basis for quantifying such reductions in risk. However, some Member States have introduced more stringent requirements for precautionary reasons. (See the sections above for an extended discussion of these points.) **It is important to recognise that the potential environmental and health benefits resulting from more stringent sludge standards in Options 2 and 3 (as well as the total ban in Option 4) are not quantified in this CBA.**

Table 4: Overview of impacts considered and approach

Economic impacts	Stakeholder	Description	Quantified?	Qualitative assessment if no quantification and other comments
Costs of alternative disposal	Water and sludge management operators	As sludge recycled will be ended, there will be internal costs from its disposal	Yes	-
Obligation of treatment	Water and sludge management operators	Sludge will need further treatment to deal with new standards	Yes	-
Changes to regulation	Regulators	There will be costs from changing legislation and consultation (not monetised)	No	These are expected to be moderate in comparison with total costs
Policy implementation and control	Regulators	Costs from monitoring in order to check that legislation is being met	No	These are expected to be moderate in comparison with total costs
Benefits/costs if meeting related legislation requirements (e.g. WFD)	Regulators	Option 2 and 3 likely to influence positively meeting the objectives of WFD but may act against Waste Directive (especially Option 4)	No	Depends on the level of changes. A ban may compromise objectives of Waste Directive
Loss of use of sludge as a fertiliser and fertiliser replacement costs	Farmers	As sludge is no longer available, they will have to be replaced by fertiliser (this could be organic and/or mineral)	Yes (included under net internal costs)	-
Environmental impacts				
Environmental benefits from end to application	General public	Impacts on biodiversity, ecosystems, quality of water and groundwater from an end to application	Partly	Only some impacts from air emissions; other impacts, such emissions to water and soil impacts could not be quantified.
Benefits/costs from alternative routes of disposal including climate change	General public	Impacts from increase in use of landfill and incineration for sludge	Partly	Values include externalities from air emissions (including energy recovery) but excludes impacts to the environment and human health through emissions to soil and water
Social Impacts				
Human health benefits from end to application	General public	Owing to national practices and standards, benefits uncertain due to lack of evidence	Partly	As above – Only some impacts from air emissions have been valued
Human health from alternative routes of disposal	General public	Values include human health externalities from emissions (including energy recovery)	Partly	As above – Only some impacts from air emissions have been valued

For Option 5, the impacts are highly uncertain; in particular, the environmental and health impacts could be large. Moreover, a preliminary analysis indicates that Option 5 is not acceptable on the basis of the precautionary principle. Responses received in the second consultation confirmed this assessment. A cost-benefit analysis has not been undertaken for this option, however, due to the uncertainty about the potential impacts on national legislation and practices.

Table 5: Scenario 1 (high cost) – Summary of the net costs of the options for the EU27 (compared to Option 1)

EU TOTAL	Option 2	Option 3	Option 4
Present value	2,144,665,000	4,493,702,000	7,822,364,000
Annualised Cost	219,730,000	460,398,000	801,433,000
PV discounted at 4% for the period from 2010 to 2020			

Table 6: Scenario 2 (low cost) – Summary of the net Costs of the options (compared to Option 1)

EU TOTAL	Option 2	Option 3	Option 4
Present value	8,040,000	460,398,000	7,822,364,000
Annualised Cost	824,000	4,943,000	801,433,000
PV discounted at 4% for the period from 2010 to 2020			

Tables 5 and 6 summarise the costs calculated for the options.

It should be noted that the analysis faced a key problem. A major factor in terms of the economic costs is the proportion of sewage sludge that would not meet the more stringent limits under Options 2 and 3. This has been estimated for each major component of the new limits – e.g. for the proposed limits on heavy metals in sludge, for those on organic compounds and for those in other components.

Most of the information available to make these estimates of costs is by individual component, and there is no way to estimate the cumulative effective of the different components in each option based on the data at hand. Simply totalling the separate shares of sludge failing each component's limits would in part result in a double-counting of the impacts.

The analysis instead focused on the costs of each component in turn. To estimate the total costs of each option, the analysis used two cost scenarios:

1. Scenario 1 (higher cost): the highest cost among the different components is taken as an indicator of the total costs for the Option. For both Option 2 and Option 3, the most expensive component concerns the proposed limits on organic compounds (followed by more stringent limits on PTEs in soil, with costs of similar magnitude);

2. Scenario 2 (lower cost): the lowest costs among the different options' component is taken as an indicator of the total cost for the Option. This reflects a situation where only quality assurance and monitoring requirements are changed.

As it can be seen from the Tables, Option 2 and Option 3 are significantly less expensive than Option 4 for both scenarios. (Moreover, the total ban on spreading sewage sludge on land in Option 4 may act against the principles of the Waste Directive, which give priority to the recycling and reuse of waste.)

The advantage of the component by component analysis used here, is that it allows the Commission services and others to consider the difference in costs among the different components and, as a result, make decisions concerning the individual components of each option. Such decisions could take into account the various responses with regard to the impacts from the different aspects under analysis.

Final notes

The estimates produced here are subject to many uncertainties and as a result should be only interpreted as an approximation of the total estimates for the different components of the options. This is due to uncertainties regarding the amount of sludge affected, disposal options and also the scope of the costs and the uncertainties concerning the unitary values as well as, more importantly, uncertainties concerning the baseline (i.e. percentile distribution of sludge pollutants by MS, level of treatment and background concentrations of heavy metals in soil by MS). The results nonetheless are based on the information gathered, including the responses from the two consultations, and as a result represent the best estimate currently possible based on the information available.

Based on the findings, the Commission may wish to include or exclude specific components from an option or, alternatively, implement only the least costly components. Based on our analysis and the responses received, the most costly components appear to be the limits on organics (in particular the limits on PAHs) and those on heavy metals in soil. The component with the lowest cost implications is that for quality assurance and/or increased monitoring. The limits proposed under Option 2 concerning heavy metals in sludge seem to be quite achievable and indeed many consultation responses called for such changes on the basis that national standards are already more stringent. For this reason, the costs of the more stringent limits on heavy metals in sludge in this option are likely to be limited.

As has been noted, the results do not reflect all costs and benefits. In addition to the unquantifiable reduction in risk from reduced recycling, there may be additional benefits in terms of amenity and public perception from Options 2, 3 and 4. These costs and benefits are highly uncertain, however. One other benefit from these options is that in some geographical areas the more stringent requirements under these options could help to meet other EU objectives, such as those for the Water Framework Directive. Such trade-offs will have to be borne into consideration in any decision on possible revisions to the directive.

Table 7: Overview of the options

	Option 1. Baseline Scenario	Option 2. Moderate changes (some standards more stringent)		Option 3. More significant changes (more stringent standards)		Option 4. Total Ban	Option 5. Repeal of the Directive
Limits on sewage sludge content							
Heavy metals	Retain existing limits (as given in Annex IB and IC)	More stringent standards		More stringent standards		Total ban	N/a
		PTE	mg/kg	PTE	mg/kg		
		Cd	10	Cd	5		
		Cr	1000	Cr	150		
		Cu	1000	Cu	400		
		Hg	10	Hg	5		
		Ni	300	Ni	50		
		Pb	750	Pb	250		
		Zn	2500	Zn	600		
Organics	No change – no limits	1-2 standards for "indicator" organics: PCB and PAH PAH 6mg/kg dry matter PCB 0.8 mg/kg dry matter		Introduce standards for organics for PAH, PCB, LAS, NPE, Dioxins, DEHP PAH[8] 6 mg/kg dry matter PCB[9] 0.8 mg/kg dry matter PCDD/F[10] 100 ng ITEQ/kg dry matter LAS[11] 5 g/kg dry matter NPE[12] 450 mg/kg dry matter		Total ban	

[8] Sum of the following polycyclic aromatic hydrocarbons: acenapthene, phenanthrene, fluorene, flouranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1, 2, 3-c, d)pyrene.

[9] Sum of the polychlorinated biphenyls components number 28, 52, 101, 118, 138, 153, 180.

[10] Polychlorinated dibenzodioxins/ dibenzofuranes.

[11] Linear alkylbenzene sulphonates.

[12] It comprises the substances nonylphenol and nonylphenolethoxylates with 1 or 2 ethoxy groups.

<table>
<tr><th></th><th>Option 1. Baseline Scenario</th><th colspan="4">Option 2. Moderate changes (some standards more stringent)</th><th colspan="4">Option 3. More significant changes (more stringent standards)</th><th>Option 4. Total Ban</th><th>Option 5. Repeal of the Directive</th></tr>
<tr><td>Pathogens</td><td>No change – no limits</td><td colspan="4">Conventional treatment, i.e. any sludge treatment capable of achieving a reduction in Escherichia coli to less than 5x105 colony forming units per gram (wet weight) of treated sludge.</td><td colspan="4">Advanced standard that sanitises sludge and achieves: a) a 99.99% reduction of Escherichia coli to less than 1·103 colony forming unit per gram (dry weight) of treated sludge; b) a 99.99% reduction in Salmonella Senftenberg W775 for sludge spiked with this micro-organism; c) no Ascaris ova; c) a sample of 1 gram (dry weight) of the treated sludge does not contain more than 3·103 spores of Clostridium perfringens; d) and a sample of 50 grams (wet weight) of the treated sludge does not contain Salmonella spp.</td><td>Total ban</td><td rowspan="4"></td></tr>
<tr><td>Nutrients</td><td>No change – no limits</td><td colspan="4">No standards but provision of information on N:P and C content.</td><td colspan="4">As in Option 2</td><td>Total ban</td></tr>
<tr><td>Other changes concerning quality and aimed at prevention</td><td>No change</td><td colspan="4">Require stabilisation (or pseudostabilisation) to reduce methane emissions during storage and from land. A potential indicator is the lack of oxygen demand; use volatile solid (VS) reduction of 38% or specific oxygen uptake rate of less than 1.5mg/h/g total solids</td><td colspan="4">As in Option 2 and Hazard Assessment and Critical Control Points Assessment (HACCP)</td><td>Total ban</td></tr>
<tr><td colspan="11">More stringent conditions on application of treated sludge to land</td></tr>
<tr><td colspan="11">Soil composition</td><td rowspan="13">N/a</td></tr>
<tr><td rowspan="9">Heavy metals</td><td rowspan="9">No change</td><td colspan="4">Heavy metal concentration (mg/kg)</td><td colspan="4">Heavy metal concentration (mg/kg)</td><td rowspan="9">Total ban</td></tr>
<tr><td>PTE</td><td>5≤pH<6</td><td>6<pH<7</td><td>pH≥7</td><td>PTE</td><td>5≤pH<6</td><td>6<pH<7</td><td>pH≥7</td></tr>
<tr><td>Cd</td><td>0.5</td><td>1</td><td>1.5</td><td>Cd</td><td>0.5</td><td>1</td><td>1.5</td></tr>
<tr><td>Cr</td><td>50</td><td>75</td><td>100</td><td>Cr</td><td>50</td><td>75</td><td>100</td></tr>
<tr><td>Cu</td><td>30</td><td>50</td><td>100</td><td>Cu</td><td>30</td><td>50</td><td>100</td></tr>
<tr><td>Hg</td><td>0.1</td><td>0.5</td><td>1</td><td>Hg</td><td>0.1</td><td>0.5</td><td>1</td></tr>
<tr><td>Ni</td><td>30</td><td>50</td><td>70</td><td>Ni</td><td>30</td><td>50</td><td>70</td></tr>
<tr><td>Pb</td><td>70</td><td>70</td><td>100</td><td>Pb</td><td>70</td><td>70</td><td>100</td></tr>
<tr><td>Zn</td><td>100</td><td>150</td><td>200</td><td>Zn</td><td>20</td><td>20</td><td>200</td></tr>
<tr><td>Organics</td><td>No change</td><td colspan="4">No limits , i.e. no change</td><td colspan="4">No limits, i.e. no change</td><td>Total ban</td></tr>
<tr><td>Pathogens</td><td>No change</td><td colspan="4">No limits, i.e. no change</td><td colspan="4">No limits, i.e. no change</td><td>Total ban</td></tr>
<tr><td>Nutrients</td><td>No change</td><td colspan="4">Information only</td><td colspan="4">As in option 2</td><td>Total ban</td></tr>
</table>

<table>
<tr><th></th><th>Option 1. Baseline Scenario</th><th>Option 2. Moderate changes (some standards more stringent)</th><th>Option 3. More significant changes (more stringent standards)</th><th>Option 4. Total Ban</th><th>Option 5. Repeal of the Directive</th></tr>
<tr><td>Conditions on application</td><td>No change</td><td>Setting periods for harvesting for grassland and/or forage crops– Article 7.a
Make compulsory 10 month period for fruit, vegetable crops
Ban the application of untreated sludge – changes to Article 6 which currently allows MS to authorise under certain conditions the use of untreated sludge if injected or worked into the soil.
Outright ban on the use of untreated sludge injected or worked into the soil – changes to Article 6
Liquid sludge may only be used if injected or immediately worked into soil.</td><td>Ban of application of sludge for fruit, vegetable crops and grassland</td><td>Total ban</td><td></td></tr>
<tr><td>Other changes, i.e. sampling and monitoring, Quality assurance scheme</td><td></td><td>
<table>
<tr><th rowspan="2">Quantity of sludge (tDS/year/ plant)</th><th colspan="5">Minimum number of analyses per year</th></tr>
<tr><th>Agronomic parameters</th><th>Heavy metals</th><th>OCs (except dioxins)</th><th>Dioxins</th><th>Micro-organisms</th></tr>
<tr><td>< 50</td><td>1</td><td>1</td><td>-</td><td>-</td><td>1</td></tr>
<tr><td>50 – 250</td><td>2</td><td>2</td><td>-</td><td>-</td><td>2</td></tr>
<tr><td>250 – 1000</td><td>4</td><td>4</td><td>1</td><td>-</td><td>4</td></tr>
<tr><td>1000 – 2500</td><td>4</td><td>4</td><td>2</td><td>1</td><td>4</td></tr>
<tr><td>2500 – 5000</td><td>8</td><td>8</td><td>4</td><td>1</td><td>8</td></tr>
<tr><td>> 5000</td><td>12</td><td>12</td><td>6</td><td>2</td><td>12</td></tr>
</table>
Ease the sampling and reporting requirements in case of QAS for separate discussion. Should be available for both option 2 and 3. Include CEN TC 308 procedures.</td><td>As in Option 2 but Option 3 could have more substances to be tested (organics)</td><td>Total ban</td><td></td></tr>
<tr><td colspan="6">Source: Adapted from CEC (2003): Proposal for a Directive of the European Parliament and of the Council on spreading of sludge on land. Brussels, 30 April 2003.</td></tr>
</table>

Environmental, economic and social impacts of the use of sewage sludge on land

Final Report

Part II: Report on Options and Impacts

milieu
ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by RPA, Milieu Ltd and WRc for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Ms Rocio Salado. Additional expertise was provided by Daniel Vencovsky, Elizabeth Daly, Tony Zamparutti and Rod Palfrey. The views expressed herein are those of the consultants alone and do not necessarily represent the official views of the European Commission.

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Executive Summary

Introduction

Milieu Ltd, together with partners WRc and Risk & Policy Analysts Ltd (RPA), has carried out a contract for the European Commission's DG Environment, entitled *Study on the environmental, economic and social impacts of the use of sewage sludge on land* (DG ENV.G.4/ETU/2008/0076r).

The Sewage Sludge Directive (86/278/EEC) could be said to have stood the test of time in that sludge recycling has expanded since its adoption without environmental problems. Since its adoption, however, several Member States have put in place stricter national requirements. Moreover, EC legislation has evolved in many related fields, such as chemicals regulation. Any revision should aim to retain the flexibility of the original Directive which has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the expanded EU.

The aim of the study is to provide the Commission with the necessary elements for assessing the environmental, economic and social impacts, including health impacts, of present practices of sewage sludge use on land, provide an overview of prospective risks and opportunities and identify policy options related to the use of sewage sludge on land. This could lay the basis for the possible revision of Community legislation in this field.

This is the final deliverable of the study: the first was a review of literature on the topic, *Assessment of existing knowledge*. The second was the development of a baseline scenario to 2020 concerning the spreading of sewage sludge on land and an analysis of the relevant risks and opportunities. The project Interim Report reviewed the results of the first consultation.

This report provides the list of Options for the revision of Directive 86/278/EEC as well as an assessment of the impacts of these Options, including a cost-benefit analysis (CBA).

The Options

An initial set of five options for the revision of the Sewage Sludge Directive (Directive 86/278/EEC) was developed based on the review of literature and of regulations in Member States as well as comments received from Member States and stakeholders in the first consultation for this study and the first workshop. The options are as follows:

Option 1: do-nothing: keeping the Directive as it is;
Option 2: introduce certain more stringent standards, especially for heavy metals, standards for some organics and pathogens, and more stringent requirements on the application, sampling and monitoring of sludge;
Option 3: introduce more stringent standards across all substances and bans on application of sludge to some crops;
Option 4: total ban on the use of sludge on land; and
Option 5: repeal of the Directive.

The Options were formulated in discussion with the Commission, based on the interim project results. The specific components of the Options are detailed in section 1.2 of this report.

Approach to Data Gathering

The information used for the analysis was gathered in several stages. Report III provides the results of the information-gathering phase of the project, together with an overview of the results of the first consultation, held in July and August 2009. On this basis, a preliminary impact assessment was prepared: this was the subject of the second project consultation, held in December 2009 and January 2010. Results from this consultation, including additional information on costs, were used in revising the assessment.

In total, 39 responses were received in the second consultation, providing valuable information on the costs and benefits from the different options and the magnitude of impacts on sludge recycling. A summary of the responses is provided in Annex 1. The following table summarises the numbers and types of stakeholders that replied in the consultation. Some further information was gathered at a workshop held in Brussels in late January 2010.

Table 1: Project consultation 2: Number of responses by type of stakeholder

National authority (MS)	8
Regional authority (MS-R)	4
Statutory advisor, agency, public institution (MS-A)	3
International Professional association/federation (EF)	6
National Professional association/federation (NF)	7
Company/industry (IS)	8
Consultancy	1
Research/academic institute	0
NGO	1
Other	1

Comparison of the Options

An impact screening of the different options was one of the first steps of the assessment. This was carried out following the EC Impact Assessment Guidelines. The most important impacts identified in this screening were carried forward for detailed assessment. Table 2 sets out the results of this first assessment of the Options in qualitative terms (this assessment uses the information gathered throughout the project, including the responses provided in the second consultation). It should be noted that the original list was longer: only those impacts considered as significant are presented in the table below (other impacts, e.g. impacts on agricultural production, are considered to be limited; the consultation responses agreed with these judgements).

Table 2: Initial qualitative assessment

Option	Economic Impacts	Environmental Impacts	Social Impacts
Option 1 - Baseline Scenario	0	0	0
Option 2 – “moderate	Costs of alternative disposal (-) Obligation of treatment (-)	Environmental benefits from reduced application (?/+)	Human health benefits from reduced application (?/+)

Option	Economic Impacts	Environmental Impacts	Social Impacts
changes”	Changes to regulation: including costs of consultation (-) Policy implementation and control (-) Benefits/costs if meeting other related legislation requirements (i.e. WFD, Waste Directive) (?) Loss of use of sludge as a fertiliser and fertiliser replacement costs (-/?)	Environmental benefits/costs from alternative routes of disposal including climate change impacts from incineration, landfilling (-)	Human health costs from alternative routes of disposal, e.g. air pollution from incineration (-) Odour/amenity impacts (-/?)
Option 3 – more significant changes	As above but greater in magnitude		
Option 4 - Total Ban	Fertiliser replacement costs (--) Alternative routes of disposal for all sludge arisings (--)	Environmental benefits from reduced application (?/+) Environmental benefits/costs from alternative routes of disposal including climate change impacts (--)	Human health benefits from reduced application (?/+) Human health from alternative routes of disposal including climate change impacts (--) Odour/amenity impacts from increased landfilling and incineration (-/?)
Option 5 - Repeal of the Directive	Benefits from reduced policy monitoring and compliance (+)	Environmental benefits/costs from alternative routes of disposal including climate change (?) Potential environmental risks if a MS abandons all sludge regulation (?/--)	Human health from alternative routes of disposal including climate change (?) Potential risks to human health if a MS abandons all sludge regulation (?/--) Odour/amenity impacts from increased landfilling and incineration (-/?)
0: impact expected to be negligible; - : low/moderate negative impacts expected --: significant negative impacts expected +: low/moderate positive impacts ++: significant impacts expected			

This report presents a cost-benefit analysis (CBA) for a number of impacts. It should be emphasised, however, that not all impacts could be valued. The following table summarises which impacts are valued in the assessment.

Table 3: Overview of impacts considered and approach

Economic impacts	Stakeholder	Description	Quantified?	Qualitative assessment when no quantification/other comments
Costs of alternative disposal	Water and sludge management operators	As sludge recycling will be ended, there will be internal costs from its disposal	Yes	-
Obligation of treatment	Water and sludge management	Sludge will need further treatment to deal with new standards	Yes	-

Economic impacts	Stakeholder	Description	Quantified?	Qualitative assessment when no quantification/other comments
	operators			
Changes to regulation	Regulators	There will be costs from changing legislation and consultation (not monetised)	No	These are expected to be moderate in comparison with total costs
Policy implementation and control	Regulators	Costs from monitoring in order to check that legislation is being met	No	These are expected to be moderate in comparison with total costs
Benefits/costs if meeting related legislation requirements (e.g. WFD)	Regulators	Option 2 and 3 likely to influence positively meeting the objectives of WFD but may act against Waste Directive (especially Option 4)	No	Depends on the level of changes. A ban may compromise objectives of Waste Directive
Loss of use of sludge as a fertiliser and fertiliser replacement costs	Farmers	As sludge is no longer available, they will have to be replaced by fertiliser (this could be organic and/or mineral)	Yes (included under net internal costs)	-
Environmental impacts				
Environmental benefits from end to application	General public	Impacts on biodiversity, ecosystems, quality of water and groundwater from an end to application	Partly	Only some impacts from air emissions; other impacts, such as emissions to water and soil impacts could not be quantified.
Benefits/costs from alternative routes of disposal including climate change	General public	Impacts from increase in use of landfill and incineration for sludge	Partly	Values include externalities from air emissions (including energy recovery) but excludes impacts to the environment and human health through emissions to soil and water
Social Impacts				
Human health benefits from end to application	General public	Owing to national practices and standards, benefits uncertain due to lack of evidence	Partly	As above – Only some impacts from air emissions have been valued
Human health from alternative routes of disposal	General public	Values include human health externalities from emissions (including energy recovery)	Partly	As above – Only some impacts from air emissions have been valued

Comparison of the Options

Option 1 is the baseline: the costs and benefits of the other options are assessed in comparison with this one.

Options 2, 3 and 4 will reduce potential environmental and health impacts from spreading sewage sludge to land, but increase impacts from alternative disposal paths. While some of these impacts – e.g. climate change and air pollution impacts from greater incineration – can be assessed, this is not true for all. In particular, Options 2, 3 and 4 will reduce environmental and health impacts from spreading sludge on land.

Here, however, the project team has not found literature quantifying this reduction; nor did the responses to the first consultation provide relevant data. Much of the literature and many responses to the first consultation indicate that the current levels (Option 1) adequately protect environment and human health. However, some Member States have introduced more stringent requirements for precautionary reasons, and it is not possible to indicate the extent to which adequate protection is due to the Directive or to more stringent national requirements. **It is important to recognise that the potential environmental and health benefits resulting from more stringent sludge standards in Options 2 and 3 (as well as the total ban in Option 4) are not quantified in this CBA.**

For Option 5, the impacts are highly uncertain and the environmental and health impacts could be large. In a preliminary analysis, it appears that Option 5 is not acceptable on the basis of the precautionary principle. This has also been confirmed by responses to the consultation. A cost-benefit analysis has not been undertaken for this option on the basis of the uncertainty about the potential national reactions (i.e. how national legislation and practice would change).

Tables 4 and 5 below summarise the costs for the options, as calculated under this CBA.

It should be noted that the analysis faced a key problem. A major factor in terms of the economic costs is the proportion of sewage sludge that would not meet the more stringent limits under Options 2 and 3. This has been estimated for each major component of the new limits – i.e. for heavy metals, for organic compounds, pathogens and also for the monitoring and quality assurance requirements.

Most of the information available, however, is by individual component, and it has not been possible to estimate the cumulative effective of the different components in each option. Simply summing the separate shares of sludge failing each component's limits would in part double-count the results and thus would likely represent an over-estimate of the costs.

The analysis has instead used two scenarios, a high and a low estimate, for each option.

1. Scenario 1 (high estimate): the highest costs among the different components of each option is taken as an indicator of the total costs for the Option. For both Option 2 and Option 3, the most expensive component concerns the new limits on organics, which is the component leading to the greatest costs (followed by limits of PTEs in soil, with costs of similar magnitude);
2. Scenario 2 (low estimate): the lowest costs among the different options' component is taken as an indicator of the total cost for the Option. This reflects a situation when only quality assurance and monitoring requirements are changed.

While scenario 1 may underestimate the total costs of each option, it is believed that it will provide a good comparison of the costs among the different options.

This approach has an advantage: the detailed component by component analysis (provided in the full report) allows decision-makers to consider the separate costs for each component. This can help in weighing the individual components of each option and considering options that include only some of them. This may be an important consideration, as the consultation responses and workshop discussion indicated varying support for the different components.

As it can be seen from the Tables, Option 2 and Option 3 are significantly less costly than Option 4 for both scenarios. Among the three options, it appears that Option 2 will have the most limited cost implications. Option 3 is likely to affect a larger number of sewage treatment plants and a higher share of sewage sludge. The greatest economic costs are expected from Option 4, a total ban.

Table 4: Scenario 1 – Summary of Net costs of Options (against Option 1)

PV	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	2,174,438,000	4,540,742,000	7,964,555,000
Annualised Costs	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	222,780,000	465,217,000	816,001,000
PV discounted at 4% covering period from 2010 to 2020			

Table 5: Scenario 2– Summary of Net Costs of Options (against Option 1)

PV	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	8,040,000	48,242,000	7,964,555,000
Annualised Costs	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	824,000	4,943,000	816,001,000

Concluding notes

The estimates produced here are subject to many uncertainties and as a result should be only interpreted as an approximation of the costs each option. This is due to uncertainties regarding the amount of sludge affected, disposal options and also the scope of the costs and the uncertainties concerning the unitary values as well as, more importantly, uncertainties concerning the baseline (i.e. percentile distribution of sludge pollutants by MS, level of treatment and background concentrations of heavy metals in soil by MS). The results nonetheless provide an idea about the order of magnitude of these costs. Moreover, they incorporate the information provided through the second consultation and as a result represent the best estimate possible based on the information available.

Based on the findings, the Commission may wish to include or exclude specific components from the Options or, alternatively, implement only the least costly components. Based on our analysis and the responses from the consultees, the most costly components appear to be the limits on organic compounds (in particular the limits on PAHs) and those on heavy metals in soil. The component with the smallest cost implications is that for quality assurance and/or increased monitoring (although the costs appear to vary significantly in range). The limits proposed under Option 2 concerning heavy metals in sludge seem to be achievable and most Member State and stakeholder responsdents called for this type of change on the basis that most national standards are already more stringent than the current Directive. As a result the costs of only introducing more stringent limits on PTEs in sludge (at levels such as those in Option 2) appear to be limited.

The above figures do not reflect all costs and benefits. In addition to the unquantifiable reduction in human health and environmental risks from reduced recycling, there may be additional benefits in terms of amenity and public perception from Option 2, 3 and 4. These are highly uncertain, however. One other benefit from Options 2, 3 and 4 is that in some geographical areas they could help meet other EU environmental objectives, such as those for the Water Framework Directive. A total ban, on the other hand, may act against the waste hierarchy set forth in the Waste Directive: this gives priority to the recovery and recycling of waste.

Such trade-offs will have to be borne into consideration in a decision on the revision of the Directive.

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List of abbreviations

AD	Anaerobic digestion
AOX	Total adsorbable organo-halogen
APD	Acid phase digestion processes
BAT	Best available techniques
BOD, BOD5	Biochemical oxygen demand
CBA	Cost-benefit analysis
CEN	Comité Européen de Normalisation
CHP	Combined heat and power plant
COD	Chemical oxygen demand
CoGP	Code of good practice
DEHP	Bis(2-ethylhexyl)phthalate
DG ENV	Directorate General Environment of the European Commission
DM	Dry matter, or dry solids, or total solids
DS	Dry solids, dry matter, total solids
ECJ	European Court of Justice
EEA	European Environment Agency
EoW	End-of-waste
EPA	Environmental Protection Agency
EQS	environmental quality standards
EU 12	The 12 Member States that joined the EU in 2004 and 2008
EU 15	The 15 Member States that joined the EU before 2004
EU 27	All 27 Member States since 2008
FAO	Food and Agriculture Organization
FWD	Food waste disposal
GHG	Green house gas
GWP	Global warming potential
HACCP	Hazard analysis and critical control point
IA	Impact Assessment
IPPC	Integrated pollution prevention and control
LAS	Linear alkylbenzene sulfonate
LCA	Life-cycle analysis
MAD	Mesophilic anaerobic digestion
MBT	Mechanical biological treatment
MS	Member State of the European Union
MSW	Municipal solid waste
Mt	Million tonnes
ND	Nitrate Directive
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
OC	Organic compounds / Organic contaminants
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCDD/F	Polychlorinated dibenzodioxins and polychlorinated dibenzofurans
pe	population equivalent
PPP	Public private partnerships
PTE	Potentially toxic elements; refers to heavy metals
QA	Quality assurance

QMRA	Quantitative microbial risk assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive
SEPA	Scottish Environmental Protection Agency
SSM	Safe sludge matrix
TD	Thermal Destruction
tDS	Tonnes of dry solids
THP	Thermal hydrolysis process
TOC	Total organic content/carbon
TRF	Toxicological reference value
TS	Total Solids, dry matter, dry solids
TSP	Total sludge production
UBA	Umweltbundesamt
UWWTD	Urban waste-water treatment
VOSL	Value of statistical life
WFD	Water Framework Directive
WI	Waste incineration
WWTP	Wastewater treatment plant

1. Introduction

1.1 Scope of this Study

The objective of the impact assessment was to inform the commission about the different impacts expected from a set of Options concerning the use of sludge on agriculture.

The options considered below are concerned only with sewage sludge as defined in Directive 86/278/EEC, i.e.:

i) *residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of a composition similar to domestic and urban waste waters [..]*

Art.2 (a)

As for the uses the options are only concern with the use of sludge on agriculture, where agriculture means:

the growing of all types of commercial food crops, including for stock-rearing purposes

Art.2 (c)

Consultation proposed extending the scope to cover other industrial uses and the use of sludge on other land rather than agriculture, i.e. forestry. However, these aspects are believed to be outside the scope of this study as the options agreed did not concern expanding the scope of the Directive.

1.2 Overview of Options

An initial set of options for the revision of the Sewage Sludge Directive was developed based on the review of literature and of regulations in Member States, as well as comments received from Member States and stakeholders in the first consultation for this study and the first workshop.

The consultation on the previous report, the Interim Report[1], has revealed different opinions concerning changes to the Directive, with some member states (MS) favouring the status quo whilst others consider that changes to the Directive are required. The changes proposed included the following:

- Revision of current limit values for heavy metals;
- Introduction of limit values for organic pollutants;
- Introduction of pathogen concentration limits; and
- Introduction of a quality assurance system.

The project team developed a long list of options, which was reviewed with the European Commission. The original list included options which were deemed technically unfeasible or out of the scope of this study (for instance extending the boundary of the Directive to include uses such as reclamation, recreational and energy crops). As a result, five options were developed. The options carried out for this IA have also considered the previous Commission Communication in 2003[2]. There are five options as follows:

[1] WRc, Milieu and RPA (2009): Environmental, economic and social impact of the use of sewage sludge on land, Interim Report, October 2009.

[2] CEC (2003): Proposal for a Directive of the European Parliament and the Council on spreading of sludge on land, Brussels, 30 April 2003.

- **Option 1**: do-nothing: keeping the Directive as it is;
- **Option 2**: introduce certain more stringent standards, especially for heavy metals, standards for some organics and pathogens, and more stringent requirements on the application, sampling and monitoring of sludge;
- **Option 3**: introduce more stringent standards across all substances and bans on application of sludge to some crops;
- **Option 4**: total ban on the use of sludge on land; and
- **Option 5**: repeal of the Directive.

A brief summary of each option is provided in Table 6.

Table 6: Option comparison by component

	Option 1 = Baseline Scenario	Option 2 = Moderate changes (some standards more stringent)		Option 3 – More significant changes (more stringent standards)		Option 4 = Total Ban	Option 5 = Repeal of the Directive
Limits on sewage sludge content							
Heavy metals	Retain existing limits (as given in Annex IB and IC)	More stringent standards		More stringent standards		Total ban	N/a
		PTE	mg/kg	PTE	mg/kg		
		Cd	10	Cd	5		
		Cr	1000	Cr	150		
		Cu	1000	Cu	400		
		Hg	10	Hg	5		
		Ni	300	Ni	50		
		Pb	750	Pb	250		
		Zn	2500	Zn	600		

	Option 1 = Baseline Scenario	Option 2 = Moderate changes (some standards more stringent)	Option 3 – More significant changes (more stringent standards)	Option 4 = Total Ban	Option 5 = Repeal of the Directive
Organics	No change – no limits	1-2 standards for "indicator" organics: PCB and PAH PAH 6mg/kg dry matter PCB 0.8 mg/kg dry matter	Introduce standards for organics for PAH, PCB, LAS, NPE, Dioxins, DEHP PAH3 6 mg/kg dry matter PCB4 0.8 mg/kg dry matter PCDD/F5 100 ng ITEQ/kg dry matter LAS6 5 g/kg dry matter NPE7 450 mg/kg dry matter	Total ban	
Pathogens	No change – no limits	Conventional treatment, i.e. any sludge treatment capable of achieving a reduction in Escherichia coli to less than 5x105 colony forming units per gram (wet weight) of treated sludge.	Advanced standard that sanitises sludge and achieves: a) a 99.99% reduction of Escherichia coli to less than 1·103 colony forming unit per gram (dry weight) of treated sludge; b) a 99.99% reduction in Salmonella Senftenberg W775 for sludge spiked with this micro-organism; c) no Ascaris ova; c) a sample of 1 gram (dry weight) of the treated sludge does not contain more than 3·103 spores of Clostridium perfringens; d) and a sample of 50 grams (wet weight) of the treated sludge does not contain Salmonella spp.	Total ban	
Nutrients	No change – no limits	No standards but provision of information on N:P and C content.	As in Option 2	Total ban	

3 Sum of the following polycyclic aromatic hydrocarbons: acenapthene, phenanthrene, fluorene, flouranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1, 2, 3-c, d)pyrene.

4 Sum of the polychlorinated biphenyls components number 28, 52, 101, 118, 138, 153, 180.

5 Polychlorinated dibenzodioxins/ dibenzofuranes.

6 Linear alkylbenzene sulphonates.

7 It comprises the substances nonylphenol and nonylphenolethoxylates with 1 or 2 ethoxy groups.

	Option 1 = Baseline Scenario	**Option 2 = Moderate changes (some standards more stringent)**				**Option 3 – More significant changes (more stringent standards)**				**Option 4 = Total Ban**	**Option 5 = Repeal of the Directive**
Other changes concerning quality and aimed at prevention	No change	Require stabilisation (or pseudostabilisation) to reduce methane emissions during storage and from land. A potential indicator is the lack of oxygen demand; use volatile solid (VS) reduction of 38% or specific oxygen uptake rate of less than 1.5mg/h/g total solids				As in Option 2 and Hazard Assessment and Critical Control Points Assessment (HACCP)				Total ban	
More stringent conditions on application of treated sludge to land											
Soil composition											N/a
Heavy metals	No change	Heavy metal concentration (mg/kg)				Heavy metal concentration (mg/kg)				Total ban	
		PTE	5<pH<6	6<pH<7	pH>7	PTE	5<pH<6	6<pH<7	pH>7		
		Cd	0.5	1	1.5	Cd	0.5	1	1.5		
		Cr	50	75	100	Cr	50	75	100		
		Cu	30	50	100	Cu	30	50	100		
		Hg	0.1	0.5	1	Hg	0.1	0.5	1		
		Ni	30	50	70	Ni	30	50	70		
		Pb	70	70	100	Pb	70	70	100		
		Zn	100	150	200	Zn	20	20	200		
Organics	No change	No limits , i.e. no change				No limits, i.e. no change				Total ban	
Pathogens	No change	No limits, i.e. no change				No limits, i.e. no change				Total ban	
Nutrients	No change	Information only				As in option 2				Total ban	
Conditions on application	No change	Setting periods for harvesting for grassland and/or forage crops– Article 7.a Make compulsory 10 month period for fruit, vegetable crops Ban the application of untreated sludge – changes to Article 6 which currently allows MS to authorise under certain conditions the use of untreated sludge if injected or worked into the soil. Outright ban on the use of untreated sludge injected or worked into the soil – changes to Article 6 Liquid sludge may only be used if injected or immediately worked into soil.				Ban of application of sludge for fruit, vegetable crops and grassland				Total ban	
Other changes, i.e.		Quantity of	Minimum number of analyses per year			As in Option 2 but Option 3 could have more substances to be tested (organics)				Total ban	

<table>
<tr><th></th><th>Option 1 = Baseline Scenario</th><th colspan="6">Option 2 = Moderate changes (some standards more stringent)</th><th>Option 3 – More significant changes (more stringent standards)</th><th>Option 4 = Total Ban</th><th>Option 5 = Repeal of the Directive</th></tr>
<tr><td rowspan="8">sampling and monitoring, Quality assurance scheme</td><td rowspan="8"></td><td>sludge (tDS/year/ plant)</td><td>Agronomic para-meters</td><td>Heavy metals</td><td>OCs (except dioxins)</td><td>Diox-ins</td><td>Micro-organ-isms</td><td rowspan="8"></td><td rowspan="8"></td><td rowspan="8"></td></tr>
<tr><td>< 50</td><td>1</td><td>1</td><td>-</td><td>-</td><td>1</td></tr>
<tr><td>50 – 250</td><td>2</td><td>2</td><td>-</td><td>-</td><td>2</td></tr>
<tr><td>250 – 1000</td><td>4</td><td>4</td><td>1</td><td>-</td><td>4</td></tr>
<tr><td>1000 – 2500</td><td>4</td><td>4</td><td>2</td><td>1</td><td>4</td></tr>
<tr><td>2500 – 5000</td><td>8</td><td>8</td><td>4</td><td>1</td><td>8</td></tr>
<tr><td>> 5000</td><td>12</td><td>12</td><td>6</td><td>2</td><td>12</td></tr>
<tr><td colspan="6">Ease the sampling and reporting requirements in case of QAS for separate discussion. Should be available for both option 2 and 3. Include CEN TC 308 procedures.</td></tr>
<tr><td colspan="11">Source: Adapted from CEC (2003): Proposal for a Directive of the European Parliament and of the Council on spreading of sludge on land. Brussels, 30 April 2003.</td></tr>
</table>

2. Approach to the Impact Assessment

2.1 Overview

A preliminary impact assessment was conducted in November 2009. This report was published for consultation with interested stakeholders. The report included a number of questions in order to check the assumptions and gather more data on the impacts. The level of response was substantial and a total of 39 responses were gathered around the 20 questions presented in the study. The list of respondents as well as a summary of responses is provided in Annex 1. The results of the consultation have helped in refining the previous assumptions and assessing the impacts on disposal.

The assessment of options follows a similar approach to the CBA conducted in 2002 (by Sede and Andersen; although there are differences in the limits proposed). This Impact Assessment (IA) aims to quantify all the impacts where data are available that allow initial estimates to be made of the costs and benefits. When impacts are not quantified, qualitative descriptions are provided.

2.2 Initial Screening

Table 7 shows the impact screening based on the IA Guidelines by the Commission for the different Options. When impacts are uncertain, they have been carried forward for the analysis. The greatest uncertainty applies to Option 5 as this will finally rely on any changes to national legislation and implementation at MS level.

Table 7: Impact Screening

	Option 1 - BAU	**Option 2 - moderate changes**	**Option 3 - more significant changes**	**Option 4 - ban on the use of sludge on land**	**Option 5 - Repeal of the Directive**
	Impacts likely?				
ECONOMIC IMPACTS					
Functioning of the internal market and competition	No	Uncertain	Uncertain	Uncertain	Uncertain
Competitiveness, trade and investment flows	No	Uncertain	Yes	Yes	Uncertain
Operating costs and conduct of SMEs	No	Yes	Yes	Yes	Uncertain
Administrative burdens on business	No	Yes	Yes	Uncertain	Uncertain
Public authorities	No	Yes	Yes	Yes	Uncertain
Property rights	No	No	No	No	Uncertain
Innovation and research	No	Uncertain	Uncertain	Yes	Uncertain
Consumers and household	No	Uncertain	Uncertain	Yes	Uncertain
Specific regions and sectors	No	Yes	Yes	Yes	Uncertain
Third countries and international relation	No	No	No	No	No
Macroeconomic environment	No	Uncertain	Uncertain	Uncertain	Uncertain
SOCIAL IMPACTS					
Employment and Labour markets	No	Uncertain	Uncertain	Uncertain	Uncertain
Standards and rights related to job quality	No	No	No	No	No

	Option 1 - BAU	Option 2 - moderate changes	Option 3 - more significant changes	Option 4 - ban on the use of sludge on land	Option 5 - Repeal of the Directive
Social inclusion and protection of particular groups	No	No	No	No	No
Gender equality, non-discrimination	No	No	No	No	No
Governance, participation	No	No	No	Uncertain	Uncertain
Public health and safety	No	Yes	Yes	Yes	Uncertain
Crime, terrorism and security	No	No	No	No	No
Access to social protection and health	No	No	No	No	No
Culture	No	No	No	No	No
Impacts on third countries	No	No	No	No	Uncertain
ENVIRONMENTAL IMPACTS					
The climate	No	Yes	Yes	Yes	Uncertain
Transport and the use of energy	No	Yes	Yes	Yes	Uncertain
Air quality	No	Yes	Yes	Yes	Uncertain
Biodiversity, flora, fauna and landscape	No	Yes	Yes	Yes	Uncertain
Water quality and resources	No	Uncertain	Uncertain	Uncertain	Uncertain
Soil quality and resources	No	Uncertain	Uncertain	Uncertain	Uncertain
Land use	No	Uncertain	Uncertain	Yes	Uncertain
Renewable and non-renewable sources	No	Yes	Yes	Yes	Uncertain
Environmental consequences	No	Uncertain	Uncertain	Uncertain	Uncertain
Waste production/generation/recycling	No	Yes	Yes	Yes	Uncertain
Likelihood of environmental risk	No	Yes	Yes	Yes	Uncertain
Animal welfare	No	No	No	No	Uncertain
International and environmental impacts	No	Uncertain	Uncertain	Uncertain	Uncertain

2.3 Identification of stakeholders

The range of stakeholders affected and types of costs and benefits considered are set out in Table 5. Consultation has helped to reassess the impacts, for instance, it has been confirmed that impacts on agricultural outputs are expected to be negligible as well as impact on employment in the agricultural sector. However, consultation has also highlighted that these impacts would be limited. On the other hand, the sector producing recycling equipment noted during consultation that they would be affected.

Table 8: Stakeholders and costs/benefits

Stakeholder	Economic impacts	Environmental Impacts	Social Impacts
Water and sludge management operators	Costs of alternative disposal Quality assurance – including reporting requirements Obligation of treatment *Distributional impacts	Environmental benefits/costs from changes in risk of application and alternative routes of	Amenity (odour) Reduction/increase in risk – human health Employment impacts in

Stakeholder	Economic impacts	Environmental Impacts	Social Impacts
Regulatory authorities	Changes to regulation –including costs of consultation Policy implementation and control Benefits/costs if meeting other related legislation requirements (i.e. WFD and Waste Directive)	disposal including climate change	related sector (recycling manufacture)
Farmers	Loss of use of sludge as a fertiliser and fertiliser replacement costs Loss of agricultural output/crops		
Consumers/Public	Increased bills (from water companies due to greater obligation of treatment) *Distributional impacts		
*: Distributional impacts are assessed separately under this IA based on total cost /benefit estimation. However, they come under the economic impact category in the Impact Assessment. We have included them separately in this IA.			

2.4 Approach to assessment of impacts

For all options, the approach to the impact assessment will involve the following steps:

- Step 1: Identification of MS affected by changes to the Directive, due to current national legislation and current practices;
- Step 2: Direct impact estimation when impacts are considered likely on recycling rates and changes in amount going to different disposal options; and
- Step 3: Indirect impacts from changes in the above in terms of costs and benefits to the different stakeholders (e.g. fertiliser replacement, costs of incineration, etc). The approach will then be the following:

Costs/Benefits = amount of sludge affected x impact (in quantitative term) x unit costs (€) for impact

The approach to the impact assessment has considered the impact of the new standards of the different treatment options as well as disposal. In this regard, the current management of countries have been taken into account to generate the estimates (with the help of consultation). Unitary costs have then been applied to account for the switch from recycling to different disposal options. The unitary costs and benefits considered in this IA are presented in Section 3.

Where impacts have not been quantified due to a lack of data, these are described qualitatively. When impacts are highly uncertain, ranges have been used or qualitative descriptions used. The below Table presents a summary of the impacts that have been quantified in this IA.

Table 9: Impact quantification

Impacts	Quantified	Comments
Economic impacts		
Costs of alternative disposal	Yes	These costs are the main costs stemming from the options when the new standards will affect the level of recycling
Loss of use of sludge as a fertiliser and fertiliser replacement costs	Yes	
Obligation of treatment	Yes	
Quality assurance – including reporting requirements	Yes	
Loss of agricultural production	No	Stakeholder identified that impacts in this regard are unlikely as sludge could be replaced by fertilisers (organic and mineral)

Impacts	Quantified	Comments
Employment impacts	No	Difficult to estimate with accuracy – some stakeholder have highlighted that there may be impacts should a ban or very stringent limits be implemented (i.e. manufacturers of recycling equipment) but others have highlighted negligible impacts
Amenity (increase in real or perceived value of land from reduced sludge application)	No	Highly uncertain, hence not estimated
Energy recovery	Partially	Market price of incineration and landfilling takes into account energy recovery. External benefits have not been quantified; however, in relation to incineration, this is perceived to be wholly or partially counterbalanced by the need for sludge drying
Impact on markets for mineral and other natural fertilizers	No	The impacts are considered low, as the fertilizer market is much larger in volume than sludge market (but impact might be greater under Option 4)
Increased water bills	No	Depend on national practices – some costs may be passed on to farmers and consumers in terms of increased waterbills but this may vary significantly among MS
Increased consumer confidence (linked to food sales)	No	Highly uncertain, hence not estimated
Innovation and research	No	Highly uncertain, hence not estimated
Environmental impacts		
Environmental benefits/costs from changes in risk from changes in quantity of recycled sludge: e.g. soil impacts, discharges to surface water and groundwater	Partially	Only some impacts from air emissions and reduced need to use fertiliser quantified; other impacts, such emissions to water and soil impacts could not be quantified.
Environmental benefits/costs from changes in risk from alternative disposal: • CO_2 emissions and impact on climate change • Other air pollutants • Discharges to water and groundwater	Partially	Some impacts linked to air emissions have been quantified and the results have been included in the impact assessment. However, some other impacts, such as discharges to water, could not be quantified.
Social impacts		
Amenity (odour)	No	Highly uncertain and variable among MS
Human health impacts from changes in risk from changes in quantities of recycled sludge	Partially	Some impacts from air emissions have been valued as these are included in the overall valuation of air emissions.
Human health benefits/costs from changes in risk from alternative disposal • Air emissions from incineration in particular	Partially	Health impacts linked to air emissions have been quantified as these are included in the overall impact valuation of air emissions.
Benefits if meeting other related legislation requirements (i.e. WFD)	No	Difficult to quantify. Significant data requirements on degree of implementation of relevant policies

The period for analysis is the same as that used in the Interim report: to 2020. The benefits and costs have been discounted at 4%.

3. Valuation methodology used to assess costs and benefits from different sludge management options

3.1 Overview

When the policy options are expected to affect the recycling route, impacts will be likely. In other words, there will be costs and benefits related to the increased incineration, landfilling and/or further treatment when the volumes of recycling are affected by the policy option or by any of the option components. In this Section, we explain the methodology used for estimating the benefits and the costs of changes to the different sludge management options.

The costs and benefits fall in two main categories:

1. **Financial benefits and costs** – also called “internal” benefits and costs. These costs are aimed to capture the financial costs and benefits as reflected in the market place. It is important to note that subsidies/taxes to the different management options, e.g. subsidies for recycling and or taxes on incineration are not included in the estimates. This is because such payments represent a transfer and as such they are not a net gain/loss to the economy; and
2. **External benefits and costs** – externalities are defined *as impacts on a party that is not directly involved in the transaction stemming from the action of another party who does not bear the costs*. In such a case, prices do not reflect the full costs or benefits in production or consumption of a product or service[8]. An example of an externality in this context is for instance the environmental impacts from air emission from incineration processes through deposition.

The valuation methodology in this report largely follows the methodology for valuing internal and external costs and benefits from sludge disposal routes developed by Sede and Andersen (2002). Unit costs given in Sede and Andersen (2002) have been updated to reflect the increase in average price levels since 2002 (using the retail price index[9]) and changes in EU-wide price levels as a result of EU enlargements in 2004 and 2007 (we estimate that this reduced the average price level by approximately 9%).

The remainder of this section provides an overview of the current disposal routes which have helped to estimate the impacts in the different MS as well as a summary of the unit costs used for their analysis; including the sources of uncertainty. All unit costs used for further analysis in this report are summarised at the end of this section.

3.2 Incineration

3.2.1 Overview of sludge incineration rates in EU Member States

Incineration is used as a treatment for a very wide range of wastes. The objective of waste incineration is to treat wastes so as to reduce their volume and hazard, whilst capturing (and thus concentrating) or destroying potentially harmful substances that are, or may be, released during incineration. Incineration processes can also provide a means to enable recovery of the energy, mineral and/or chemical content from waste.

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8 An advantageous impact is called an external benefit or positive externality, while a detrimental impact is called an external cost or negative externality.

9 Prices updated by RPI (215.3/178.5)

Incineration of sludges can be performed in designated incinerators (mono-incineration) or in municipal solid waste incinerators (co-incineration). After pre-drying sludge can also be incinerated in cement kilns because they have a high calorific value.

Specific sludge incineration facilities have been operating for many years. However, the availability of these vary significantly according to Member States. Currently data are sparse about the incineration capacities in different MS. The following Table shows the number and total capacity of existing incineration plants (not including planned sites) for general waste and dedicated sewage sludge incinerators based on information from 2001[10]. No more recent information has been found available. As a result, this information is only presented to illustrate the split among MS and types of incineration. As it can be seen, a number of MS have been, in the past, at the forefront of mono-incineration, i.e. Germany, Denmark and the UK. However, from our consultation we believe that there are existing plans to develop incineration facilities in countries such as Portugal and the Czech republic.

Table 10: Number and total capacity of incineration plants

Country	Total number Of MSW incinerators	Capacity Mt/yr	Total number of dedicated sewage sludge incinerators	Capacity Mt/yr (dry solids)
Austria	5	0.5	:	1
Belgium	17	2.4	1	0.02
Denmark	32	2.7	5	0.3
Finland	1	0.07	:	:
France	210	11,748	1	:
Germany	59	13.4	23	0.63
Greece	0	na	:	:
Ireland	0	na	:	:
Italy	32	1.71	:	:
Luxembourg	1	0.15	:	:
Portugal(a)	3	1.2	:	:
Spain	9	1.13	:	:
Sweden	30	2.5	:	:
Netherlands	11	5.3	2	0.19
United Kingdom	17	2.97	11	0.42
Note: the ":" sign denotes no data are available.				

More recent data are available on the amount of sludge being incinerated across EU. The following Table shows information from Eurostat on the trends of sludge being incinerated up to 2007. However, it is not clear whether this is incinerated with other municipal waste or in specific incinerators.

Table 11: Sludge going to incineration (kt, DS)

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Belgium	16.2	18.0	18.2	:	55.1	66.4	71.0	28.1	36.2	:	:	:
Bulgaria	:	:	:	:	:	:	:	:	0.0	0.0	0.0	0.0
Czech Republic	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.0	0.0
Denmark	32.7	33.2	31.9	:	:	:	:	:	:	:	:	:
Germany	:	:	396.0	:	:	554.9	:	:	711.2	941.7	965.1	:
Estonia	:	:	:	:	:	:	:	:	:	0.3	0.3	0.3
Ireland	:	:	:	:	:	:	:	:	:	0.0	:	:
Greece	:	:	:	:	:	0.0	0.0	0.0	0.0	0.0	0.0	:

[10] Available in CEC (2006): Integrated Pollution Prevention and Control Reference Document on the Best Available Techniques for Waste Incineration August 2006

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Spain	32.0	20.0	33.5	33.5	70.2	54.8	68.9	76.8	77.5	77.8	41.1	:
France	:	:	154.1	:	:	166.4	:	:	178.4	:	:	:
Italy	:	:	:	:	:	:	:	:	:	30.8	:	:
Cyprus	:	:	:	:	:	:	:	:	0.0	0.5	:	:
Latvia	:	:	:	:	:	:	0.0	0.0	0.0	0.0	0.0	0.0
Lithuania	:	:	:	:	:	:	:	:	:	0.0	0.0	0.0
Luxemb.	:	:	:	:	:	:	:	:	:	:	:	:
Hungary	0.0	0.1	0.5	:	:	:	:	:	:	0.0	0.0	:
Malta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	:
Netherl.	102.0	98.0	162.0	184.0	180.0	207.6	204.3	212.6	235.7	232.8	252.5	:
Austria	:	68.2	68.4	:	150.2	:	162.1	:	151.3	:	98.3	:
Poland	:	:	5.0	5.0	5.9	6.9	6.8	6.3	1.4	6.3	4.5	1.7
Portugal	:	:	:	:	:	:	:	:	:	:	:	:
Romania	:	:	:	:	:	:	:	:	:	0.0	:	:
Slovenia	:	:	:	:	:	:	:	0.0	0.0	0.0	5.2	5.1
Slovakia	0.0	0.0	0.0	:	:	:	:	:	:	:	0.0	0.0
Finland	0.0	0.0	0.0	0.0	0.0	:	:	:	:	:	:	:
Sweden	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	:
United Kingdom	:	:	:	:	:	241.2	305.8	314.3	273.2	281.9	:	:
Note: the ":" sign denotes no data are available**; "0"** less than half of the unit used**; "- "** not applicable or real zero or zero by default												

The next Table summarises the percentages currently going to incineration based on more recent data from our first consultation and projections of how these incineration capacities could be developed in the future. Again, the percentage of sludge going together with municipal solid waste (MSW) against special incineration is not clear.

Table 12 Disposal methods for sewage sludge in EU Member States as percentage incinerated (AMF 2007, Doujak 2007, Eureau 2006 reported by Smith 2008, IRGT 2005, Leonard 2008, COM personal communication, 2009) and projections for 2010 and 2020

Member State	Year of data	Incineration	2010 Projection	2020 projection
Austria	2005	47	40	85
Belgium			90	90
• Flemish Region	2005	76	:	:
• Walloon Region	2005	62	:	:
• Brussels region	2002	66	:	:
Denmark	2002	43	45	45
Finland	2000	:	:	5
France	2002	20	15	15
Germany	2003	38	50	50
Greece	:	:	:	
Ireland	2003	:	:	
Italy	2005	7	20	30
Luxembourg	2004	20	5	20
Netherlands	2006	60	100	100
Portugal	2005	0	30	40
Spain	:	:	10	25
Sweden	:	2	5	5
UK	2004	19.5	:	25
Bulgaria	2005	0	:	10
Cyprus	:	:	:	10

Member State	Year of data	Incineration	2010 Projection	2020 projection
Czech republic	2004	:	25	20
Hungary	2006	:	5	30
Poland	2000	:	5	10
Romania		:	5	10
Slovakia	2006	:	5	40
Slovenia	2006	:	5	70
Note: the ":" sign denotes no data are available.				

As it can be seen from the above Table, most of the countries will maintain and increase their incineration rates, with some of them showing a significant increase. Although the decision to mono incinerate or co-incinerate will depend on costs, other factors will also affect the choice of disposal. For instance, in case of co-incineration, the treatment capacity and treatment efficiency depend on the saturation of the incinerator by other solid waste streams and/or the ratio of sludge mass to solid waste mass.

The first consultation revealed that while several authorities and commercial stakeholders recognised the advantages of co-treatment of sludge, some regard mono-incineration as the preferred option in order to enable phosphorus recovery. Among the disadvantages of incineration are the air emissions and other externalities related to transport.

The incineration sector has undergone rapid technological development over the last years. Much of this change has been driven by legislation specific to the industry and this has, in particular, reduced emissions to air from individual installations[11]. Continual process development is ongoing, with the sector now developing techniques which limit costs, whilst maintaining or improving environmental performance. Despite this, incineration use, costs, energy benefits and emissions are contentious with strongly held views for and against the use of incineration and different estimates have been produced on the financial and external costs from incineration. These are described below.

3.2.2 Internal costs and benefits from incineration

Incinerators are normally capital intensive and probably only warranted on the basis of large volumes of material to be incinerated. The following costs categories are considered "internal costs" to incineration process:

- Costs of storage systems;
- Costs of furnace;
- Treatment of off-gas and other incineration residues, i.e. bottom ash, fly ash, clinker;
- Operating costs;
- Transport costs to the treatment site; and
- Quality control.

[11] The Waste Incineration Directive (WI Directive) sets emission limit values and monitoring requirements for pollutants to air such as dust, nitrogen oxides (NOx), sulphur dioxide (SO2), hydrogen chloride (HCl), hydrogen fluoride (HF), heavy metals and dioxins and furans. The Directive also sets controls on releases to water in order to reduce the pollution impact of waste incineration and co-incineration on marine and fresh water ecosystems. Most types of waste incineration plants fall within the scope of the Directive, with some exceptions, such as those treating only biomass (e.g. vegetable waste from agriculture and forestry). Many of the plants that are covered by the WI Directive are also covered by the Integrated Pollution Prevention and Control (IPPC) Directive.

There are a number of sources in the literature that report different costs of co-incineration. More limited is the information on the costs of mono-incineration. Sede and Andersen estimated that the costs could be of the following magnitude:

- co-incineration: €290 t/DS[12]
- mono- incineration: €374t/DS

Other costs are summarised in the next Table. As it can be seen from the Table, the costs can vary significantly; however, it is not always certain what is included under operating costs.

Table 13: Incinerator Cost Information (€2009)

Co-incineration	**Mono-incineration**	**Type of costs considered**	**Specific assumptions**	**Source**
c. €290/tDS	c. €374/tDS	Capital costs Operating costs (includes labour, energy and other consumable), transportation, disposal of residues.	€2009 prices Investment costs assessed and annualised (6% discount rate). Life of equipment ranging from 8 to 15 years depending on equipment.	Sede and Andersen (2002)
€191 - €271 /tDS	€281/tDS to €478/tDS	Capital costs and operating costs, including final disposal of residues	€2009 prices Up to 5,000 tonnes of dry material per year, representing stations from 200,000 to 800,000 pe	EEA (1998)[13]
6,500–8,500(USD/kW)	nd	Typical current investment costs	Plant size: 10–100 MW Using a 10% discount rate Other assumptions uncertain – year of value assumed 2008	IEA[14]
€486 – €1164/tpa capital costs €32 – €74/t running costs	nd	Capital Operating costs	€2004 values Size range from 40 ktpa to 450ktpa	Murphy and McKeogh[15]
€46m to €137m capital costs c. €30 to c. €70/tonne operating costs	nd	Capital Operating costs	Assumes energy recovery Costs depend on capacities ranging from 100 ktpa to 400 ktpa	Last[16]
~€190€/tDS		Capital + Operating costs	(2009)	WRc

The costs of incineration are highly variable to design aspects (and especially for mono-incineration the sensitivity of these costs were estimated to vary by around ±50% in Sede and Andersen, 2002). Assumptions regarding energy recovery from incineration have an important impact on results of analyses comparing alternative options for managing waste. From the economic point of view, energy recovery is an

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[12] Prices updated by RPI (215.3/178.5)

[13] Sludge treatment and disposal, management practices and experiences

[14] International Energy Agency (2008), Deploying Renewables. Principles for Effective Policies.

[15] Murphy, J.D. and McKeogh; E. (2004), Technical, economic and environmental analysis of energy production from municipal solid waste, Renewable Energy 29, pp 1043-1057.

[16] Last, S (2008), An Introduction to Waste Technologies, The processes Used to Recycle, Treat, and Divert Municipal Solid Waste Away from Landfills, Waste Technologies UK Associates.

important aspect, as sales of both electricity and heat can generate substantial revenue that can cover part of the incineration costs. Information on the current trends for energy recovery, however, is not available in order to calculate the revenues from selling electricity, heat and/or both.

As newer technologies develop maximising energy recovery it is expected that the marginal costs may decrease, also responding to economies of scale. A lower estimate of such costs could be illustrated by the current costs of pyrolisis or gasification (as highlighted by the stakeholders) although this is not yet common practice and these processes are currently at the development stage. The capital costs of the plants can be smaller at £19m to £93 m (based on Lust, 2008) for a 100,000 tpa plant. Information on operating costs, however, is not available although they could be expected to be similar to those of a mono-incineration plant.

For the valuation of impacts, we have chosen to use unit costs of sludge incineration that are based on an update of data provided by Sede & Andersen (2002). Sede & Andersen's valuation includes capital and operational costs of incineration which is based on the market price of incineration and thus includes all relevant costs and benefits, including that of disposal of residues and energy recovery. The internal unit costs of sludge incineration are summarised in the below Table[17].

Table 14: Internal cost of incineration used for further analysis in this study (€/t DS)

Type of cost	Co-incineration	Mono-incineration
Internal cost - investment	113	161
Internal cost - operational	177	213
Total cost	**290**	**374**

3.2.3 External costs and benefits from incineration

Incineration generates emissions into the air (particles, acid gases, greenhouse gases, heavy metals, volatile organic compounds, etc.), soil (disposal of ashes and flue gas treatment residues to landfill, atmospheric deposition of air emissions) and water (flue gas treatment wet processes). Emissions into the air may be reduced thanks to flue gas treatment. From an environmental point of view, recovered energy displaces alternative energy production and related environmental impacts. Operation of an incineration plant may also produce noise, dust, odour and visual pollution.

The environmental impacts from incineration are summarised in the next Table.

Table 15: Environmental impacts from incineration

Emissions	**Impacts**
Energy production	Displaced emissions of pollutants to air
Emissions of pollutants to air via smoke stack	Human health impacts Ecosystem degradation Climate change Building degradation
Emissions of wastewater to surface water	Human health Decrease in surface water quality
Emissions of leachate to soil from landfilling of ash	Human health impacts Soil micro-organisms reduction Decrease in groundwater quality
Emission of leachate to water (landfilling of ash)	Human health impacts Decrease in surface water quality
Visual intrusion	Social acceptance

[17] These values are inferred from a figure available in the report.

Emissions	Impacts
	Public anxiety
Transportation	Exhaust emissions due to transportation
Source: adapted from Sede and Andersen 2002	

A number of impacts from the above list are expected to be minimised on the basis of existing legislation. These include for instance lanfilling of ash (and this is subject to stricter legislative requirement than conventional waste); as a result impacts from leachate are expected to be negligible. Some other impacts will not be subject to valuation in this study, i.e. visual intrusion as this will depend on site specifics and other perception issues that are not subject to modelling. Other impacts may be considered negligible, i.e. transportation, as sludge transportation is considered to be very low in comparison with the total traffic. In addition, it will depend on local conditions.

More detailed discussion of individual environmental impacts from sludge incineration and of the method for their valuation (or of the reasons for not valuing them in this study) is given below.

Energy production

Incineration of sludge and/or wastes generates excess heat which may be used as such or converted into electricity. Energy recovery could therefore be considered as an external benefit of sludge incineration, considering the saving of non-renewable resources. Currently however there is limited information on the energy recovery from incineration, including anaerobic digestion.

Several studies have calculated the benefits from energy reduction ranging from €0 to €100/tonne waste. The following Table summarises the benefits from energy recovery in a number of studies.

Table 16: Valuation of energy recovery (reduced emissions) from incinerators (€2009/tonne waste/MSW)

Source	**Valuation of savings from energy recovery (€2009/tonne waste)**
CSERGE et al (1993)	6.55 - 22.47
Powell and Brisson (1994)	10.46 - 14.32
Enosh (1996)	8.14
EMC (1996)	8.14
EC (2000)	0 - 109.51
Dijkgraaf and Vollebergh (2003)	21.54
Source: Eshet et al (2006): Valuation of externalities of selected waste management alternatives Assumes $1=€0.88 (2003), updated to €2009 with HPCI	

COWI (2000)[18] also considered that the benefits of displaced emissions could vary significantly according to the type of waste being considered and the type of incineration. The values for various types of incineration plants are replicated in the following Table.

[18] European Commission, DG Environment A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste Final Main Report October 2000.

Table 17: Valuation of energy recovery (reduced emissions) (€2009)

I1.	I2.	I3.
-87 (-141 – -23)	-26 (-36 – -5)	0 (-)
I1. Energy recovered will generate electricity and heat (CHP), which normally implies a high recovery percentage. This percentage is assumed to be 83%. **I2.** Energy recovered will generate electricity only, which normally implies a lower recovery percentage. This percentage is assumed to be 25%. **I3.** The flue gas cleaning technology is an electrostatic precipitator. There is no energy recovery.		

The above values however reflect energy recovery from general waste. In the context of sludge however, this will have to be dried prior to the incineration process. The 2002 report by Sede and Andersen was based on the assumption that energy production from sludge incineration is counterbalanced by energy needs of reduction of the water content of sludge, and as a result the net benefit was considered to be negligible. For this reason, this type of benefit was not valued by Sede and Andersen. This approach is also followed here although owing to more recent technologies the costs may represent an overestimate of the real cost in this context.

Human health

Incineration can impact human health directly and indirectly. The former is related to exposure to flue gas inhalation, containing compounds such as heavy metals, dioxins, HCl, NOx, SO2, or particulate matter. The latter may be due to ingestion of contaminated vegetal or animal products. Human health may also be affected by waste water produced during the wet treatment of flue gas if this is emitted to surface or groundwater. Generally though, human health risk from wet treatment of flue gas may be minimised on the basis of available legislation. The risk from contamination is also expected to be limited.

Incineration of sludge however could be regarded as carbon neutral. This is line with the approach on biowaste[19] incineration in the meaning of the renewable energy directive and the proposed Directive on the promotion of the use of energy from renewable resources. This is also the new approach by the IPCC. Under international GHG accounting methods developed by the Intergovernmental Panel on Climate Change (IPCC), non-fossil CO_2 is considered to be part of the natural carbon balance and therefore not a contributor to atmospheric concentrations of CO_2. The rationale behind the IPCC's decision is that non-fossil carbon was originally removed from the atmosphere via photosynthesis, and under natural conditions, it would eventually cycle back to the atmosphere as CO_2 due to degradation processes. Given this, CO_2 emissions from combustion of biomass fuels should not be included in totals for the energy sector. As a result, CO_2 is not considered here under the air emissions below.

The following Table shows emissions to air from incineration.

Table 18: Air emissions from sludge incineration (unit g/tDS unless otherwise stated)

Emission type	Mono-Incineration	Co-incineration
CH_4(kg/tDS)	0	0
NO_x	1,253	1,233
CO	331	610
SO_2	1005	841
HC	20	1394
PST	85	216

[19] Although sludge is not considered a biowaste, it is believed that the same principles for carbon accounting apply here.

HCl	50	50
HF	5	5
Cr	1	1
Cu	1	1
Ni	1	1
Pb	1	1
Zn	1	1
Note: includes exhaust emissions from transportation		

COWI valued the external impacts from incineration arising from air emissions, based on ExternE. These however included environmental and health impacts. The ranges reflect the fact that different studies used different valuation methods and in some cases different impacts were valued.

Table 19: Valuation estimates for air emissions (€/kg emissions)[20]

Emission type	Best estimate	Low estimate	High estimate
CH_4	0.184	0.086	0.372
NO_x	19.631	4.037	26.325
SO_2	11.043	5.005	16.191
HC	1.840	-	-
PST	29.447	-	-
HCl	0.000	-	-
HF	0.000	-	-
Cr	613.484	163.187	1175.436
Cu	0.000	-	-
Ni	12.270	3.681	24.539
Pb	0.000	-	-
Zn	0.000	-	-

Combining the above cost with the air emissions, the human health costs from incineration can be estimated.
The following estimates have been used in further analyses in this report.

Table 20: External costs of emissions to air from incineration (€/tDS)

Emission type	Mono-incineration	Co-incineration
CH_4	0.0	0.0
NO_x	24.6	24.2
SO_2	11.098	9.287
HC	0.037	2.566
PST	2.503	6.361
HCl	0	0
HF	0	0
Cr	0.613	0.613
Cu	0	0
Ni	0.012	0.012
Pb	0	0
Zn	0	0

[20] Valuation estimates are

Ecosystem degradation

As above, ecosystems may be impacted directly or indirectly following sludge incineration by the emission of flue gas to air, or by the emission of wastewater following the wet treatment of flue gas.

Heavy metals, dioxins, NOx, SO2, HCl, and particulate matter are contained in flue gas which may have an impact on plants and crops due to air deposition and/or absorption. These may further contaminate livestock and wild fauna via ingestion of contaminated plants. Emission of waste water to surface water may also have an impact on wild fauna and flora, especially on aquatic organisms. Such impacts, however, are difficult to model and are expected to be minimised on the basis of existing legislation. On the other hand, the COWI values take into account impacts linked to air emissions so these have been used as a surrogate of the impacts, although they may be an undervalue.

Buildings degradation

Flue gas produced following sewage sludge incineration contains SO2 and NOx which are known to have an impact on buildings due to acidic deposition on materials. The COWI coefficients above, however, include such impacts (however, according to Sede and Andersen, it is not clear whether all impacts related to buildings degradation are included in the valuation methodology developed by COWI and used by Sede and Andersen).

Climate change

When sludge is incinerated, flue gas is produced, containing greenhouse gases (GHG) such as CO_2 and NO_x. The following Table shows the range in emissions of greenhouse gases and NOx (which is seen as contributing to climate change in an indirect manner) for the different types of incineration. On the other hand, due to the nature of sludge, the CO2 emissions are not considered here (as it is deemed carbon neutral).

Table 21: Emissions from sludge incineration (unit g/tDS unless otherwise stated)

Emission type	Mono-Incineration	Co-incineration
CH_4(kg/tDS)	0	0
NO_x	1,253	1,233
Notes: includes exhaust emissions from transportation		

GHGs are known to have both environmental and human health impacts. Human beings may be affected directly, by gas inhalation, or indirectly, following ingestion of contaminated vegetable or animal products. The environmental impacts are related to:

- loss of crops (due to SO_2 and O_3); and
- impacts on buildings and materials.

The following cost estimates are used in Sede and Andersen (2002) and based on COWI (in turn based on ExternE). The ranges reflect different studies using different valuation methods and in some cases not valuing the same impacts. Due to the difficulties in assessing dose-response data from environmental impacts, the values are mainly linked to human health impacts (95% of the total costs, especially mortality).

Table 22: Valuation estimates for air emissions (€/kg emissions)[21]

Emission type	Best estimate	Low estimate	High estimate
CH_4	0.184	0.086	0.372
NO_x	19.631	4.037	26.325

Combining the emissions from incineration with the COWI estimates, the following estimates can be produced for the external costs of incineration in terms of climate change.

Table 23: External costs of emissions from incineration (€/tDS)

Emission type	Mono-incineration	Co-incineration
CH_4	0.0	0.0
NO_x	24.6	24.2

The above estimates have been used in the assessment of policy options in this report. It is important to note however that such costs are included under the net external costs for this disposal route, and more specifically in the valued given in **Table 23**).

Summary of external costs from incineration

Information presented above shows that external costs of sludge incineration are around € 44 per tDS for mono-incineration and around € 48 per tDS for co-incineration.

The external costs for incineration as estimated by Rabl *et al* (2008)[22] and based on the results of ExternE range from about €4 to €21/tonne waste and damage costs. However, these costs do not include the cost of dewatering since they are estimates produced for municipal solid waste (MSW). Amenity impacts are not included either. These costs therefore may be an under-estimate of the total costs of incineration in the case of sludge. The above costs are thus considered to be more appropriate.

3.2.4 Summary of approach to valuing impacts from sludge incineration

Internal costs have been monetised based on an update of the market price of sludge incineration given in Sede and Andersen (2002). External unit costs have been valued based on updated unit costs developed by COWI (2000) and reproduced in Sede and Andersen (2002); these include the health and other impacts (such as buildings degradation) which occur due to air emissions from incineration.

The unit costs of sludge incineration for mono-incineration and co-incineration are given separately in Table 24. Sensitivity analysis will be undertaken on the unitary costs to reflect the uncertainties surrounding the estimates (Sensitivity on Unitary costs and benefits).

Table 24: Net cost of sludge incineration (€/tDS)

Cost	Mono-incineration	Co-incineration
Internal cost – investment	161	62
Internal cost – operational	213	228
External cost	37	41
Total cost	**417**	**339**

[21] Valuation estimates are

[22] Rabl *et al* (2008): Environmental impacts and costs of solid waste: a comparison of landfill and incineration, Waste Management and Research, Vol 26, Fasc 2, pg 147-162.

3.3 Sludge recycling

3.3.1 Overview of sludge recycling rates in EU Member States

The purpose of using sludge in agriculture is partly to utilise nutrients such as phosphorus and nitrogen and organic substances for soil improvement. Sludge can be spread on farmland if it fulfils the quality requirements (heavy metals, pathogens, pre-treatment) laid down by the European and national legislation. Most often, the amounts of sludge allowed to be spread are limited by the amount of nutrients required by the plants and the total amount of dry solids.

The amount of sludge produced and recycled is replicated below.

Table 25: Recent sewage sludge quantities recycled to agriculture in the 27 EU Member States (Doujak 2007, EC, 2006, EC, personal communication, 2009, IRGT 2005, Eurostat 2007(as reported by France-need to check), DSD/DPS 2009, personal communication)

Member State	Year	Agriculture (t DS)	As a percentage of sludge production (%)
Austria	2005	47,190	18
Belgium			
• Brussels region	2006	0	0
• Flemish region	2008	0	0
• Walloon region	2007	10,927	35
Denmark	2002	82,029	59
Finland	2005	4,200	3
France	2007	787,500	70
Germany	2007	592,552	29
Greece	2006	56.4	0
Ireland	2003	26,743	63
Italy	2006	189,554	18
Luxembourg	2003	3,300	43
Netherlands	2003	34	<0
Portugal	2002	189,758	46
Spain	2006	687,037	65
Sweden	2006	30,000	14
United Kingdom	2006	1,050,526	68
Sub-total EU 15		***3,701,406***	***42***
Bulgaria	2006	11,856	40
Cyprus	2006	3,116	41
Czech republic	2007	59,983	26
Estonia	2005	3,316	?
Hungary	2006	32,813	26
Latvia	2006	8,936	37
Lithuania	2007	24,716	32
Malta	-	nd	nd
Poland	2006	88,501	17
Romania	2006	0	0
Slovakia	2006	0	0
Slovenia	2007	18	0
Sub-total for EU 12		***233,255***	***19***
Total		**3,934,661**	**39**

Although the advantages of sludge application have been recognised by the stakeholders consulted for this study (with this including among others the utilisation of nutrients and organic substances for improvement of the humus layer of the soil, i.e. soil improvement) there are also a number of disadvantages (e.g. investments in storage facilities in farms, through legislative controls, public perception issues, etc). The costs and benefits from sludge recycling that will be quantified in the impact assessment for each policy option are described further below.

3.3.2 Internal costs and benefits from recycling

The main costs related to the application of sludge on land stem from treatment by waste water treatment facilities in order to meet the new standards.

3.3.2.1 Obligation of treatment

Some MS will have to treat the sludge to higher standards in order to meet some new limits, i.e. standards on pathogens. The total costs will depend not only on the type of treatment but also on the percentage of sludge that will have to be treated. The types of treatment considered for this IA are described in the following Table.

Table 26: Advanced treatments (CEC, 2003)

Type of advanced treatment	Description of process
Windrow composting	All material maintains a temperature of at least 55°C for at least four hours between each turning. The heaps shall be turned at least three times and in any case a complete stabilisation of the material shall be reached. The costs of sludge composting in Germany are between 100 and 200 €/Mg of dry matter for windrow composting[23]
In-vessel composting	All material maintains a temperature of at least 55°C for at least four hours and reaches complete stabilisation.
Thermal drying	Temperature of the sludge particles reaches at least 80°C for ten minutes and moisture content reduced to less than 10%.
Thermophilic aerobic or anaerobic stabilisation	Temperature of at least 55°C for a continuous period of at least four hours after the last feed and before the next withdrawal. Plant should be designed to operate at a temperature of at least 55°C with a mean retention period sufficient to stabilise the sludge.
Thermal treatment of liquid sludge	For a minimum of ten minutes at 80°C or 20 minutes at 75°C or 30 minutes at 70°C followed by mesophilic anaerobic digestion at a temperature of 35°C with a mean retention period of 12 days
Conditioning with quicklime (CaO)	Reaching a pH of at least 12.6 or more and maintaining a temperature of at least 55°C for two hours. The sludge and lime shall be thoroughly mixed.

However, there is limited information as to the costs of such treatment, especially due to the variability of costs among MS. Some information on costs is presented in the next Table.

[23] Martin Kraner, Gerold Hafner, Ingrid Berkner, Ertugrul Erdin (2008) Compost from sewage sludge – a product with quality assurance system.

Table 27: Advanced treatment Costs

Type of advanced treatment	Capital, €k/tRwDS/d	Operating for 15tRwDS/d, €k/year	Costs (€/tRwDS)
Pre-pasteurisation + digestion	667 - 935	400 – 534 (less energy income)	74 – 93 (less energy income)
Drier to agriculture	400	667 – 801	134
Lime treatment	80 - 200	467 – 1067	80

Our consultation asked stakeholders about the current practices and costs to deal with pathogens. Consultees' responses varied significantly, with some stating that lime application is not currently widespread practice while some others saying that this was common. Similarly the costs of adding lime were reported to vary significantly, from €22/tDS to €160/tDS (including capital and operating costs). A recent study published by our Federal Environment Agency (UBA - Umweltbundesamt) in 2009 indicates the following costs for hygienisation, depending on plant size[24]:

- o 207-1.100 € per ton of DS (lime hydrate treatment of wet sludge)
- o 84-167 € per ton of DS (unhydrated lime treatment of dewatered sludge)

This second estimate is closer to the estimates in Sede and Andersen of applying solid and digested semi-solids. From experience, the consultants estimates are c. €90/tDS. Owing to the uncertainties surrounding the costs the following bounds have been taken to develop our estimates.

Table 28: Costs €/tDS for enhanced treatment

Lower	Upper
€90	€160

3.3.2.2 Quality assurance

Quality assurance system costs were estimated by Andersen and Sede (2002) at €15/tDS; i.e. €18/tdS (2009).
Prior consultation suggested that CEN TC 308 procedures should be introduced. TC 308 concerns the standardization of the methods for characterising and classifying sludges and products from storm water handling, night soil, urban wastewater collection systems, wastewater treatment plants for urban and similar industrial waters (as defined in EC directive 91/271/EEC1), water supply treatment plants, but excluding hazardous sludges from industry. The sampling methods included are the physical, chemical and microbiological analyses required for characterising these sludges with a view to facilitating decisions on the choice of the treatment procedures and of the utilization and disposal. Included is the drafting of good practice documents in the production, utilization and disposal of sludges. The Scope of the TC considers all sludges that may have similar environmental and/or health impacts. Quality assurance systems will have to be applied to all sludge recycled; so costs are likely to be significant. Another quality control could be a Hazard Analysis and Critical Control Point (HACCP) system with monitoring and measurement as appropriate.

Consultees were asked about their experience with such management systems as well as costs information that could aid in the assessment. Some consultees stated that HACCP is not a widespread practice, as it stems from the food processing industry, but suggested alternative quality assurance systems. The costs provided by the consultees vary significantly. A UK company noted that the costs of HACCP are of the

[24] This was quoted by one of the consultees.

region of £5,000 to £8,000 per treatment per year, equivalent to €5,700 to €9,200. A German company provided costs of around €2-3/tDS to implement quality assurance systems.

The following range has been applied in our estimates for quality assurance costs: €3/tDS, lower bound, and €18/dDS.

There are a number of other costs that will determine its use in agriculture. These are set out in the following box.

Table 29: Costs from sludge recycling

- Transport costs from treatment plant to storage
- Storage investments and operating costs
- Transport costs from storage to farmer
- Investments in spreading equipment (can often be omitted as the farmer uses his own equipment)
- Expenses for spreading and ploughing (can often be omitted as the farmer uses his own equipment)
- Expenses for analysis of sludge quality
- Expenses for analysis of soil quality
- Administrative expenses for e.g. declaration of sludge, conclusion of agreements with farmers and control of application.

3.3.2.3 Summary of net internal costs

Net costs from the use of sludge on land have been estimated earlier at around €96 to €255/tonne of sludge, with 20% dry solids (EEA, 1998[25]). But the prices are reported to vary considerably depending on local conditions, e.g. price of sludge itself, price of alternative fertilisers (including availability of other organic fertilisers), distance, etc.

Sede and Andersen (2002) differentiate internal costs according to the type of sludge applied. The following Table summarises the internal costs from application of sludge in its different forms; both capital and operational costs (these costs have been updated to take account of increased price levels in 2009 and to take account of EU enlargements in 2004 and 2007). As it can be seen, the first three types of application are of similar order of magnitude to the upper range of the costs provided in the EEA report. On the other hand, the costs of composting significantly increase the internal costs of sludge recycling.

Table 30: Internal costs from sludge application in agriculture (€/tDS) (€2009)

Type of sludge	Land-spreading of semisolid	Land-spreading of semisolid digested	Land-spreading of solid	Land-spreading of composted
Internal cost – investment	68	68	74	120
Internal cost – operational	125	125	174 (incl. 32 for extra drying)	245 (incl.124 for composting)
Internal costs - total	**193**	**193**	**248**	**365**

The costs of composting sludge are reported to vary significantly. Costs for France have been reported up to range from €175 to €335/tonne (EEA, 1999[8]). The upper range, however, is not far off from the Sede and Andersen (2002) estimate.

There are a number of financial benefits from recycling sludge. The main benefits include:

[25] Prices given in DEM 1999 values. Converted using 1999 conversion rates and updated by HICP (1DEM (1999)= €0.64(2009))

- benefits to waste operators in terms of reduced costs from alternatives routes of disposal; and
- benefits to farmers as sludge is a "cheap" fertiliser.

The current practices in EU Member States in terms of charging for sludge vary. In some countries/regions sludge is charged[26] whereas in others, e.g. Scotland, it is believed to be given for free to the farmers or given as symbolic price. On the other hand, it is expected that even in the case of a charge this will not be significant. The internal benefits from the replacement of fertilisers were given in Sede and Andersen (2002) but varied according to the type of sludge being applied. However, it is not certain from the study which type of alternative fertiliser was considered although due to the high figures one may consider that this is mineral fertiliser.

Table 31: Internal benefits from sludge application in terms of saving in fertiliser (€/tDS)

Land-spreading of semisolid	Land-spreading of semisolid digested	Land-spreading of solid	Land-spreading of composted
-63	-63	-63	-92
Negative sign indicates a benefit			

Consultation for this study however has suggested that other organic bio-fertilisers and other organic resources rather than mineral fertilisers could be increased as a replacement should sludge not be available. Generally, these are expected to be cheaper than mineral fertilisers (although the prices are also reported to range according to the level of treatment). However, the consultants believe that when such organic fertilisers are readily available these are currently being used as opposed to sludge (as these are less contentious and likely to be more available to farmers). Because of this, we believe that the above costs are generally applicable for estimating the marginal impacts; these cost estimates will be used in the impact assessment of policy options presented later in this report. Sensitivity analysis will also be undertaken on such estimates.

3.3.3 External costs and benefits from recycling

Humans and the environment could be affected by sludge borne pollutants from application on land. The impacts from recycling are summarised in the next Table.

Table 32: Impacts from recycling of sludge on land

Emissions	**Impacts**
Pollutant volatilisation to air	Human health impacts Ecosystem degradation
Emissions of pollutants to surface water	Human health Decrease in surface quality
Emissions of pollutants to soil	Human health impacts Livestock health Ecosystem degradation Soil micro-organisms reduction Decrease in groundwater quality Decrease is soil value
Odour	Social acceptance Amenity impacts Public anxiety
Transportation	Exhaust emissions due to transportation
Source: adapted from Sede and Andersen (2002)	

[26] Prices range from around £1.50 per tonne for sludge cake (conventionally treated sludge) to around £12.00 per tonne for sludge pellets (enhanced treated) in the UK. This broadly reflects the differing fertiliser value and cost of treatment.

A number of impacts reported are difficult to value, e.g. decrease in soil value from application and impacts from odour. This depends on the perception of the landspreading practice, which varies over time in each Member State, even in each region, and is therefore not predictable. Such impacts cannot be modelled within this study with accuracy. Transportation costs are expected to be limited as sludge is only expected to be transported short-distance and represent a very low percentage of total traffic.

The Sede and Andersen (2002) report considered that the impacts of recycling on the value of land were difficult to estimate (as it will depend on the level of contamination of the land and the perception of the landspreading practice). Similarly, social acceptance and public anxiety are not subject to valuation.

Human health

Humans may be affected by the application of sludge on land through different exposure routes, i.e.:

- Soil: by dermal contact with soil or volatile compounds inhalation and consumption of contaminated foodstuff;
- Surface and groundwater: through water ingestion and consumption of animal products; and
- Sludge manipulation by workers and inhalation of particles and/or pollutants by the general public.

The main problem with the valuation of impacts from the application of sludge on land however stem from the fact that at to this time there is no evidence of such impacts from contamination of surface waters and/or soils. However, it is uncertain whether this is due to the existing directive or the current practices. Previous work to this study on gathering the evidence on impacts has revealed that the dose-response data in terms of ecosystem degradation, human health (from consumption of contaminated foodstuff) and impacts on livestock are also limited. As a result, valuation of impacts is not feasible at the time of writing. **Quantification of environmental and human health impacts from sludge recycling through the aquatic and terrestrial environmental compartments is thus at the time of writing not feasible, due to the lack of dose-response data.**

However, impacts that can be quantified relate to human health and the environment (i.e. building degradation) from airborne emissions. The basis for valuation is information given in Sede and Andersen (2002) based on the COWI (2000) study, in turn based on ExternE values. Please note that these data include both emissions from transportation[27] and pollutant volatilisation to air; however.

Table 33: External costs of emissions to air from recycling (€/tDS unless otherwise stated)

Emission type	Land-spreading of semi-solid	Land-spreading of solid	Land-spreading of composted	Land-spreading of semi-solid digested
CO_2	0	3.62	2.41	7.24
PST	1.21	1.21	2.41	1.21
SO_2	1.21	1.21	3.62	1.21
NO_x	1.21	1.21	2.41	1.21
CH_4	0	0	0	0
CO	0	0	0	0
HC	0	0	1	1
HCI	0	0	0	0
HF	0	0	0	0

[27] No information is available on the transport distances considered for the valuation so assumptions cannot be checked.

Emission type	Land-spreading of semi-solid	Land-spreading of solid	Land-spreading of composted	Land-spreading of semi-solid digested
H_2S	0	0	0	0
As	0	0	0	0
Cd	0	0	0	0
Cr	0	0	0	0
Ni	0	0	0	0
Dioxins	0	0	0	0
Total[28]	**2**	**7**	**13**	**11**
Note: includes exhaust emissions from transportation				

The EFAR report (2007) concluded that global risk based on the results of the quantitative risk assessment was acceptable under the following:

- limits proposed under Annex III of the CEC (2003) communication;
- Bis(2-ethylhexyl) phthalate (DEHP) limit of 100mg/kg DM; and
- Lower limit for lead of 500mg/kg DM (as opposed to 750 mg/kg).

This would suggest that when the limits are not set at this level, there could be limited benefits in terms of reduced health risk. When national limits are more stringent and/or the quality of the sludge complies with such limits, the benefits in terms of health risk are expected to be negligible. The current limits on DEHP seem highly variable and appear to be unlinked to other substances. A European range is of 0.095 to 47mg/kg DS, median 7.2. Other limits include:

- UK: 0.3 to 1020 mg/kg with median of 110 mg/kg;
- Norway: 17 to 178 mg/kg with median of 53 mg/kg; and
- N Rhine: 0.93 to 110 mg/kg with median of 22 mg/kg and 90%ile of 57 mg/kg.

As a result there may be benefits in some specific regions. Thus, although we believe these impacts may be an underestimate of the total environmental and human health risks from application, no further data has been provided to estimate these impacts with more accuracy.

Ecosystems degradation

Because sludge contains heavy metals, pollutants and pathogens, sludge landspreading may have an impact on ecosystems.

It may be assumed that current regulatory provisions and codes of practice implemented in Member States reduce the risk of exposure to pathogens. In particular, plant pathogens have in general low optimum growth temperature, so that disinfection will be achieved at a lower temperature than for mammalian pathogens. Sludge treatment will therefore reduce the application of plant pathogens to soil.

On the other hand, wild fauna and flora may be contaminated by heavy metals and organic pollutants released into the environment. Aquatic organisms could also be affected by those pollutants if they are transferred to surface water following run-off. As above, however, the evidence on such impacts is sparse.

28 There is a slight divergence between the total values and values for individual pollutants. This is believed to stem from Sede and Andersen (2002) presenting rounded figures. Therefore, updating of data to 2009 prices results in a discrepancy between the total costs and costs for individual pollutants. Where such discrepancies occurred, the updated totals were used in the impact assessment presented later in this report..

As a result, quantification of such impacts is not feasible at the time of writing. In addition, other fertilisers may also contain heavy metals, which may have the same impact on ecosystems as those contained in the sludge-borne ones so marginal impacts in this regard are considered negligible.

Climate change

Impacts due to emissions of greenhouse gases (CO_2 and CH_4) and NOx are included in the valuation done for air emissions above.

Fertiliser replacements

Sede and Andersen (2002) also quantify external benefits from sludge replacing fertiliser. These data are given in the Table below. A negative sign indicates a net benefit. As it can be seen although there are benefits these are not expected to be significant. This is in line with recent findings concerning externalities from the production of mineral fertilisers (which state that emissions from fertilisers equal represent a very little proportion of GHG[29]).

Table 34: External cost from recycled sludge replacing fertiliser (€/tDS of sludge)

Land-spreading of semi-solid	Land-spreading of solid	Land-spreading of composted	Land-spreading of semi-solid digested
-6	-7	-6	-6

Summary of external costs from sludge recycling

The impacts quantified relate to human health and the environment (i.e. building degradation) from airborne emissions, as for incineration. Although we believe these impacts may be an under-estimate due to the lack of readily available data on environmental risks that may be due to current application practices, these are deemed to be the best estimates to date on the net external costs from recycling[30].

Data on external costs from air emissions can thus be combined with data on external benefits from fertiliser replacement to derive the net external costs from sludge recycling. These data are given in the Table below.

Table 35: Total external cost from recycled sludge; negative sign indicates benefits (€/tDS)

Land-spreading of semi-solid	Land-spreading of solid	Land-spreading of composted	Land-spreading of semi-solid digested
-4	0	7	5

Other impacts of recycling, such as impacts on the value of land, were difficult to estimate (as it will depend on the level of contamination of the land and the perception of the landspreading practice).

3.3.4 Summary of approach to valuing impacts from sludge recycling

The unit costs of sludge recycling have been valued for the different types of landspreading. All costs have been monetised based on updated unit costs from Sede and Andersen (2002). External unit costs include

[29] International Fertiliser Industry Associations (IFIA) (2009): Fertiliser, Climate Change and Enhancing agricultural Productivity Sustainibly, Paris.

[30] The dose-response data in terms of ecosystem degradation, human health (from consumption of contaminated foodstuff) and impacts on livestock are also limited. Valuation of impacts on soil micro-organism was not feasible either due to the lack of valuation studies and dose-response data.

impacts from air emissions on human health and other types of impacts (such as buildings degradation) and benefits from avoided fertiliser use. Internal costs include investment and operational costs of landspreading, dewatering (where applicable), and benefits from avoided fertiliser use. All costs have been updated to 2009 prices.

The total of internal and external cost, per tonne of DS of sludge recycled, which will be used for the purpose of the assessment of policy options later in this report is detailed in the Table below.

Table 36: Net costs and benefits from sludge recycling (€/tDS) (€2009)

Type of sludge	Land-spreading of semisolid	Land-spreading of semisolid digested	Land-spreading of solid	Land-spreading of composted
Internal cost – investment	68	68	74	120
Internal cost – operational	125	125	174 (incl. 32 for extra drying)	245 (incl.124 for composting)
Internal benefits - fertiliser replacement	-63	-63	-63	-63
External costs	2	11	7	13
External benefits – fertiliser replacement	-6	-6	-7	-6
Total costs	**126**	**134**	**185**	**280**

3.4 Landfill

3.4.1 Overview of sludge incineration rates in EU Member States

Although landfilling of sludge was a favoured method in the past, the amount of sludge going to landfill has been decreasing in the last decade not only due to legislation but also due to more limited capacities and pressure to utilise these from other sources. The following Table shows this trend. As it can be seen from the Table, and also reflected by the consultation, the reduction is more significant in some countries (e.g. in the UK and Sweden) than others.

Table 37Estimates of annual sludge production and percentages to disposal routes, 1995 – 2005

Country	**1995**		**2000**		**2005**	
	total sludge	**landfill**	**total sludge**	**landfill**	**total sludge**	**landfill**
	tds/a	**%**	**tds/a**	**%**	**tds/a**	**%**
Austria a)	390,000	11	401,867	11	238,100	5
Belgium	87,636	32	98,936	14	125,756	4
Denmark	166,584		155,621	2	140,021	
Finland	141,000		160,000		147,000	
France	750,000	20	855,000	20	1,021,472	13
Germany	2,248,647		2,297,460	3	2,059,351	2
Greece	51,624	95	66,335	95	116,806	95
Ireland	34,484	43	33,559	54	59,827	17
Italy	609,256	30	850,504	30	1,074,644	31
Luxembourg	7,000		7,000		8,200	0
Netherlands	550,000		550,000		550,000	
Portugal	145,855	70	238,680	84	401,017	44
Spain	685,669	54	853,482	47	986,086	46
Sweden	230,000	50	220,000	44	210,000	4
United Kingdom	1,120,000	10	1,066,176	5	1,510,869	1
Bulgaria	20,000	100	20,000	100	33,700	60

Country	1995		2000		2005	
	total sludge	landfill	total sludge	landfill	total sludge	landfill
	tds/a	%	tds/a	%	tds/a	%
Cyprus	4,000	100	4,000	100	6,542	48
Czech Republic	146,000	50	210,000	30	220,700	10
Estonia b)	15,000		15,000		26,800	
Hungary	30,000		30,000		125,143	25
Latvia	20,000		20,000	38	28,877	40
Lithuania	48,000	90	48,000	90	65,680	6
Malta	0		0			
Poland	340,040	56	397,216	50	495,675	18
Romania			171,086	100	134,322	97
Slovakia					56,360	30
Slovenia			8800	85	16,900	56
EU12 % of total EU	8	4	11	6	12	4
EU15 % of total EU	92	15	89	16	88	13
EU27 % of total EU	100	19	100	22	100	17

3.4.2 Internal costs from landfill

The internal costs from landfill include the following costs categories:

- the capital costs for the site. Such costs will include site assessment, acquisition, site development, restoration and aftercare. The main variable will be the size of the site as site acquisition is one of the main factors affecting the cost of a landfill;
- operating costs: these relate mainly to labour costs and the cost of operating equipment but also to the needed treatment of sludge prior to final disposal and transport.

The main issue with the estimation of landfill costs across the EU is that these are highly variable among MS. Notwithstanding landfill taxes, which are not part of this analysis, the costs will vary significantly according to transportation distances and dewatering requirements. Stabilisation costs can also vary significantly. Sede and Andersen estimated costs were of €300/tDS across Europe (updated to 2009 values). The study however noted that the variation between the maximum costs and the average could reach 80%.

Although we believe that these cost may be an underestimate, they are adopted on the basis that as energy can be recovered from landfilled sludge (if landfill gas is utilised) these internal benefits may be offset by the cost from drying (although the cost will fall onto different stakeholders).

The relevant costs from Sede and Andersen (2002) are presented below (updated to 2009 values).

Table 38: Internal costs from landfilling of sewage sludge (€/tDS) (€2009)

Investment	44
Operational costs – dewatering	47
Operational costs – landfilling (incl. transport)	209
Total	**300**

3.4.3 External costs from landfill

The impacts from landfill are summarised in the next Table.

Table 39: Impacts from landfill

Emissions	Impacts
Emissions of landfill gas to air	Human health impacts Ecosystem degradation Climate change
Emission of leachate to soil	Human health Soil micro-organisms reduction Decrease in groundwater quality
Emissions of untreated or treated leachate to water	Human health impacts Ecosystem degradation Decrease in surface water quality
Emissions from transport	Human health impacts Ecosystem degradation Climate change Amenity impacts
Odour	Social acceptance Amenity impacts Public anxiety
Visual intrusion	Social acceptance Amenity impacts Public anxiety
Transportation	Exhaust emissions due to transportation
Source: adapted from Sede and Andersen (2002)	

Impacts from leachate would be limited on the basis of regulatory requirements on landfills to use best available technologies. Similarly the impacts from transportation are considered negligible (in comparison with the total volume of traffic).

Although the social costs and benefits such as unpleasant odours, the fears associated with the perception of environmental or health risks are key factors to be considered in assessing the overall impact and costs of landfill, these factors were not quantified as this would require significant data requirements concerning location and management practices so they cannot be modelled within this study.

Energy production

As noted above there may be benefits from the recovery of energy from landfill gas. Currently however there is limited information as to the number of landfills with energy recovery for these impact to be valued.

Human health

Human beings may be directly affected by landfill gas inhalation, or indirectly following ingestion of contaminated vegetal or animal products. Human health may also be affected by leachate if this is emitted to surface or groundwater. No study is available in the literature enabling to assess the sludge-borne pollutants concentration in the surface water and the soil, the resulting increased concentration in the food chain, and the human exposure to those pollutants. Moreover, as noted earlier these are expected to be limited in the case of a landfill complying with regulation. Thus direct impacts on health are not expected.

The following Table shows emissions to the air from landfilling.

Table 40: Air emissions from landfilling of sludge (unit g/tDS unless otherwise stated)

CO_2	791
CH_4	23

NO_x	0.003
CO	57
SO_2	-10
HC	382
PST	26
H_2S (kg/tDS)	10
HCl	4
HF	1
Note: includes exhaust emissions from transportation	

As a result, the impacts values from landfill relate to the human health (and other impacts) from airborne pollution, as calculated in ExternE, and other environmental impacts. These are replicated below.

Table 41: External costs of air emissions from landfill (€/tDS unless otherwise stated)

Emission type	Cost
CO_2	3.82
CH_4	2.50
NO_x	0.087
PST	1
SO_2	1
CO	0
HC	0
HCI	0
HF	0
H_2S	0

Ecosystem degradation

Some emissions following disposal of sludge to landfill may have an impact on ecosystems. Those considered herein are the emissions of landfill gas to air, or the emission of leachate to surface water.

Landfill gas contains pollutants that may have an impact on plants and crops due to air deposition and/or absorption. It may further contaminate livestock and wild fauna after ingestion of contaminated plants. These impacts however are included in the costs given above under health (based on the valuation from ExternE).

Emission of leachate to surface water may also have an impact on wild fauna and flora, especially on aquatic organisms. In addition to those direct impacts on species, emissions may induce changes in their biotope following eutrophication or acidification. This impact arises mainly in old landfills without a bottom liner to retain and collect leachate and without gas collection and treatment. It may however be considered as negligible when considering landfills complying with regulatory requirements and using best available technologies.

Buildings degradation

As before, the building degradation is given in the above estimates for air emissions.

Climate change

The impacts in terms of climate change stem from landfill gas. There is information on the impacts in terms of air borne emissions from landfill (point 4) as well as information on costs (point 5). **Table 42** sets out the emissions from landfill in terms of GHGs.

Table 42: GHG emissions from sludge landfilling (kg/tDS)

Emission type	Best estimate(kg/tDS)
CO_2	791
CH_4	23
NO_x	0.003
Note: includes exhaust emissions from transportation	

The same cost estimates that have been introduced in the section on valuing costs from incineration (please see this section for more details on what is included in these cost estimates) are used to derive the following external costs from emission of GHG and NOx emissions from landfill.

Table 43: External costs of emissions from landfilling of sludge (€/tDS)

Emission type	€/tDS of emissions
CO_2	3.82
CH_4	2.50
NO_x	0.087

The above costs however are included in the net costs of landfill.

3.4.4 Summary of approach to valuing impacts from sludge landfilling

The unit costs of sludge landfilling are, again, based on an update to 2009 values of estimates given in Sede and Andersen (2002). External unit costs include impacts from air emissions on human health and other types of impacts (such as buildings degradation). Internal costs include investment and operational costs of landfilling including transport and dewatering. The total of cost of sludge landfilling that will be used for the purpose of the assessment of policy options is detailed in the Table below.

Table 44: Total cost of sludge landfilling (€/tDS) (€2009)

Type of cost	€/tDS
Internal cost – investment	44
Internal cost – operational	256
External cost	9
Total	**309**

3.5 Summary of cost and benefit valuation methodology used in this Impact Assessment

The amount of information on the costs of the different disposal methods for sludge is plentiful. More often than not, the costs are of similar order of magnitude, as revealed above. However the costs are highly variable according to a number of sensitivities such as:

- type of process and technologies used;
- storage duration;
- specific equipment;
- transport distances.

The Sede and Andersen (2002) estimates of the financial costs and the external costs and benefits are considered to date the best estimates of the costs and benefits from the different disposal methods. Generally, although the costs were collated for 2002, consultants' experience and the review of the literature have shown that the relative positions do not significantly change, and that adjustments for such guidance assessments can be made using inflation indices within reasonable periods of the initial assessments. This also applied to the externality costs.

The costs used in this IA are set out in the next Table. The estimates produced in 2002 were calculated for the EU-15. Although Sede and Andersen appear to have used variation across MS for the internal costs, it has not been possible to verify such assumptions. Instead, new published figures on prices levels[31] have been used to estimate the variation among MS (noting however that these only apply to the internal costs). The net costs by MS are replicated in **Table 46: Net Cost by MS of Different Disposal Methods**).

Table 45: Summary of unit costs used in the impact assessment (€2009)

Type of Costs	Landspreading of semisolids	Landspreading of semisolid digested	Landspreading of solid	Landspreading of composted	Landfilling	Co-incineration	Mono-incineration
Internal costs	193	193	248	365	300	290	374
Internal benefits (savings in fertiliser)	-63	-63	-63	-92	0	0	0
Net internal costs	**129**	**129**	**185**	**273**	**300**	**290**	**374**
Quantifiable external costs (EU15 average)	2	11	7	13	9	41	37
Quantifiable external benefits (use of fertiliser)	-6	-6	-7	-6	0	0	0
Net external costs	-4	5	0	7	9	41	37
Net internal and external costs	**126**	**134**	**185**	**280**	**309**	**332**	**411**

[31] http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-16072009-AP/EN/2-16072009-AP-EN.PDF

Table 46: Net Cost by MS of Different Disposal Methods

Net costs - internal and external by MS	Land-spreading of semisolids	Land-spreading of semisolid digested	Land-spreading of solid	Land-spreading of composted	Landfilling	Co-incineration	Mono-incineration
Austria	121	129	178	269	298	320	396
Belgium	128	136	188	284	314	336	417
Denmark	163	172	238	359	397	416	519
Finland	145	153	211	319	353	374	465
France	128	136	188	284	314	336	417
Germany	120	128	176	267	295	318	393
Greece	108	116	159	242	268	291	359
Ireland	147	155	215	324	358	379	472
Italy	121	129	178	269	298	320	396
Luxembourg	134	142	196	297	328	350	434
Netherlands	118	127	174	264	292	315	389
Portugal	100	108	147	224	248	273	335
Spain	110	118	162	247	273	296	365
Sweden	132	140	193	292	322	344	427
United Kingdom	114	122	167	254	281	304	376
New MS							
Bulgaria	57	65	86	134	149	177	211
Cyprus	103	111	152	232	257	281	345
Czech Republic	82	90	122	187	207	233	283
Estonia	88	96	130	199	221	246	300
Hungary	79	88	118	182	202	227	276
Latvia	85	94	127	194	215	241	293
Lithuania	76	84	113	174	193	219	266
Malta	89	97	132	202	224	249	304
Poland	78	86	117	179	199	225	273
Romania	70	78	105	162	180	206	249
Slovakia	79	88	118	182	202	227	276
Slovenia	95	103	140	214	237	262	321

In order to estimate the costs however is it important to consider the costs of the switch for sludge failing and going to other disposal options. As there is not enough information on the type of recycling occurring by MS, the average of recycling has been taken in order to estimate the costs of switching disposal routes.

Table 47: Costs Differences in Sludge Management Methods (€/tDS)

MS	From land-spreading to landfill	From land-spreading to co-incineration	From land-spreading to mono-incineration
Austria	124	146	222
Belgium	130	152	233
Denmark	163	183	286
Finland	146	167	258
France	130	152	233
Germany	122	145	220
Greece	111	135	202
Ireland	148	169	261
Italy	124	146	222
Luxembourg	136	157	242
Netherlands	121	144	218
Portugal	104	128	190
Spain	114	137	206
Sweden	133	155	238
United Kingdom	117	140	211
New MS			
Bulgaria	64	91	126
Cyprus	107	131	195
Czech Republic	87	113	163
Estonia	93	118	172
Hungary	85	111	160
Latvia	90	116	168
Lithuania	81	107	154
Malta	94	119	174
Poland	84	110	158
Romania	76	102	145
Slovakia	85	111	160
Slovenia	99	124	183

4. Option 1: Do-nothing

4.1 Overview of Option

This Option will be the business as usual scenario. This will be the baseline for estimating the amount of recycled sludge affected and is based on the analysis presented in project report 2, updated by the information and comments on this report given during consultation.

The impacts of the existing legislation however need to be taken into account when describing the baseline. The results of previous consultation show that respondents expect only limited effects on the amount of sludge recycled onto agricultural land by some regulation. For the REACH regulations, although there is an expectation that metals and organic contaminants are likely to reduce, some believe that the effect would be insufficient to achieve the level of purity they would find acceptable. The WFD may affect the location and frequency of return to available land but this has not been identified as a significantly increased cost.

Existing local restrictions have already driven the rate of agricultural recycling and there is no expectation of further significant changes based on sludge quality being driven by other regulations.

The most significant other drivers identified by respondents are the amounts of sludge being produced as sewerage collection systems are developed, increased rates of sludge production due to more stringent sewage effluent quality consents, and reduction in the availability of landfill disposal for sewage sludge.

The following Table (based on consultation) shows the predicted increase in sludge production from 2010 to 2020. The projections are based on projections about population connected as well as sludge production per capita as estimated by the stakeholders (as explained in the baseline report). As can be seen, the majority of the increase is due to the newer MS. These figures will be the basis for considering the marginal impacts from the Options.

4.2 Assessment of the option

Option 1 will have limited impacts on the MS as it will not involve any changes to the Directive.

Under this Option, the amount of sludge produced and recycled will depend on national legislation and practices. More information on the current legislation and practices is available on our baseline report.

There may be a risk with some of the newer MS who may introduce limits complying with the Directive but not conservative enough to reduce the risk to the extent now considered desirable by many consumers as well as regulatory bodies. These could give rise to greater environmental and human health risks than those present in other EU member states. On the other hand, this option may not preclude some MS from undertaking pollution prevention measures to improve sludge quality based on public perception issues and/or other legislative drivers at national level, as noted above.

Only few respondents to our consultation document seem to agree with this Option; mostly on the basis of subsidiarity.

Table 48: Future forecasted (2010 and 2020) sludge arisings in the EU27

Member State	2010 (x10^3 tds pa)	2020 (x10^3tds pa)
Austria	270	280
Belgium	166	166
Denmark	140	140
Finland	155	155
France	1,300	1,600
Germany	2,060	2,060
Greece	290	290
Ireland	135	135
Italy	1,500	1,500
Luxembourg	15	15
Netherlands	560	560
Portugal	420	420
Spain	1,280	1,280
Sweden	250	250
United Kingdom	1640	1,640
EU15	***10,181***	***10,491***
Bulgaria	30	180
Cyprus	9.8	17.6
Czech Republic	260	260
Estonia	33	33
Hungary	130	250
Latvia	25	50
Lithuania	80	80
Malta	10	10
Poland	520	950
Romania	165	520
Slovakia	55	135
Slovenia	20	50
EU12	***1,338***	***2,485***
EU27	**11,519**	**12,977**

Notes: As working estimates 2010 production rates have been taken to be the same as 2020 production for states expected to be in full compliance in 2010. For non-compliant states rounded 2006 production rates have been used – see text in Annex 2 for detail.
The estimate for Belgium includes 110,000 tds for the Flemish region; 50,500 tds for the Walloon Region and 5,000 tds for the Brussels region.

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4.2.1 Environmental Impacts

Few respondents from the first consultation considered that the risks to be associated with PTE and OCs in sludge outweighed the benefits from nutrients and soil conditioning that could be achieved by using suitable and treated sludge.

Although the 2003 communication highlighted the risk that the Directive was not conservative enough to take into account the long-term accumulation of metals to the topsoil, as for the time of writing, there is no scientific evidence (as distinct from news stories) that describes adverse effects when the conditions of the Directive have been met. However, this could be due to the fact that many MS have adopted more stringent standards than those given in the Directive. Indeed most MS including Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Malta, Netherlands, Poland, Romania, Slovakia, Slovenia, and Sweden have limit values for metal concentrations more stringent than the lowest limits set in the 1986 Directive. Some MS have also additional standards for pathogens, metals and organics.

4.2.2 Social Impacts

Both the recent consultation and EC's Communication in 2003 regarding possible changes to the provisions of the Directive have highlighted that Directive 86/278 has proven quite effective in preventing the spread of pathogenic micro-organisms to crops and outbreaks of epidemics in humans, in reducing the amount of heavy metals brought to the soil when using sewage sludge as well as in harmonising the pieces of national legislation existing before 1986 (CEC, 2003[32]).

While no evidence of health risks related to the current directive has been found, we also note that this may be influenced by the more stringent standards set by some Member States. Moreover, some respondents to the first consultation strongly opposed the application of sewage sludge to land for precautionary reasons.

In these circumstances, it is not possible to quantify any health impacts for the Baseline Scenario.

[32] CEC(2003): Proposals for a Directive of the European Parliament and of the Council on spreading of sludge on land, Brussels, 30 April 2003.

5. Option 2: more stringent standards (moderate change)

5.1 Overview

Option 2 will consist of the following:

- Changes to the limits on heavy metals concerning the quality of the sludge (as given in the CEC (2003)) and in soil;
- Setting limits for PCBs and PAHs for sludge quality;
- Introduce standards for treatment compatible with CEC (2003) conventional treatment;
- Provision of information on nutrients;
- More stringent conditions on application; and
- Small changes to sampling and monitoring requirements.

The main issue associated with this Option relates to the limitations on sludge use by restrictions that require higher standards in areas where there is no added value in terms of human health and the environment.

This Option is expected to impact the availability of sludge for application (percent of sludge produced that is failing the standards). This is likely to have economic, environmental and human health implications. Economic impacts will stem primarily from further treatment and the internal costs of alternative disposal options. The environmental and human health impacts will be related to the impact from the alternative routes of disposal and also from the potential reduction in environmental and human health risk from recycling.

Overall, when the national limits are less stringent than the new limits the percentile sludge quality distribution will help to assess the quantity of sludge failing to meet the requirement. We have limited information on the percentile sludge distribution in different MS however. Information is available on the average sludge content. Thus we produced estimates on the amount of sludge affected. These estimates have been backed up by consultation. For a summary of impacts valued under this Option please refer to **Table 9: Impact quantification**.

5.2 Heavy metal content in sludge

5.2.1 Step 1: Identification of MS affected by changes to the Directive

As noted earlier, most MS have set more stringent standards than those in the current Directive. The current MS regulatory standards for heavy metals are given in Table 36. The Table sets out which MS may be affected by the limit on heavy metals under Option 2. Shaded in grey are the national limits that would have to be tightened. These MS will have to amend their national legislation so this will have some costs implications. The costs of changing the legislation are not expected to be significant in comparison with the costs that may arise from changes in disposal[33].

[33] Although they will vary according to national procedures, information on the administrative costs of changes to legislation are not widely available.

Table 49: Proposed limit values on Potentially Toxic Elements (PTE) in sewage sludge

PTE	CEC 2003 (mg/kg)
Cd	10
Cr	1000
Cu	1000
Hg	10
Ni	300
Pb	750
Zn	2500

Table 50: Countries with national limits less stringent than those proposed under Option 2 e.i. setting limits on Maximum level of heavy metals (mg per kg of dry substance) - in grey

PTE	Cd	Cr	Cu	Hg	Ni	Pb	Zn
New limits	10	1000	1000	10	300	750	2500
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
France (4)	10	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Portugal	20	1000	1000	16	300	750	2500
Spain	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Czech Republic	5	200	500	4	100	200	2500

In practice however, information on the quality of sludge seems to indicate that the quality of sludge may be better that the national limits given in Table 49. There is limited information however on the percentile distribution of metal in sludge by MS. Thus, the information presented in Table 50 is based on country averages and has been used for estimating the impacts (this information was provided to the consultants by the Commission services). Although the quality of the sludge seems to be better than those given under the proposed new limits, it can not be stated that all sludge arisings within these are compliant with the new limits. Indeed the first consultation revealed that the content can vary significantly, so these figures need to be read with caution. (In addition, the data do not cover all Member States).

Table 51: Quality of sewage sludge (on dry solids) recycled to agriculture (2006) against new Option 2 limits

Parameter	**Cadmium**	**Chromium**	**Copper**	**Mercury**	**Nickel**	**Lead**	**Zinc**
New limits Option 2	**10**	**1000**	**1000**	**10**	**300**	**750**	**2500**
BE –Flanders	1	20	72	0.2	11	93	337
BE-Walloon	1.5	54	167	1	25	79	688
Bulgaria	1.6	20	136	1.2	13	55	465

Parameter	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc
New limits Option 2	**10**	**1000**	**1000**	**10**	**300**	**750**	**2500**
Germany	1	37	300	0.4	25	37	713
Spain	2.1	72	252	0.8	30	68	744
Finland	0.6	18	244	0.4	30	8.9	332
France	1.3	43	272	1.1	21	50	598
Italy	1.3	86	283	1.4	66	101	879
Portugal	<0.4	20	12	<1	15	27	341
Sweden	0.9	26	349	0.6	15	24	481
UK	1.3	61	295	1.2	30	112	574
Cyprus	6.9	37	180	3.1	21	23	1188
Czech Republic	1.5	53	173	1.7	29	40	809
Estonia	2.8	14	127	0.6	19	41	783
Hungary	1.4	57	185	1.7	26	36	824
Lithuania	1.3	34	204	0.5	25	21	534
Latvia	3.6	105	356	4.2	47	114	1232
Portugal	4	127	153	4.6	32	51	996
Slovenia	0.7	37	190	0.8	29	29	410
Slovakia	2.5	73	221	2.7	26	57	1235

The CBA conducted in 2002 highlighted that the percentage of sludge failing to comply with the new limits on heavy metals could be 12% of the total sludge being produced, in the short term, without pollution prevention[34]. Based on more recent data from our consultation on sludge quality, however, we believe that this may be an overestimate. Indeed the consultation undertaken for this impact assessment has provided us with some estimates about the percentage of sludge affected in some MS. The following Table summarises the percentages assumes for this assessment but includes also our estimates on the percentage failure[35].

Table 52: % recycled sludge failing new limits on heavy metals under Option 2

Parameter	% affected	Source of data
Austria	0%	E
Belgium	0%	C
Brussels region	0%	C
Flemish region	0%	C
Walloon Region	0%	C
Denmark	0%	C
Finland	0%	C
France	1%	C
Germany	0%	C

[34] These percentages vary however according to country and range from 0% to 20% depending on whether pollution prevention measures are in place.

[35] The estimate has been in cases calculated based on standard deviation from the UK response, as there is available information to the consultants on the percentile distribution for this particular MS, and assuming that the distribution among EU countries remains the same. In other cases, when this estimate was considered too high, the frequency of failure has been revised downwards.

Parameter	% affected	Source of data
Greece	12%	E
Ireland	12%	E
Italy	5%	C
Luxembourg	10%	E
Netherlands	0%	Due to ban on application
Portugal	>5% , <15%	C
Spain	5%	E
Sweden	0%	E
United Kingdom	5%	C
Bulgaria	0.1%	E
Cyprus	12%	E
Czech Republic	0%	C
Estonia	6.5%	E
Hungary	8%	E
Latvia	20%	E
Lithuania	0.6%	E
Malta	-	nd
Poland	12%	E
Romania	0%	C
Slovakia	20%	E
Slovenia	0.2%	E
Key to source: C – provided by consultee; E- estimate by consultant based on information gathered for Report 2		

5.2.2 Step 2: Impacts on Sludge Management

For the sludge that is failing, there will be two scenarios:

- specific treatment measures are taken to reduce the heavy metals loads in sludge by waste management operators ; or
- alternative disposal options (i.e. to landfill or incineration).

Both of the scenarios will have costs implications for water and sludge management operators. The treatment available for reducing heavy metals by sludge operators is, according to the state of the art, rather limited. Most of the consultees to the impact assessment concluded that the most likely outcome was incineration. In absence of any information on the different disposal routes, the following estimates have been used to estimate the costs of Option 2, based on information available in the literature (trend in mono-incineration and co-incineration) and consultation responses.

Table 53: Impacts from Option 2- disposal options for sludge failing standards

Parameter	% going to co-incineration	% going to mono-incineration	% going to landfill
France	40%	50%	10%
Greece	25%	50%	25%
Ireland	80%	-	20%
Italy	80%	-	20%
Luxembourg	50%	50%	10%

Parameter	% going to co-incineration	% going to mono-incineration	% going to landfill
Portugal	30%	50%	20%
Spain	40%	40%	20%
United Kingdom	0%	100%	0%
Bulgaria	50%	-	50%
Cyprus	50%	-	50%
Estonia	50%	-	50%
Hungary	50%	-	50%
Latvia	50%		50%
Lithuania	50%	-	50%
Poland	50%	-	50%
Slovakia	50%	-	50%
Slovenia	100%	-	0%

5.2.3 Step 3: Impacts from the component – Costs and Benefits

The following costs are calculated on the basis of the costs of the alternative disposal options. The unit cost presented in Section 3 are used for the analysis. It is important to note that owing to the nature of the unit costs, such costs include both environmental and human health costs in addition to financial costs. The environmental costs, on the basis of the degree of quantification possible to date however, represent around 10% of the total costs (although in the case of incineration, the externality are closer to the 10% value of the total quantifiable costs). Estimates on the GHG for this component are presented at the end of the Section separately.

Table 54 Costs from New Limits of PTE in sludge: Option 2 (EAC, €2009)

MS	Costs from switch to mono-incineration	Costs from switch to co-incineration	Costs from switch to landfill	TOTALS
France	980,000	513,000	110,000	1,602,000
Greece	158,000	53,000	43,000	254,000
Ireland	1,381,000	446,000	391,000	2,217,000
Italy	1,770,000	1,166,000	492,000	3,428,000
Luxembourg	111,000	91,000	16,000	217,000
Portugal	1,789,000	723,000	391,000	2,903,000
Spain	3,185,000	2,120,000	878,000	6,182,000
United Kingdom	10,527,000	-	-	10,527,000
EU15	19,900,000	5,111,000	2,320,000	27,331,000
Bulgaria	-	2,000	2,000	4,000
Cyprus	-	47,000	39,000	86,000
Estonia	-	17,000	13,000	30,000
Hungary	-	494,000	379,000	872,000
Latvia	-	114,000	89,000	203,000
Lithuania	-	10,000	7,000	17,000
Poland	-	1,364,000	1,042,000	2,406,000
Romania	-	-	-	-
Slovakia	-	456,000	350,000	805,000
Slovenia	-	1,000	-	1,000
EU-new	**-**	**2,504,000**	**1,920,000**	**4,424,000**
EU-TOTAL	**19,900,000**	**7,614,000**	**4,241,000**	**31,755,000**

5.3 Limits on organics

5.3.1 Step 1: Identification of MS affected by changes to the Directive

The previous report highlighted that, currently, some MS have limits on organics although this is not the general norm. Some countries such as UK, USA and Canada have not set any limit on organic contaminants (OCs) in sludge suggesting that concentrations present are not hazardous to human health, the environment or soil quality. However, other countries have set limits for some OC groups. For example, Germany has set limits for PCBs and dioxins but not PAHs. France has limits for PAHs and PCBs but not dioxins. Denmark has set limits for a range of OCs including linear alkyl sulphonates, nonylphenol and nonylphenol ethoxylates and the phthalate, di(ethylhexyl)phthalate (DEHP). The following Table shows the different limits on organics based on previous consultation.

Table 55: Existing legislative limits on organics

	Polycyclic aromatic hydrocarbon (PAH) mg/kg DS	Polychlorinated biphenyls (PCB) mg/kg DS
Option 2	6	0.8
Austria		
Lower Austria	-	0.2 c)
Upper Austria		0.2 c)
Vorarlberg		0.2 c)
Carinthia	6	1
Denmark (2002)	3a)	
France	Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)
Germany (BMU 2002)		0.2 d)
Germany (BMU 2007) e)	Benzo(a)pyrene: 1	0.1 d)
Sweden	3a)	0.4b)
Hungary	10	1
Czech Republic	-	0.6

Notes:
a)sum of 9 congeners
b)sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
c)sum of 6 congeners:PCB28,52,101,138,153,180
d)Per congener
e)Proposed new limits in Germany (BMU 2007)

Out of the 40 consultees' responses to the first consultation, eight would like OC limits, or stricter limits than currently in place in some location (with another respondent stating that any recycling is unacceptable), five argued that there is no evidence of sufficient risk to require limits on OCs, and another four would prefer it if limits were based on a common risk assessment and applied generally. There were no common views amongst those responding in favour of introducing EU limits on OCs in sewage sludges on which substances should be regulated. Under Option 2, we agreed with the Commission that limits are set on PCBs and PAHs as follows:

Table 56: Limit values for organics in sludge

PAH	6mg/kg dry matter
PCB	0.8 mg/kgdry matter

Under this option, most MS will be affected, excluding:

- Austria (three of Austria's nine states already have a sufficient limit on PCBs in place and another state [Carinthia] has a limit on PAH and a limit on PCBs that is slightly higher than the proposed 0.8 mg/kg);
- Denmark (currently only has a limit on PAH);
- Germany;
- Sweden; and
- Czech Republic (will comply with PCB limit but not limit on PAH).

The IA in 2003 estimated that 50% of sludge meeting the new heavy metal limits would fail to meet the new organics limits (although this included more standards than those proposed under this Option). Some consultees have stated that the maximum amount of sludge failing would be less than 50%. However, there is limited evidence on this. Although there appear to be a reduction of organic content, there are no detailed data on the amount of OC in sludges at different concentrations. The following table summarises the assumptions and information provided by the stakeholders on the amount of sludge affected.

Table 57: % recycled sludge failing the new limits on OCs under Option 2

MS	% affected	Source of data
Austria	0%	E
Belgium	20%	E
Denmark	0%	C
Finland	20%	C
France	1%	C
Germany	0%	C
Greece	50%	E
Ireland	50%	E
Italy	50%	E
Luxembourg	50%	E
Netherlands	0%	Due to ban on application
Portugal	>30 and <50%	C
Spain	50%	E
Sweden	50%	E
United Kingdom	10% - 50%	C
Bulgaria	50%	E
Cyprus	50%	E
Czech Republic	40%	C
Estonia	50%	E
Hungary	50%	E
Latvia	50%	E
Lithuania	50%	E
Malta	nd	nd
Poland	50%	E
Romania	50%	E
Slovakia	50%	E
Slovenia	50%	E
Key to source: C – provided by consultee; E- estimate by consultant		

5.3.2 Step 2: Impacts on Sludge Management

A UK DETR study considered that composting would reduce the concentration of most organic compounds below the limit. The ICON study confirmed that aerobic sludge treatment (such as composting) would destroy most of the LAS, NPE or DEHP. However, persistent organic compounds such as PAHs, PCBs, PCDD/Fs would probably not be sufficiently destroyed by composting. This will entail that the options for that sludge failing will be again incineration and landfill.

The same percentages going to incineration and landfill as for PTE have been applied here. However, new estimates need to be developed for those countries which did not fail the limits on heavy metals but will fail the limits on organic contaminants. The estimates on the different disposal routes used in the calculations are provided in the next Table.

Table 58: Disposal for sludge failing OC (% of failing sludge)

Alternative disposal	Co-incineration	Mono-incineration	Landfill
Belgium	40	50	10
Denmark	-	-	-
Finland	50	50	0
France	40	50	10
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Portugal	30	50	20
Spain	40	40	20
Sweden	40	50	10
United Kingdom	-	100	-
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	40	50	10
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50
Lithuania	50	-	50
Poland	50	-	50
Romania	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

5.3.3 Step 3: Impacts from the component – Costs and Benefits

The following table summarises the annual costs from this component and option (including the costs of externalities due to alternative disposal options, i.e. landfilling and incineration).

Table 59 Costs from New Limits of OC: Option 2 (EAC, €2009)

MS	Costs from mono-incineration	Costs from co-incineration	Costs of landfill	TOTALS
Belgium	347,000	182,000	39,000	567,000
Finland	179,000	116,000	-	295,000
France	980,000	513,000	110,000	1,602,000
Greece	658,000	220,000	181,000	1,059,000
Ireland	5,753,000	1,857,000	1,628,000	9,239,000
Italy	17,699,000	11,659,000	4,924,000	34,282,000
Luxembourg	556,000	453,000	78,000	1,086,000
Portugal	7,158,000	2,892,000	1,562,000	11,612,000
Spain	31,847,000	21,195,000	8,781,000	61,823,000
Sweden	2,003,000	1,046,000	225,000	3,274,000
United Kingdom	63,162,000	-	-	63,162,000
EU15	130,341,000	40,133,000	17,528,000	188,001,000
Bulgaria	-	1,138,000	796,000	1,934,000
Cyprus	-	197,000	161,000	357,000
Czech Republic	4,888,000	2,699,000	522,000	8,109,000
Estonia	-	131,000	103,000	233,000
Hungary	-	3,085,000	2,367,000	5,452,000
Latvia	-	284,000	222,000	506,000
Lithuania	-	801,000	607,000	1,408,000
Malta	-	-	-	-
Poland	-	5,682,000	4,342,000	10,024,000
Romania	-	857,000	636,000	1,493,000
Slovakia	-	1,139,000	874,000	2,013,000
Slovenia	-	197,000	-	197,000
EU-new	**4,888,000**	**16,210,000**	**10,630,000**	**31,728,000**
EU-TOTAL	**135,229,000**	**56,343,000**	**28,157,000**	**219,730,000**

5.4 Standards for pathogens

5.4.1 Step 1: Identification of MS affected by changes to the Directive

Seventeen respondents to the first consultation specifically mentioned or discussed pathogens in sludge. Most of these either inferred or specifically described the evidence that there have been no adverse health effects on humans, animals or plants whilst using sludge for agriculture treated and recycled in accordance with the Sludge Directive requirements. Five of the respondents specifically described a desire for pathogen controls to be based on different standards for different purposes, and possibly even with requirements adjusted by location as well, whilst three respondents would prefer consistent or harmonised controls.

None of the respondents made any specific recommendations other than by referring to existing quality limits or more stringent recycling controls used in some Member States either as regulatory controls or as codes of practice.

Option 2 will involve introducing standards for pathogens in line with the conventional treatment as given in the Commission Communication in 2003. Conventional treatment means any sludge treatment capable of achieving a reduction in *Escherichia coli* to less than $5x10^5$ colony forming units per gram (wet weight) of treated sludge.

Currently, only a few MS are known to have limits on pathogens, shown in Table 18. The 2002 CBA concluded that pollution prevention for pathogens by reducing at source was not feasible. However, local controls which specify indicator pathogen limits in the sludge have been implemented in several of the EU15 countries, driven by stakeholder demands. Sludge producers have installed new treatment processes that achieve more reliable and greater levels of pathogen destruction during treatment. Countries without equivalent systems to conventional standard however are using anaerobic digestion or aerobic digestion but this may not reliably achieve the standards.

Table 60: Standards for maximum concentrations of pathogens in sewage sludge (Sede and Andersen, 2002; Alabaster and LeBlanc, 2008)

	Salmonella	Other pathogens
Denmark a)	No occurrence	Faecal streptococci:< 100/g
France a)	8 MPN/10 g DS	Enterovirus: 3 MPCN/10 g of DS Helminths eggs: 3/10 g of DS
Finland (539/2006)	Not detected in 25 g	Escherichia coli <1000 cfu
Italy	1000 MPN/g DS	
Luxembourg	-	Enterobacteria: 100/g no eggs of worm likely to be contagious
Hungary	-	Faecal coli and faecal streptococci decrease below 10% of original number
Poland	Sludge cannot be used in agriculture if it contains salmonella	

No attempt has been made at this time to closely model the forms of sludge treatment used in each country as the combinations of sewage and sludge treatment processes lead to a very wide variety of possible scenarios. Consultation for the interim report revealed that the % of sludge being treated with anaerobic digestion can range from 20% (Norway) to 49% (Belgium). Consultation for the impact assessment provided some estimates about the % of sludge affected but in cases the range varies significantly (in such cases the median has been taken).

Table 61: % recycled sludge affected

Parameter	% affected	Source of data
Austria	0%	E
Belgium	40%	E
Denmark	20%	E
Finland	0%	C
France	5%-20%	C
Germany	0-40%	C
Greece	50%	E
Ireland	50%	E
Italy	50%	E
Luxembourg	50%	E
Netherlands	0%	Due to ban on application
Portugal	C. 90%	C
Spain	50%	E
Sweden	50%	E
United Kingdom	20%	C
Bulgaria	40%	E
Cyprus	40%	E
Czech Republic	40%	E
Estonia	40%	E
Hungary	40%	E
Latvia	40%	E
Lithuania	40%	E
Malta	nd	nd
Poland	40%	E
Romania	30%	C
Slovakia	40%	E
Slovenia	40%	E
Key to source: C – provided by consultee; E- estimate by consultant		

5.4.2 Step 2: Impacts on Sludge Management

This sludge will have to be treated further in order to meet the new limits on pathogens. Treatment processes to deal with pathogens include biological (digestion), chemical (lime treatment), and physical (high temperature drying). All these have different pathogen removal or inactivation characteristics (which vary from the relatively modest capability of mesophilic anaerobic digestion to reduce measurable *E.coli* concentrations by one hundred-fold with significant variation in effectiveness, to the substantially complete inactivation of vegetative cells achieved by thermal drying).

On this basis, we have assumed that all failing sludge will receive further treatment and use the costs given in Section 3, **Table 28: Costs €/tDS for enhanced treatment**. However, this may be an underestimate and/or an overestimate of the costs if companies decide to dispose of failing sludge by landfill and incineration in the former cases or use a more expensive way of treatment in the latter case.

5.4.3 Step 3: Impacts from the component – Costs and Benefits

The following table summarises the annual costs from this component and option.

Table 62: Costs from New Limits of Pathogens: Option 2 (EAC, €2009)

MS	Lower bound	Upper bound	Average
Belgium	238,000	423,000	331,000
Denmark	319,000	567,000	443,000
France	1,314,000	2,336,000	1,825,000
Germany	1,917,000	3,408,000	2,663,000
Greece	275,000	489,000	382,000
Ireland	2,517,000	4,475,000	3,496,000
Italy	9,418,000	16,743,000	13,080,000
Luxembourg	300,000	533,000	417,000
Portugal	11,954,000	21,252,000	16,603,000
Spain	16,702,000	29,692,000	23,197,000
Sweden	863,000	1,535,000	1,199,000
United Kingdom	3,551,000	6,314,000	4,932,000
EU15	**49,369,000**	**87,768,000**	**68,568,000**
Bulgaria	367,000	652,000	509,000
Cyprus	78,000	139,000	108,000
Czech Republic	1,554,000	2,762,000	2,158,000
Estonia	49,000	88,000	68,000
Hungary	1,125,000	2,001,000	1,563,000
Latvia	106,000	189,000	148,000
Lithuania	288,000	511,000	400,000
Poland	2,062,000	3,666,000	2,864,000
Romania	168,000	299,000	234,000
Slovakia	416,000	739,000	577,000
Slovenia	38,000	68,000	53,000
EU-new	**6,251,000**	**11,113,000**	**8,682,000**
EU-TOTAL	**55,620,000**	**98,880,000**	**77,250,000**

5.5 Provision of Information on Nutrients

As for the component providing information on nutrients, this is unlikely to affect MS significantly. This is because there is currently a requirement to measure N&P in accordance with the existing directive although the frequency is relatively low (6 months or when significant changes in quality). Although there will be costs these are not expected to be significant against the other components.

5.6 Other changes concerning quality and aimed at prevention

Option 2 will require that sludge shall be stabilised (or pseudo-stabilised) to reduce degradability during field side storage or after landspreading, to reduce methane emissions during storage and after landspreading, and to reduce odours. There are a number of means of demonstrating stability from which the most appropriate measurement may be agreed; for example, achieving 38% volatile solids reduction, or demonstrating that the specific oxygen uptake rate of the sludge is less than 1.5mgO_2/hour/g total solids.

Based on our estimates on sludge arising[36] from 2010-2020 the costs of quality assurance could be significant; however, as some plants are expected to be applying them already and due to economies of scale the following assumptions could apply:

- 50% of total sludge affected for newer MS and 20% for "older" MS (EU-15);
- lower range of cost: €3/tDS and
- upper range of costs: €18/tDS.

On this basis the following costs can be calculated.

Table 63: Costs from Quality Assurance: Option 2 (EAC, €2009)

MS	Lower bound	Upper bound	Average
Austria	3,000	19,000	11,000
Belgium	2,000	12,000	7,000
Denmark	11,000	64,000	37,000
Finland	1,000	6,000	4,000
France	112,000	673,000	392,000
Germany	64,000	383,000	224,000
Greece	1,000	9,000	5,000
Ireland	13,000	81,000	47,000
Italy	50,000	301,000	176,000
Luxembourg	2,000	10,000	6,000
Portugal	20,000	118,000	69,000
Spain	89,000	534,000	312,000
Sweden	5,000	28,000	16,000
United Kingdom	118,000	710,000	414,000
EU15	491,000	2,948,000	1,720,000
Bulgaria	19,000	115,000	67,000
Cyprus	4,000	24,000	14,000
Czech Republic	81,000	486,000	283,000
Estonia	3,000	15,000	9,000
Hungary	59,000	352,000	205,000
Latvia	6,000	33,000	19,000
Lithuania	15,000	90,000	52,000
Poland	107,000	644,000	376,000
Romania	16,000	93,000	55,000
Slovakia	22,000	130,000	76,000
Slovenia	2,000	12,000	7,000
EU-new	**332,000**	**1,994,000**	**1,163,000**
EU-TOTAL	**824,000**	**4,943,000**	**2,883,000**

[36] Total sludge recycled from 2010 to 2020 is estimated at around 56,817,200 tDS. Extrapolated quantities of sludge from 2010-2020

5.7 Change in limits on heavy metals based on soil conditions

5.7.1 Step 1: Identification of MS affected by changes to the Directive

Option 2 will involve changes to Annex IA, with more stringent limits of heavy metals in soil as proposed below.

Table 64: Proposed limit values of heavy metals in soil

PTE	86/278/EEC (6<pH<7)	5≤pH<6	6<pH<7	pH≥7
Cd	1-3	0.5	1	1.5
Cr	-	50	75	100
Cu	50-140	30	50	100
Hg	1-1.5	0.1	0.5	1
Ni	30-75	30	50	70
Pb	50-300	70	70	100
Zn	150-300	100	150	200

Table 21 sets out the maximum permissible concentrations in soil across different MS. Grey highlight denotes that the national limit is higher than proposed under Option 2. When there is no distinction based on pH, the highest bound has been applied.

Table 65: Maximum permissible concentrations of potentially toxic elements in sludge-treated soils (mg kg^{-1} dry soil) in EC Member States, (SEDE and Andersen, 2002)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Option 2 5£pH<6	**0.5**	**50**	**30**	**0.1**	**30**	**70**	**100**
Option 2 6<pH<7	**1**	**75**	**50**	**0.5**	**50**	**70**	**150**
Option2 pH³7	**1.5**	**100**	**100**	**1**	**70**	**100**	**200**
Austria							
Lower Austria	1.5/1h)	100	60	1	50	100	200
Upper Austria	1	100	100	1	60	100	300/150(9)
Burgenland	2	100	100	1.5	60	100	300
Vorarlberg	2	100	100	1	60	100	300
Steiermark	2	100	100	1	60	100	300
Carinthia if 5<pH<5.5	0.5	50	40	0.2	30	50	100
if 5.5<pH<6.5	1	75	50	0.5	50	70	150
if pH>6.5	1.5	100	100	1	70	100	200
Belgium-Brussels	2		50	1	30	50	150
Belgium, Flanders	0.9	46	49	1.3	18	56	170
Belgium, Wallonia	2	100	50	1	50	100	200
Bulgaria							
pH=6-7.4	2	200	100	1	60	80	250
pH>7.4	3	200	140	1	75	100	300
Cyprus	1-3		50-140	1-1.5	30-75	50-300	150-300
Denmark	0.5	30	40	0.5	15	40	100
Finland	0.5	200	100	0.2	60	60	150
France	2	150	100	1	50	100	300
Germany (6)	1.5	100	60	1	50	100	200
Germany (7)							
Clay	1.5	100	60	1	70	100	200
Loam/silt	1	60	40	0.5	50	70	150

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Option 2 5£pH<6	**0.5**	**50**	**30**	**0.1**	**30**	**70**	**100**
Option 2 6<pH<7	**1**	**75**	**50**	**0.5**	**50**	**70**	**150**
Option2 pH³7	**1.5**	**100**	**100**	**1**	**70**	**100**	**200**
Sand	0.4	30	20	0.1	15	40	60
Greece	3	-	140	1.5	75	300	300
Ireland	1	-	50	1	30	50	150
Italy	1.5	-	100	1	75	100	300
Luxembourg	1-3	100-200	50-140	1-1.5	30-75	50-300	150-300
Estonia (10)	3	100	50	1.5	50	100	300
Hungary	1	75/1 (8)	75	0.5	40	100	200
Latvia	0.5-0.9	40-90	15-70	0.1-0.5	15-70	20-40	50-100
Lithuania	1.5	80	80	1	60	80	260
Malta							
pH 5<6	0.5	30	20	0.1	15	70	60
pH 6-7	1	60	50	0.5	50	70	150
pH >7	1.5	100	100	1	70	100	200
Netherland	0.8	10	36	0.3	30	35	140
Portugal							
Soil ph<5.5	1	50	50	1	30	50	150
5.5<soil<7	3	200	100	1.5	75	300	300
Soil ph>7	4	300	200	2	110	450	450
Poland							
Light soil	1	50	25	0.8	20	40	80
Medium soil	2	75	50	1.2	35	60	120
Heavy soil	3	100	75	1.5	50	80	180
Romania	3	100	100	1	50	50	300
Slovakia	1	60	50	0.5	50	70	150
Slovenia	1	100	60	0.8	50	85	200
Spain							
Soil ph<7	1	100	50	1	30	50	150
Soil ph>7	3	150	210	1.5	112	300	450
Sweden	0.4	60	40	0.3	30	40	100
UK(1)	3	400 (5)	135	1	75	300 (3)	20

Notes:

(1) For soil of pH ≥5.0, except Cu and Ni are for pH range 6.0 – 7.0; above pH 7.0 Zn = 300 mg kg-1 ds (DoE, 1996);
(2) Approximate values calculated from the cumulative pollutant loading rates from Final Part 503 Rule (US, EPA 1993);
(3) Reduction to 200 mg kg-1 proposed as a precautionary measure;
(4) EC (1990) – proposed but not adopted;
(5) Provisional value (DoE, 1989).
(6) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(7) Proposed new German limits (BMU, 2007)
(8) Chromium VI
(9) For ph<6
(10) In soils where 5<ph<6 it is permitted to use lime-sterilised sludge

Source: Andersen and Sede (2002a): Disposal and Recycling Routes for Sewage Sludge Regulatory sub-component report – Part 1, 29 January 2002 as reproduced in DSR1 p.19

Note: Unless specified otherwise, we assume that limits listed in Andersen & Sede (2002) refer to ph between 6 and 7. Where Member State legislation includes ranges, the higher limit is taken as indicative of compliance with proposed Option 2

The above table depicts a number of MS with less stringent limits. However, this may not relate to the actual concentrations in soil. There is limited information on the percent of soil at different concentrations of pH.

The previous IA estimated that the percent of soil failing the new standards would range from 10% to 100% in some MS (the latter is relevant to the UK). However, the 100% figure is based on compounding data on the proportion of land failing to comply with limits on individual heavy metals and as such represents a worst-case scenario and we believe that it may be an overestimate. Indeed WRc estimated that 40% of the total agricultural land in the UK will not be available for sludge recycling should these limits be implemented[37]. Thus, this component is expected to have impacts on the land available for spreading. The following Table presents our estimates on the % of land failing for estimating the costs in terms of fertiliser replacement.

Table 66: % of failing land considered under Option 2 affected by limits in soil

Parameter	% affected	Source of data
Austria	10%	E
Belgium	0%	C
Denmark	0%	E
Finland	0%	C
France	2%-3%	C
Germany	25-35%	C
Greece	40%	E
Ireland	10%	E
Italy	30%	E
Luxembourg	30%	E
Netherlands	0%	Due to ban on application
Portugal	30%	C
Spain	20%	E
Sweden	50%	E
United Kingdom	15-65%	C
Bulgaria	30%	E
Cyprus	30%	E
Czech Republic	0%	C
Estonia	30%	E
Hungary	30%	E
Latvia	30%	E
Lithuania	30%	E
Malta	nd	nd
Poland	30%	E
Romania	0%	C
Slovakia	0%	E
Slovenia	30%	E
Key to source: C – provided by consultee; E- estimate by consultant		

5.7.2 Step 2: Impacts on Sludge Management

The main assumption affecting our calculation is that the land affected is equated to the % of recycled sludge affected. There is no method available to reduce heavy metals in soil. Thus, the failing sludge will have to be disposed of by incineration and/or landfilling (further treatment is not consider feasible in this case as the standards concern background concentrations). The following estimates are given in order to calculate the costs.

[37] based on the following concentrations in soil:Cd – 0.6, Cr – 84, Cu – 26, Hg – 0.1, Ni – 34, Pb – 29, Zn – 60

Table 67: Alternative disposal (% of failing sludge going to different disposal)

	Co-incineration	Mono-incineration	Landfill
Austria	50	40	10
Finland	50	50	-
France	40	50	10
Germany	50	50	-
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Portugal	30	50	20
Spain	40	40	20
Sweden	40	40	20
United Kingdom	-	100	-
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	-	-	-
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50
Lithuania	50	-	50
Poland	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

5.7.3 Step 3: Impacts from the component – Costs and Benefits

The following costs are calculated on the basis of the costs of the alternative disposal options. The unit cost presented in Section 3are used for the analysis. It is important to note that owing to the nature of the unit costs, such costs include both environmental and human health costs in addition to financial costs. The environmental costs on the basis of the degree of quantification possible to date however represent around 10% of the total costs (although in the case of incineration the externality are closer to the 10% value of the total quantifiable costs). Estimates on the GHG for this component are presented at the end of the Section for the sake of brevity.

Table 68: Costs and Benefits from Limits of PTE in soil (EAC, €2009)

MS	**Costs from mono-incineration**	**Costs from co-incineration**	**Costs of landfill**	**TOTALS**
Austria	227,000	187,000	32,000	445,000
France	2,449,000	1,283,000	274,000	4,006,000
Germany	16,915,000	11,154,000	-	28,069,000
Greece	527,000	176,000	145,000	847,000
Ireland	1,151,000	371,000	326,000	1,848,000
Italy	10,619,000	6,995,000	2,954,000	20,569,000
Luxembourg	333,000	272,000	47,000	652,000
Portugal	5,368,000	2,169,000	1,172,000	8,709,000
Spain	12,739,000	8,478,000	3,512,000	24,729,000
Sweden	1,603,000	1,046,000	449,000	3,098,000

MS	Costs from mono-incineration	Costs from co-incineration	Costs of landfill	TOTALS
United Kingdom	84,216,000	-	-	84,216,000
EU15	**136,145,000**	**32,131,000**	**8,911,000**	**177,187,000**
Bulgaria	-	683,000	478,000	1,160,000
Cyprus	-	118,000	96,000	214,000
Estonia	-	78,000	62,000	140,000
Hungary	-	1,851,000	1,420,000	3,271,000
Latvia	-	171,000	133,000	304,000
Lithuania	-	481,000	364,000	845,000
Malta	-	-	-	-
Poland	-	3,409,000	2,605,000	6,015,000
Slovenia	-	118,000	-	118,000
EU-new	**-**	**6,909,000**	**5,159,000**	**12,067,000**
EU-TOTAL	**136,145,000**	**39,040,000**	**14,069,000**	**189,255,000**

5.8 Setting conditions on application

Article 7 of the Directive 86/278/EEC sets restrictions on the spreading of sludge on grassland and forage crops, and on land on which vegetables and fruits are grown. For grassland and forage crops, it requires a minimum period of 3 weeks between sludge application and grazing or harvest. For fruit and vegetable crops in direct contact with soil and normally eaten raw, a period of 10 months is required.

These dispositions have been transposed by Member States with some variations. Ireland, Portugal and the United Kingdom have transposed the exact requirements of the directive. Other countries have introduced longer delays before spreading (Austria, Belgium, Estonia, Italy, and Luxembourg). Some countries have introduced additional restrictions for specific crops such as a ban for grassland in Austria, Latvia, Poland and Sweden, or on agricultural practices, such as direct ploughing (e.g. in Finland) or the use of pasteurised / enhanced treated / hygienised sludge (e.g. in France, where delay before spreading is greater when not using pasteurised / hygienised sludge).

Most countries have also introduced additional requirements for landspreading such as restricting the use of sludge in agriculture near surface water, in forests, on frozen or snow-covered ground, and on sloping land in order to reduce the impact of erosion and run-off. Requirements may also be added in order to protect groundwater. Additional recommendations have also been introduced in codes of practice or voluntary agreements (i.e. the UK Safe Sludge Matrix).

Although there appears to have been no evidence of risks due to landspreading when carried out according to the existing rules, Option 2 will entail moderate changes to Article 7 as highlighted above and repeated here for the sake of analysis:

- Setting periods for harvesting for grassland and/or forage crops;
- Make compulsory 10 month period for fruit and vegetable crops;
- Ban the application of untreated sludge **-** changes to Article 6 which currently allows MS to authorise under certain conditions the use of untreated sludge if injected or worked into the soil. Outright ban on the use of untreated sludge injected or worked into the soil – changes to Article 6; and
- Liquid sludge may only be used if injected or immediately worked into soil.

The main costs implications could be expected to arise from the ban on untreated sludge on those MS currently using it untreated, and the requirement that liquid sludge may only be injected or immediately worked into the soil. The other conditions are not expected to impact significantly. Untreated sludge is not currently widely applied. In the Czech Republic, Denmark, Spain, Finland, Germany, Hungary, Italy, Luxembourg, the Netherlands, Slovakia, Slovenia, and in the UK it is prohibited to spread any untreated sludge on land (EC 2006). The consultation has expressed that the impacts from such ban however are not expected to be significant. A French consultee stated that the land will be less than 5%; similarly a Finish and German stakeholders stated that the impact was nil. Thus the impacts from this component are expected to be negligible.

5.9 Changes to sampling and monitoring requirements

Option 2 will involve changes to sampling and monitoring requirements in line with Annex VI of CEC (2003) and concerning the frequency of sampling and monitoring with at least the frequency shown in the following table:

Table 69: Proposed analysis

Quantity of sludge produced per year and per plant (tonnes of dry matter)	Minimum number of analyses per year				
	Agronomic parameters	Heavy metals	Organic compounds (except dioxins)	Dioxins	Micro-organisms
< 50	1	1	-	-	1
50 – 250	2	2	-	-	2
250 – 1 000	4	4	1	-	4
1 000 – 2 500	4	4	2	1	4
2 500 – 5 000	8	8	4	1	8
> 5 000	12	12	6	2	12
The frequency of analysis of any of the parameters (heavy metals, organic compounds, micro-organisms) may be reduced if it has been shown that in a two-year period each measured value of the parameter is consistently below 75% of the limit. The analysis of organic compounds may be omitted if it has been shown that in a two-year period each measured value of the parameter is consistently below 25% of the limit. The frequency of analysis of any of the agronomic parameters may be reduced if in a two-year period it has been shown that each measured value of the parameter deviates by less than 20% from the average. There are some allowances for the number of samples that can fail within certain deviation, a maximum of 2 for any substance and limit, within a maximum of 20% deviation.					

Although costs have been provided for individual sampling and analysis (e.g. €500 per analysis of dioxins), baseline data does not allow us to estimate the number of plants affected and the number of total additional analysis. Consultees have stated that the costs implication could range from modest in comparison with other standards to significant as the number of analysis will be much higher than those currently undertaken. Thus, we have assumed that the costs from this component will be similar to those of quality assurance for illustrative purposes (**Table 63: Costs from Quality Assurance: Option 2 (EAC, €2009)**).

5.10 Impacts from Option 2

The following Table summarises the net costs of the different components from this Option. These include:

- Costs of alternative disposal;
- Obligation of treatment;
- Loss of use of sludge as a fertiliser and fertiliser replacement costs;
- Benefits/costs from alternative routes of disposal including climate change; and
- Human health from alternative routes of disposal

Table 70: PV costs from Different Option Components under Option 2

Component	PTE in sludge	OC	Pathogens		QA= Increased analysis		
MS			**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	**PTE in soil**
Austria	-	-	-	-	31,000	188,000	4,341,000
Belgium	-	5,535,000	2,324,000	4,132,000	19,000	116,000	-
Denmark	-	-	3,113,000	5,534,000	104,000	623,000	-
Finland	-	2,881,000	-	-	10,000	61,000	-
France	15,638,000	15,638,000	12,827,000	22,803,000	1,095,000	6,567,000	39,096,000
Germany	-	-	18,713,000	33,267,000	624,000	3,743,000	273,967,000
Greece	2,481,000	10,338,000	2,687,000	4,776,000	14,000	86,000	8,271,000
Ireland	21,642,000	90,173,000	24,567,000	43,675,000	131,000	786,000	18,035,000
Italy	33,461,000	334,608,000	91,921,000	163,415,000	490,000	2,941,000	200,765,000
Luxembourg	2,120,000	10,601,000	2,929,000	5,207,000	16,000	94,000	6,361,000
Portugal	28,335,000	113,339,000	116,679,000	207,430,000	192,000	1,152,000	85,004,000
Spain	60,342,000	603,424,000	163,018,000	289,810,000	869,000	5,217,000	241,370,000
Sweden	-	31,956,000	8,426,000	14,980,000	45,000	270,000	30,238,000
United Kingdom	102,748,000	616,490,000	34,663,000	61,624,000	1,155,000	6,933,000	821,986,000
EU15	**266,768,000**	**1,834,983,000**	**481,867,000**	**856,653,000**	**4,796,000**	**28,777,000**	**1,729,433,000**
Bulgaria	38,000	18,872,000	3,579,000	6,362,000	186,000	1,118,000	11,323,000
Cyprus	837,000	3,489,000	760,000	1,352,000	40,000	238,000	2,093,000
Czech Republic	-	79,149,000	15,165,000	26,961,000	790,000	4,739,000	-
Estonia	296,000	2,279,000	481,000	855,000	25,000	150,000	1,367,000
Hungary	8,514,000	53,211,000	10,984,000	19,527,000	572,000	3,433,000	31,927,000
Latvia	1,977,000	4,942,000	1,037,000	1,843,000	54,000	324,000	2,965,000
Lithuania	165,000	13,746,000	2,808,000	4,991,000	146,000	877,000	8,248,000
Poland	23,482,000	97,842,000	20,127,000	35,782,000	1,048,000	6,290,000	58,705,000
Romania	-	14,577,000	1,642,000	2,919,000	152,000	912,000	-
Slovakia	7,860,000	19,651,000	4,056,000	7,211,000	211,000	1,268,000	-
Slovenia	8,000	1,924,000	371,000	660,000	19,000	116,000	1,154,000
EU-new	**43,177,000**	**309,682,000**	**61,011,000**	**108,464,000**	**3,244,000**	**19,465,000**	**117,783,000**
EU-TOTAL	**309,945,000**	**2,144,665,000**	**542,878,000**	**965,117,000**	**8,040,000**	**48,242,000**	**1,847,216,000**

Table 71: EAC costs from Different Option Components under Option 2

Component			Pathogens		QA= Increased analysis		-
MS	PTE in sludge	OC	Lower bound	Upper bound	Lower bound	Upper bound	PTE in soil
Austria	-	-	-	-	3,000	19,000	445,000
Belgium	-	567,000	238,000	423,000	2,000	12,000	-
Denmark	-	-	319,000	567,000	11,000	64,000	-
Finland	-	295,000	-	-	1,000	6,000	-
France	1,602,000	1,602,000	1,314,000	2,336,000	112,000	673,000	4,006,000
Germany	-	-	1,917,000	3,408,000	64,000	383,000	28,069,000
Greece	254,000	1,059,000	275,000	489,000	1,000	9,000	847,000
Ireland	2,217,000	9,239,000	2,517,000	4,475,000	13,000	81,000	1,848,000
Italy	3,428,000	34,282,000	9,418,000	16,743,000	50,000	301,000	20,569,000
Luxembourg	217,000	1,086,000	300,000	533,000	2,000	10,000	652,000
Portugal	2,903,000	11,612,000	11,954,000	21,252,000	20,000	118,000	8,709,000
Spain	6,182,000	61,823,000	16,702,000	29,692,000	89,000	534,000	24,729,000
Sweden	-	3,274,000	863,000	1,535,000	5,000	28,000	3,098,000
United Kingdom	10,527,000	63,162,000	3,551,000	6,314,000	118,000	710,000	84,216,000
EU15	**27,331,000**	**188,001,000**	**49,369,000**	**87,768,000**	**491,000**	**2,948,000**	**177,187,000**
Bulgaria	4,000	1,934,000	367,000	652,000	19,000	115,000	1,160,000
Cyprus	86,000	357,000	78,000	139,000	4,000	24,000	214,000
Czech Republic	-	8,109,000	1,554,000	2,762,000	81,000	486,000	-
Estonia	30,000	233,000	49,000	88,000	3,000	15,000	140,000
Hungary	872,000	5,452,000	1,125,000	2,001,000	59,000	352,000	3,271,000
Latvia	203,000	506,000	106,000	189,000	6,000	33,000	304,000
Lithuania	17,000	1,408,000	288,000	511,000	15,000	90,000	845,000
Poland	2,406,000	10,024,000	2,062,000	3,666,000	107,000	644,000	6,015,000
Romania	-	1,493,000	168,000	299,000	16,000	93,000	-
Slovakia	805,000	2,013,000	416,000	739,000	22,000	130,000	-
Slovenia	1,000	197,000	38,000	68,000	2,000	12,000	118,000
EU-new	**4,424,000**	**31,728,000**	**6,251,000**	**11,113,000**	**332,000**	**1,994,000**	**12,067,000**
EU-TOTAL	**31,755,000**	**219,730,000**	**55,620,000**	**98,880,000**	**824,000**	**4,943,000**	**189,255,000**

As it can be seen from the Tables, the component causing the greatest costs is the new limits of OC followed by PTE limits in soil. The reasons for the highest costs for OC relate to the fact that no technology is known to date that may help to address such limits, as a result failing sludge will have to be disposed of by landfill and incineration. As for the limits in soil, this was indeed one of the main concerns of the consultation as most MS considered that the existing backgrounds would limit the amount of sludge that could be recycled.

It is important to note that some costs are not included above, such as those related to changes the legislation and monitoring and control. These are not estimated to be significant however in comparison.

5.10.1 Environmental and Human Health Impacts from Climate Change

Although there will be benefits (environmental and human health) from more stricter standards these cannot be easily quantified. This is due to the lack of evidence on dose-response but it is uncertain whether this is due to the Directive and/or existing national legislation and practices.

The external costs from alternative disposal options subject to quantification are expected to be around 10% of the total costs of the values above. Table 46 presents the valuation of GHG emissions based on the rated of alternative disposal applied (environmental and human health impacts due to GHG emissions). The valuation of GHG seems to indicate that the component bearing the greatest costs is that concerning the organic contaminants in sludge (from increased amount of sludge failing the standards).

Table 72: EAC due to GHG from alternative disposal by Component

MS	PTE in sludge	OC in sludge	PTE in soil
Austria	-	-	60,000
Belgium	-	71,000	-
Denmark	-	-	-
Finland	-	35,000	-
France	200,000	200,000	499,000
Germany	-	-	3,899,000
Greece	33,000	138,000	110,000
Ireland	224,000	934,000	187,000
Italy	439,000	4,386,000	2,631,000
Luxembourg	27,000	136,000	82,000
Portugal	415,000	1,662,000	1,246,000
Spain	850,000	8,507,000	3,402,000
Sweden	-	399,000	370,000
United Kingdom	1,275,000	7,647,000	10,197,000
EU15	**3,463,000**	**24,114,000**	**22,684,000**
Bulgaria	1,000	403,000	242,000
Cyprus	12,000	48,000	29,000
Czech Republic	-	1,411,000	-
Estonia	5,000	36,000	21,000
Hungary	143,000	892,000	535,000
Latvia	31,000	79,000	47,000
Lithuania	3,000	239,000	143,000
Poland	397,000	1,654,000	992,000
Romania	-	273,000	-
Slovakia	132,000	330,000	-
Slovenia	-	40,000	24,000

EU-new	**763,000**	**5,620,000**	**2,142,000**
EU-TOTAL	**4,226,000**	**29,734,000**	**24,825,000**

5.10.2 Other Impacts

One other impact that was considered in the initial assessment was the effects on agricultural production. Consultation has revealed however that such impacts are expected to be negligible.

The costs above reflect the total costs to the economy but exclude the costs to the regulatory authorities concerning changes to legislation and monitoring. These have not been valued but are expected to be negligible in comparison. One other benefit from this Option to regulators is that it will help meeting some other legislation objectives, such as WFD objectives. The contribution towards these objectives may be limited to agricultural inputs to watercourses. As the percentage of sludge applied to agriculture is considerably low, the benefits in this regard are not expected to be significant.

There may be some benefits in terms of amenity and public perception. These are highly uncertain however and have not been valued.

5.10.3 Distributional Analysis

5.10.3.1 Distributional impacts among MS

The impacts from the different option components will vary according to the MS. The following Table sets out the percentages of costs falling on the different MS according to their contribution to the total costs. As it can be seen, the main costs will fall onto the old MS. This is mainly due to the fact that the projections from the sludge arising are more significant, and not so much to the percentage of sludge failing. Among those EU-15 that are likely to be the most affected are the UK, Spain and Italy for the components concerting PTE and OC, with Spain and Italy also affected by the limits on pathogens together with Portugal. As for the limits concerning soil, Germany will be affected significantly (based on the consultation responses). France will be most affected by quality assurance requirements together with the UK and followed by Spain.

5.10.3.2 Distributional impacts among Stakeholders

As for distributional impacts among stakeholders, the main stakeholders affected by Option 2 are:

- sludge producers: operators of sewage treatment works would have to upgrade and replace current treatment plant equipment in order to meet the new standards of treatment set out in the regulations and dispose of the sludge that will not be recycled;
- local authorities/municipalities: running the incinerators and/or landfills (and/or companies on their behalf or sub-contractors) that may need upgrading capabilities and/or setting new incinerator facilities and
- farmers: who are the sludge users, would have to comply with revised restrictions. Farmers would face costs for replacement of fertilisers (or treated sludge). However the consultation has revealed that they will use other organic fertilisers and not just mineral fertilisers which may be more expensive. The costs in terms of impacts on agricultural production are according to the stakeholders likely to be negligible. Hence unemployment impacts are expected to be negligible in this sector alone.

The exact distribution in costs is uncertain but sludge producers and waste disposal facilities will bear the greatest costs. Stakeholders have expressed concerns about the possibility that water companies may pass on the costs of existing legislation. This is possible; however, in some MS such price increases are regulated, e.g. the UK, and as a result such increases are not expected to be significant.

On the other hand, stakeholder have highlighted that strict limits on sludge may cause unemployment impacts on related sectors such as recycling machinery manufacturers. These impacts need highlighting although their quantification is surrounded by uncertainty.

Environmental and social costs will accrue from increased incineration and landfill, as these will be the alternative routes for disposal to untreated sludge. These will accrue to all stakeholders through airborne pollutants.

Table 73: Distributional Analysis

	PTE in sludge	OC	Pathogens		QA= Increased analysis		PTE in soil
MS			**Lower bound**	**Upper bound**	**Lower bound**	**Upper bound**	
Austria	0%	0%	0%	0%	0%	0%	0%
Belgium	0%	0%	0%	0%	0%	0%	0%
Denmark	0%	0%	1%	1%	1%	1%	0%
Finland	0%	0%	0%	0%	0%	0%	0%
France	5%	1%	2%	2%	14%	14%	2%
Germany	0%	0%	3%	3%	8%	8%	15%
Greece	1%	0%	0%	0%	0%	0%	0%
Ireland	7%	4%	5%	5%	2%	2%	1%
Italy	11%	16%	17%	17%	6%	6%	11%
Luxembourg	1%	0%	1%	1%	0%	0%	0%
Portugal	9%	5%	21%	21%	2%	2%	5%
Spain	19%	28%	30%	30%	11%	11%	13%
Sweden	0%	1%	2%	2%	1%	1%	2%
United Kingdom	33%	29%	6%	6%	14%	14%	44%
EU15	**86%**	**86%**	**89%**	**89%**	**60%**	**60%**	**94%**
Bulgaria	0%	1%	1%	1%	2%	2%	1%
Cyprus	0%	0%	0%	0%	0%	0%	0%
Czech Republic	0%	4%	3%	3%	10%	10%	0%
Estonia	0%	0%	0%	0%	0%	0%	0%
Hungary	3%	2%	2%	2%	7%	7%	2%
Latvia	1%	0%	0%	0%	1%	1%	0%
Lithuania	0%	1%	1%	1%	2%	2%	0%
Poland	8%	5%	4%	4%	13%	13%	3%
Romania	0%	1%	0%	0%	2%	2%	0%
Slovakia	3%	1%	1%	1%	3%	3%	0%
Slovenia	0%	0%	0%	0%	0%	0%	0%
EU-new	**14%**	**14%**	**11%**	**11%**	**40%**	**40%**	**6%**
EU-TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

6. Option 3: More stringent limits (Significant change)

6.1 Overview

Table 6 showed the different components for Option 3. Option 3 will set more stringent standards than Option 2. The Option will consist of the following:

- Changes to the limits on heavy metals concerning the quality of the sludge (as given in the CEC (2003)) and in soil;
- Setting limits for all organic contaminants for sludge quality;
- Introduce standards for treatment compatible with CEC (2003) advanced treatment;
- Provision of information on nutrients;
- Ban of application of sludge for fruit, vegetable crops and grassland; and
- Changes to sampling and monitoring requirements.

The main issues with this Option are similar to those for Option 2, i.e. setting limitations on sludge use from higher standards in areas where there is no added value in terms of human health and the environment. However, as the limits are more stringent, the main risks relate to those environmental and human health risks stemming from the increased alternative disposal options to the sludge that will not be suitable for use (landfilling and incineration routes). Other issues relate to the ability to replace all sludge with fertiliser, although this is not expected to be significant as reflected by the consultation responses and impacts on productivity.

6.2 Heavy metal content in sludge

6.2.1 Step 1: Identification of MS affected by changes to the Directive

The limits proposed under Option 3 are given in the following Table.

Table 74: Proposed limit values on the content of heavy metals in sewage sludge – Option 3

PTE	mg/kg
Cd	5
Cr	150
Cu	400
Hg	5
Ni	50
Pb	250
Zn	600

Under these new limits more MS national legislation will be affected than under Option 2. Table 74 depicts, in grey colour, the countries that will be affected based on the regulatory limits. All MS, with the exception of Denmark (which would only have to amend the limit for zinc) would have to amend their legislative limits in respect to all heavy metals.

Table 75: Countries potentially affected by Option 3 i. setting limits on Maximum level of heavy metals (mg per kg of dry substance) in sewage sludge used for agricultural purposes - in grey

PTE	Cd	Cr	Cu	Hg	Ni	Pb	Zn
New limits	**5**	**150**	**400**	**5**	**50**	**250**	**600**
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000

Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
France (4)	10	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Portugal	20	1000	1000	16	300	750	2500
Spain	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000

As noted earlier however, the fact that national limits are higher than the proposed standards does not entail that the sewage sludge being produced is of the same quality. Table 76 depicts the MS affected, in grey, against current information on average sludge quality. As noted under Option 2 however, these are national (weighted) averages so they do not show the effect of different distributions. Indeed, we believe that Option 3 limits may rule out 50% of UK medium size works on Cu and Zn. The Andersen & Sede (2002) report estimated that the percentages of sludge affected by the new limits on heavy metals would range from 50% to 80% of total sludge production[38].

Table 76: Quality of sewage sludge (on dry solids) recycled to agriculture (2006) compared with new Option 3 limits

Parameter	**Cadmium**	**Chromium**	**Copper**	**Mercury**	**Nickel**	**Lead**	**Zinc**
New limits Option 3	**5**	**150**	**400**	**5**	**50**	**250**	**600**
BE –Flanders	1	20	72	0.2	11	93	337
BE-Walloon	1.5	54	167	1	25	79	688
Bulgaria	1.6	20	136	1.2	13	55	465
Cyprus	6.9	37	180	3.1	21	23	1188
Czech republic	1.5	53	173	1.7	29	40	809
Germany	1	37	300	0.4	25	37	713
Spain	2.1	72	252	0.8	30	68	744
Finland	0.6	18	244	0.4	30	8.9	332
France	1.3	43	272	1.1	21	50	598
Italy	1.3	86	283	1.4	66	101	879
Portugal	<0.4	20	12	<1	15	27	341

[38] This was estimated for the long term scenario, whose limits are more similar to, but less stringent than, those proposed under this Option.

Parameter	Cadmium	Chromium	Copper	Mercury	Nickel	Lead	Zinc
Sweden	0.9	26	349	0.6	15	24	481
UK	1.3	61	295	1.2	30	112	574
Estonia	2.8	14	127	0.6	19	41	783
Hungary	1.4	57	185	1.7	26	36	824
Lithuania	1.3	34	204	0.5	25	21	534
Latvia	3.6	105	356	4.2	47	114	1232
Portugal	4	127	153	4.6	32	51	996
Slovenia	0.7	37	190	0.8	29	29	410
Slovakia	2.5	73	221	2.7	26	57	1235

The following Table sets out our assumptions in terms of sludge failing new limits on heavy metals under Option 3 based on the consultation responses and standard deviation from percentile distributions for the MS where such information is available.

Table 77: % recycled sludge failing new limits on heavy metals in sludge under Option 3

MS	% failure	Source
Austria	20%	E
Belgium	20%	E
Denmark	20%	E
Finland	10%	C
France	50%	E
Germany	80%	C
Greece	50%	E
Ireland	50%	E
Italy	50%	E
Luxembourg	10%	E
Netherlands	0%	E
Portugal	60%	C
Spain	50%	E
Sweden	20%	E
United Kingdom	55%	C
EU15		E
Bulgaria	60%	E
Cyprus	60%	E
Czech Republic	60%	E
Estonia	60%	E
Hungary	60%	E
Latvia	60%	E
Lithuania	60%	E
Poland	60%	E
Romania	60%	E
Slovakia	60%	E
Slovenia	60%	E

6.2.2 Step 2: Impacts on Sludge Management

For the sludge failing, there will be two scenarios:

- landfill;
- incineration.

Both of the scenarios will have costs implications for water and sludge management operators. Depending on the specific scenarios, the environmental and social impacts from alternative disposal routes will vary in magnitude. In absence of any information on the different disposal routes, the following estimates will be used based on information available in the literature and consultation (these are based on the same trends as for Option 2).

Table 78: Impacts from Option 3 – disposal options and treatment

MS	Co-incineration	Mono-incineration	Landfill
Austria	50	40	10
Belgium	50	40	10
Denmark	40	50	10
Finland	50	50	-
France	40	50	10
Germany	50	50	-
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Netherlands	-	-	-
Portugal	30	50	20
Spain	40	40	20
Sweden	40	40	20
United Kingdom	-	100	-
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	40	50	10
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50
Lithuania	50	-	50
Poland	50	-	50
Romania	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

6.2.3 Step 3: Impacts from the component – Costs and Benefits

The following costs are calculated on the basis of the costs of the alternative disposal options. The unit cost presented in Section 3 are used for the analysis. It is important to note that owing to the nature of the unit costs, such costs include both environmental and human health costs in addition to financial costs. The environmental costs, on the basis of the degree of quantification possible to date however, represent around 10% of the total costs (although in the case of incineration, the externality are closer to the 10% value of the total quantifiable costs). Estimates on the GHG for this component are presented at the end of the Section separately.

Table 79: Costs and Benefits from Limits of PTE (EAC, €2009)

MS	Costs from mono-incineration	Costs from co-incineration	Costs of landfill	TOTALS
Austria	453,000	373,000	63,000	890,000
Belgium	277,000	227,000	39,000	543,000
Denmark	1,798,000	920,000	205,000	2,923,000
Finland	90,000	58,000	-	148,000
France	48,978,000	25,654,000	5,479,000	80,111,000
Germany	45,106,000	29,745,000	-	74,851,000
Greece	658,000	220,000	181,000	1,059,000
Ireland	5,753,000	1,857,000	1,628,000	9,239,000
Italy	17,699,000	11,659,000	4,924,000	34,282,000
Luxembourg	111,000	91,000	16,000	217,000
Portugal	10,736,000	4,338,000	2,343,000	17,418,000
Spain	31,847,000	21,195,000	8,781,000	61,823,000
Sweden	641,000	418,000	180,000	1,239,000
United Kingdom	115,797,000	-	-	115,797,000
EU15	**279,945,000**	**96,755,000**	**23,839,000**	**400,539,000**
Bulgaria	-	1,365,000	955,000	2,320,000
Cyprus	-	236,000	193,000	429,000
Czech Republic	7,333,000	4,049,000	782,000	12,164,000
Estonia	-	157,000	123,000	280,000
Hungary	-	3,702,000	2,840,000	6,542,000
Latvia	-	341,000	266,000	608,000
Lithuania	-	961,000	729,000	1,690,000
Poland	-	6,818,000	5,211,000	12,029,000
Romania	-	1,029,000	763,000	1,792,000
Slovakia	-	1,367,000	1,049,000	2,416,000
Slovenia	-	237,000	-	237,000
EU-new	**7,333,000**	**20,262,000**	**12,912,000**	**40,506,000**
EU-TOTAL	**287,278,000**	**117,017,000**	**36,751,000**	**441,046,000**

6.3 Set limits on organics

6.3.1 Step 1: Identification of MS affected by changes to the Directive

Under Option 3, new standards will be introduced for all organics. The proposed standards for PCBs and PAHs will be the same as those suggested under Option 2. However, additional limits will be introduced for PCDD/F, LAS and NPE. These are set out in Table 79.

Table 80: New limits on organics proposed under Option 3

OC	Limit value
PAH[39]	6 mg/kg dry matter
PCB[40]	0.8 mg/kg dry matter
PCDD/F[41]	100 ng ITEQ/kg dry matter
LAS[42]	5 g/kg dry matter
NPE[43]	450 mg/kg dry matter

As concerning the regulatory limits, this will impact all MS with the exception of Denmark. From surveys carried out in different countries/regions[44] (Norway, North Rhine Westphalia, UK) the range of concentrations of different contaminants is wide. Individual components are not necessarily linked with others. The median concentrations in these surveys are within the limit values for Option 3 (apart from UK LAS median concentration of 5.5g/kg DS), with values from 10% to 80% of the limit values, but the maximum values are all greater than the limit values shown. Hence it is expected that the new limits will affect a significant percentage of the total sludge recycled. It is not clear if the amount of sludge affected would be as high as the 50% estimated in the Andersen & Sede (2002) report. Estimates of sludge failing to meet these new OC limits are shown in Table 34; we have undertaken a conservative scenario for those MS from which information was not provided on the basis of other consultees responses.

Table 81: % recycled sludge which may fail the new limits on OCs under Option 3

MS	% affected	Source of data
Austria	50%	E
Belgium	30%	E
Denmark	0%	C
Finland	50%	C
France	30%	E
Germany	50%	C
Greece	50%	E
Ireland	50%	E

39 Sum of the following polycyclic aromatic hydrocarbons: acenapthene, phenanthrene, fluorene, flouranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1, 2, 3-c, d)pyrene.

40 Sum of the polychlorinated byphenls components number 28, 52, 101, 118, 138, 153, 180.

41 Polychlorinated dibenzodioxins/ dibenzofuranes.

42 Linear alkylbenzene sulphonates.

43 It comprises the substances nonylphenol and nonylphenolethoxylates with 1 or 2 ethoxy groups.

44 Norwegian Scientific Committee for Food Safety (VKM) 2009; Risk assessment of contaminants in sewage sludge applied on Norwegian soils. www.vkm.no.; Ministry of the Environment, Conservation,Agriculture and Consumer Protection of theState of North Rhine-Westfalia (2005) Characterization and assessment of organic pollutants in Sewage Sludge; Smith S & Riddell-Black (2007) Sources and Impacts of past Current and Future contamination of soil: Appendix 2. Organic contaminants. Final report to Defra.

MS	% affected	Source of data
Italy	50%	E
Luxembourg	50%	E
Netherlands	0%	E
Portugal	60%	C
Spain	50%	E
Sweden	50%	E
United Kingdom	95%	C
Bulgaria	50%	E
Cyprus	50%	E
Czech Republic	50%	E
Estonia	50%	E
Hungary	50%	E
Latvia	50%	E
Lithuania	50%	E
Poland	50%	E
Romania	50%	E
Slovakia	50%	E
Slovenia	50%	E

6.3.2 Step 2: Impacts on Sludge Management

It is not clear what conventional treatment methods could be reasonably used to deal with a failed sludge. It might be possible to dilute the sludge by mixing it with another sludge. High temperature treatments may be capable of improving degradation. The same trends as for heavy metals will be applied for considering the impacts on alternative disposal options.

Table 82: Alternative Disposal for sludge failing OC

MS	Co-incineration	Mono-incineration	Landfill
Austria	50	40	10
Belgium	50	40	10
Denmark	40	50	10
Finland	50	50	-
France	40	50	10
Germany	50	50	-
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Netherlands	-	-	-
Portugal	30	50	20
Spain	40	40	20
Sweden	40	40	20
United Kingdom	-	100	-

MS	Co-incineration	Mono-incineration	Landfill
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	40	50	10
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50
Lithuania	50	-	50
Malta	-	-	-
Poland	50	-	50
Romania	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

6.3.3 Step 3: Impacts from the component – Costs and Benefits

The following table summarises the annual costs from this component and option. These include the internal and external costs from the alternative disposal options.

Table 83: Costs from New Limits of OC: Option 3 (EAC, €2009)

MS	Mono-incineration	Co-incineration	Costs of landfill	TOTALS
Austria	1,133,000	933,000	158,000	2,224,000
Belgium	416,000	341,000	58,000	815,000
Finland	448,000	290,000	-	738,000
France	29,387,000	15,392,000	3,287,000	48,067,000
Germany	28,191,000	18,591,000	-	46,782,000
Greece	658,000	220,000	181,000	1,059,000
Ireland	5,753,000	1,857,000	1,628,000	9,239,000
Italy	17,699,000	11,659,000	4,924,000	34,282,000
Luxembourg	556,000	453,000	78,000	1,086,000
Portugal	10,736,000	4,338,000	2,343,000	17,418,000
Spain	31,847,000	21,195,000	8,781,000	61,823,000
Sweden	1,603,000	1,046,000	449,000	3,098,000
UK	200,013,000	-	-	200,013,000
EU15	328,440,000	76,315,000	21,888,000	426,642,000
Bulgaria	-	1,138,000	796,000	1,934,000
Cyprus	-	197,000	161,000	357,000
Czech R	6,110,000	3,374,000	652,000	10,136,000
Estonia	-	131,000	103,000	233,000
Hungary	-	3,085,000	2,367,000	5,452,000
Latvia	-	284,000	222,000	506,000
Lithuania	-	801,000	607,000	1,408,000
Poland	-	5,682,000	4,342,000	10,024,000
Romania	-	857,000	636,000	1,493,000
Slovakia	-	1,139,000	874,000	2,013,000
Slovenia	-	197,000	-	197,000
EU-new	**6,110,000**	**16,885,000**	**10,760,000**	**33,755,000**

6.4 Set standards for pathogens

6.4.1 Step 1: Identification of MS affected by changes to the Directive

Option 3 will entail advanced treatment as envisaged in the 2003 communication to deal with pathogens. In other words, 'advanced treatment' means any sludge treatment listed in Section 3 or any other process that sanitises sludge and achieves:

- a 99.99% reduction (in the indicator micro-organism mentioned in Annex I) of *Escherichia coli* to less than $1 \cdot 10^3$ colony forming unit per gram (dry weight) of treated sludge;
- no Ascaris ova;
- a sample of 1 gram (dry weight) of the treated sludge does not contain more than $3 \cdot 10^3$ spores of *Clostridium perfringens*;
- and a sample of 50 grams (wet weight) of the treated sludge does not contain *Salmonella spp*; and
- a 99.99% reduction in *Salmonella senftenberg* W775 for sludge spiked with this micro-organism. This is a process validation and not used on a regular basis; it is used to demonstrate a treatment process is capable of removing Salmonella.

Table 83 shows the percentage of sludge which is expected to require advanced treatment so that it meets the proposed standards for pathogens. These percentages will be used in the cost-benefit analysis unless other estimates are suggested.

Table 84: % sludge affected under new treatment

MS	%	Source
Austria	50%	E
Belgium	50%	E
Denmark	20%	E
Finland	50%	E
France	80%	C
Germany	70%	C
Greece	50%	E
Ireland	50%	E
Italy	50%	E
Luxembourg	50%	E
Netherlands	0%	E
Portugal	90%	E
Spain	50%	E
Sweden	50%	E
United Kingdom	70%	C
Bulgaria	50%	E
Cyprus	50%	E
Czech Republic	50%	E
Estonia	50%	E
Hungary	50%	E
Latvia	50%	E
Lithuania	50%	E
Poland	50%	E

MS	%	Source
Romania	50%	E
Slovakia	50%	E
Slovenia	50%	E

6.4.2 Step 2: Impacts on Sludge Management

The consultation responses highlighted enhanced digestion, i.e. thermal treatment as the main process to deal with sludge. Owing to the stricter limits for pathogens under this Option than those under Option 2, the upper bound of unitary costs has been used for our estimates. This may, on the other hand, offset the conservative assumptions concerning the percentage of sludge failure, so a more realistic estimate can be produced.

6.4.3 Step 3: Impacts from the component – Costs and Benefits

The following table summarises the annual costs from this component and option.

Table 85: Costs from New Limits of Pathogens: Option 3 (EAC, €2009)

MS	Costs
Austria	1,072,000
Belgium	662,000
Denmark	567,000
Finland	348,000
France	95,693,000
Germany	41,752,000
Greece	489,000
Ireland	4,475,000
Italy	16,743,000
Luxembourg	533,000
Portugal	21,252,000
Spain	29,692,000
Sweden	1,535,000
United Kingdom	77,341,000
EU15	**292,154,000**
Bulgaria	1,018,000
Cyprus	216,000
Czech Republic	4,316,000
Estonia	137,000
Hungary	3,126,000
Latvia	295,000
Lithuania	799,000
Poland	5,728,000
Romania	831,000
Slovakia	1,154,000
Slovenia	106,000
EU-new	**17,727,000**
EU-TOTAL	**309,880,000**

6.4.4 Provision of Information on Nutrients

As for the component providing information on nutrients, this is unlikely to affect MS significantly. As noted under Option 2, there is currently a requirement to measure N&P in accordance with the existing Directive. This component may increase the costs but such increase is not expected to be significant.

6.4.5 Other changes concerning quality and aimed at prevention

Option 3 will require Hazard Analysis and Critical Control Point (HACCP), as for Option 2. Under this component, we have assumed that the percentages of sludge affected will be the same; only in this case, the upper bound costs will apply (as companies will have to observe more substances). The costs estimates from this are summarised below.

Table 86: Costs from Quality Assurance: Option 3(EAC, €2009)

MS	**Costs**
Austria	19,000
Belgium	12,000
Denmark	64,000
Finland	6,000
France	673,000
Germany	383,000
Greece	9,000
Ireland	81,000
Italy	301,000
Luxembourg	10,000
Portugal	118,000
Spain	534,000
Sweden	28,000
United Kingdom	710,000
EU15	2,948,000
Bulgaria	115,000
Cyprus	24,000
Czech Republic	486,000
Estonia	15,000
Hungary	352,000
Latvia	33,000
Lithuania	90,000
Poland	644,000
Romania	93,000
Slovakia	130,000
Slovenia	12,000
EU-new	**1,994,000**
EU-TOTAL	**4,943,000**

6.5 Change in limits based on soil conditions

6.5.1 Step 1: Identification of MS affected by changes to the Directive

Under Option 3, the limit for zinc in soil with be decreased to 20mg/kg DS for all soils with a pH below 7, where as the proposed limits for Cd, Cr, Cu, Hg, NI and Pb are the same as those specified under Option 2. The proposed values are replicated in the following Table.

Table 87: Limits for PTE in soil – Option 3

PTE	5≤pH<6	6<pH<7	pH≥7
Cd	0.5	1	1.5
Cr	50	75	100
Cu	30	50	100
Hg	0.1	0.5	1
Ni	30	50	70
Pb	70	70	100
Zn	20	20	200

Based on current permissible concentrations of PTEs in sludge treated soils, all member states will be affected to some extent by these revised new limits, in particular those relating to Zn. For example, we estimate that 40% of the total agricultural land in the UK will not be available for sludge recycling should these limits be implemented. This component is expected to have significant impacts on the land which is available for sewage spreading. Table 87 presents our estimates of the percentages of land failing.

Table 88: % of failing land (due to heavy metals) considered under Option 3

MS	%	Source
Austria	20%	E
Belgium	40%	E
Denmark	0%	E
Finland	20%	E
France	50%	C
Germany	40%	C
Greece	40%	E
Ireland	20%	E
Italy	40%	E
Luxembourg	40%	E
Netherlands	0%	E
Portugal	40%	C
Spain	40%	E
Sweden	40%	E
United Kingdom	80%	C
EU15		
Bulgaria	40%	E
Cyprus	40%	E
Czech Republic	40%	E
Estonia	40%	E
Hungary	40%	E

MS	%	Source
Latvia	40%	E
Lithuania	40%	E
Malta	0%	E
Poland	40%	E
Romania	40%	E
Slovakia	40%	E
Slovenia	40%	E

6.5.2 Step 2: Impacts on Sludge Management

The main assumption affecting our calculation is that the land affected is equated to the % of recycled sludge affected. Thus, the failing sludge will have to be disposed of by incineration and/or landfilling (further treatment is not consider feasible in this case as the standards concern background concentrations). The following estimates are given in order to calculate the costs.

Table 89: Alternative disposal (% of failing sludge going to different disposal)

MS	Co-incineration	Mono-incineration	Landfill
Austria	50	40	10
Belgium	50	40	10
Finland	50	50	-
France	40	50	10
Germany	50	50	-
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Portugal	30	50	20
Spain	40	40	20
Sweden	40	40	20
United Kingdom	-	100	-
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	40	50	10
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50
Lithuania	50	-	50
Poland	50	-	50
Romania	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

6.5.3 Step 3: Impacts from the component – Costs and Benefits

The following costs are calculated on the basis of the costs of the alternative disposal options. The unit cost presented in Section 2 are used for the analysis. It is important to note that owing to the nature of the unit costs, such costs include both environmental and human health costs in addition to financial costs. The environmental costs on the basis of the degree of quantification possible to date however represent around

10% of the total costs (although in the case of incineration the externality are closer to the 10% value of the total quantifiable costs). Estimates on the GHG for this component are presented at the end of the Section for the sake of brevity.

Table 90: Costs and Benefits from Limits of PTE in soil (EAC, €2009)

MS	Costs from mono-incineration	Costs from co-incineration	Costs of landfill	TOTALS
Austria	453,000	373,000	63,000	890,000
Belgium	555,000	454,000	78,000	1,086,000
Finland	179,000	116,000	-	295,000
France	48,978,000	25,654,000	5,479,000	80,111,000
Germany	22,553,000	14,872,000	-	37,425,000
Greece	527,000	176,000	145,000	847,000
Ireland	2,301,000	743,000	651,000	3,695,000
Italy	14,159,000	9,327,000	3,939,000	27,426,000
Luxembourg	444,000	362,000	62,000	869,000
Portugal	7,158,000	2,892,000	1,562,000	11,612,000
Spain	25,477,000	16,956,000	7,025,000	49,459,000
Sweden	1,282,000	837,000	359,000	2,478,000
United Kingdom	168,432,000	-	-	168,432,000
EU15	**292,498,000**	**72,763,000**	**19,364,000**	**384,625,000**
Bulgaria	-	910,000	637,000	1,547,000
Cyprus	-	157,000	129,000	286,000
Czech Republic	4,888,000	2,699,000	522,000	8,109,000
Estonia	-	105,000	82,000	187,000
Hungary	-	2,468,000	1,893,000	4,361,000
Latvia	-	227,000	178,000	405,000
Lithuania	-	641,000	486,000	1,127,000
Poland	-	4,546,000	3,474,000	8,019,000
Romania	-	686,000	509,000	1,195,000
Slovakia	-	911,000	699,000	1,611,000
Slovenia	-	158,000	-	158,000
EU-new	**4,888,000**	**13,508,000**	**8,608,000**	**27,004,000**
EU-TOTAL	**297,387,000**	**86,271,000**	**27,972,000**	**411,629,000**

6.5.4 Setting conditions on application

Option 3 proposes a ban on application of sludge for fruit and vegetable crops and a ban for grassland. This component will thus have the following costs implications:

- Costs to sludge producers: quantities of sludge currently used on fruit and vegetable will have to be disposed differently, though incineration and/or landfill; and
- Costs to farmers: fertiliser replacement and, potentially, loss of agricultural production.

Some countries already have considerable restrictions relating to the types of land or timing of application of sewage sludge. The implications of banning the use of sludge on fruit and vegetable crops and grassland are therefore expected to vary significantly by country. Currently, we have limited information on the amount of sludge applied on fruit, vegetable crops and grassland.

Some consultess have stated that this component will have limited impacts (based on national legislation and practices). Others however such as Portugal and the Uk have highlighted that there will be costs implications. As information on the application of sludge on these particular crops alone is not available, it is not feasible at the time of writing to put a monetary value on such impacts. If these crops represented a significant amount of sludge, the costs for this countries will be similar to those calculated under Option 4.

6.5.5 Changes to sampling and monitoring requirements

Under Option 3, sampling and monitoring requirements will be as for Option 2 but Option 3 could have more substances to be tested, including organics.

Table 39: Proposed Analyses

Quantity of sludge produced per year and per plant (tonnes of dry matter)	Minimum number of analyses per year				
	Agronomic parameters	Heavy metals	Organic compounds (except dioxins)	Dioxins	Micro-organisms
< 50	1	1	-	-	1
50 – 250	2	2	-	-	2
250 – 1 000	4	4	1	-	4
1 000 – 2 500	4	4	2	1	4
2 500 – 5 000	8	8	4	1	8
> 5 000	12	12	6	2	12
Note that the number of analyses per substance is likely to be the same as under Option 2. However, for Option 3, organics such as PAH, PCB, PCDD/F, LAS and NPE will require testing.					

Similarly as for Option 2, the costs of Option 3 in this regard are similar to those calculated under quality assurance.

6.6 Impacts from Option 3

The impacts from Option 3 are expected to be more significant than for Option 2, due to the more stringent limits and the conditions on application. The following Table summarises the net costs of the different components from this Option. These include:

- Costs of alternative disposal;
- Obligation of treatment;
- Loss of use of sludge as a fertiliser and fertiliser replacement costs;
- Benefits/costs from alternative routes of disposal including climate change; and
- Human health from alternative routes of disposal.

Table 91: PV costs from Different Option Components under Option 3

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
Austria	8,682,000	21,706,000	10,463,000	188,000	8,682,000
Belgium	5,302,000	7,952,000	6,457,000	116,000	10,603,000
Denmark	28,533,000	-	5,534,000	623,000	-
Finland	1,440,000	7,202,000	3,395,000	61,000	2,881,000
France	781,921,000	469,153,000	934,005,000	6,567,000	781,921,000

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
Germany	730,578,000	456,611,000	407,524,000	3,743,000	365,289,000
Greece	10,338,000	10,338,000	4,776,000	86,000	8,271,000
Ireland	90,173,000	90,173,000	43,675,000	786,000	36,069,000
Italy	334,608,000	334,608,000	163,415,000	2,941,000	267,686,000
Luxembourg	2,120,000	10,601,000	5,207,000	94,000	8,481,000
Portugal	170,008,000	170,008,000	207,430,000	1,152,000	113,339,000
Spain	603,424,000	603,424,000	289,810,000	5,217,000	482,739,000
Sweden	12,095,000	30,238,000	14,980,000	270,000	24,190,000
United Kingdom	1,130,231,000	1,952,218,000	754,888,000	6,933,000	1,643,973,000
EU15	**3,909,455,000**	**4,164,233,000**	**2,851,559,000**	**28,777,000**	**3,754,125,000**
Bulgaria	22,647,000	18,872,000	9,941,000	1,118,000	15,098,000
Cyprus	4,187,000	3,489,000	2,112,000	238,000	2,791,000
Czech Republic	118,723,000	98,936,000	42,126,000	4,739,000	79,149,000
Estonia	2,735,000	2,279,000	1,336,000	150,000	1,823,000
Hungary	63,853,000	53,211,000	30,511,000	3,433,000	42,569,000
Latvia	5,931,000	4,942,000	2,880,000	324,000	3,954,000
Lithuania	16,495,000	13,746,000	7,799,000	877,000	10,997,000
Poland	117,410,000	97,842,000	55,910,000	6,290,000	78,273,000
Romania	17,492,000	14,577,000	8,109,000	912,000	11,661,000
Slovakia	23,581,000	19,651,000	11,268,000	1,268,000	15,721,000
Slovenia	2,308,000	1,924,000	1,032,000	116,000	1,539,000
EU-new	**395,363,000**	**329,469,000**	**173,024,000**	**19,465,000**	**263,575,000**
EU-TOTAL	**4,304,818,000**	**4,493,702,000**	**3,024,583,000**	**48,242,000**	**4,017,700,000**

Table 92: EAC costs from Different Option Components under Option 3

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
Austria	890,000	2,224,000	1,072,000	19,000	890,000
Belgium	543,000	815,000	662,000	12,000	1,086,000
Denmark	2,923,000	-	567,000	64,000	-
Finland	148,000	738,000	348,000	6,000	295,000
France	80,111,000	48,067,000	95,693,000	673,000	80,111,000
Germany	74,851,000	46,782,000	41,752,000	383,000	37,425,000
Greece	1,059,000	1,059,000	489,000	9,000	847,000
Ireland	9,239,000	9,239,000	4,475,000	81,000	3,695,000
Italy	34,282,000	34,282,000	16,743,000	301,000	27,426,000
Luxembourg	217,000	1,086,000	533,000	10,000	869,000
Portugal	17,418,000	17,418,000	21,252,000	118,000	11,612,000
Spain	61,823,000	61,823,000	29,692,000	535,000	49,459,000
Sweden	1,239,000	3,098,000	1,535,000	28,000	2,478,000
United Kingdom	115,797,000	200,013,000	77,341,000	710,000	168,432,000
EU15	**400,539,000**	**426,642,000**	**292,154,000**	**2,948,000**	**384,625,000**
Bulgaria	2,320,000	1,934,000	1,018,000	115,000	1,547,000
Cyprus	429,000	357,000	216,000	24,000	286,000
Czech Republic	12,164,000	10,136,000	4,316,000	486,000	8,109,000

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
Estonia	280,000	233,000	137,000	15,000	187,000
Hungary	6,542,000	5,452,000	3,126,000	352,000	4,361,000
Latvia	608,000	506,000	295,000	33,000	405,000
Lithuania	1,690,000	1,408,000	799,000	90,000	1,127,000
Poland	12,029,000	10,024,000	5,728,000	644,000	8,019,000
Romania	1,792,000	1,493,000	831,000	93,000	1,195,000
Slovakia	2,416,000	2,013,000	1,154,000	130,000	1,611,000
Slovenia	237,000	197,000	106,000	12,000	158,000
EU-new	**40,506,000**	**33,755,000**	**17,727,000**	**1,994,000**	**27,004,000**
EU-TOTAL	**441,046,000**	**460,398,000**	**309,881,000**	**4,943,000**	**411,629,000**

As it can be seen from the Table, the component causing the greatest costs is the new limits of OC followed by PTE limits in sludge.

6.6.1 Environmental and Human Health Impacts

Although there will be benefits (environmental and human health) from more stricter standards these cannot be easily quantified. This is due to the lack of evidence on dose-response but it is uncertain whether this is due to the Directive and/or existing national legislation and practices.

The external costs from alternative disposal options subject to quantification are expected to be around 10% of the total costs of the values above. Table 92 presents the valuation of GHG emissions based on the emissions from alternative disposal applied (environmental and human health impacts due to GHG emissions).

Table 93: EAC due to GHG from alternative disposal by Component

MS	PTE in sludge	OC in sludge	PTE in soil
Austria	121,000	302,000	121,000
Belgium	71,000	106,000	141,000
Denmark	298,000	-	-
Finland	18,000	88,000	35,000
France	9,981,000	5,989,000	9,981,000
Germany	10,396,000	6,498,000	5,198,000
Greece	138,000	138,000	110,000
Ireland	934,000	934,000	374,000
Italy	4,386,000	4,386,000	3,508,000
Luxembourg	27,000	136,000	109,000
Portugal	2,493,000	2,493,000	1,662,000
Spain	8,507,000	8,507,000	6,805,000
Sweden	148,000	370,000	296,000
United Kingdom	14,020,000	24,217,000	20,393,000
EU15	**51,537,000**	**54,164,000**	**48,734,000**
Bulgaria	484,000	403,000	322,000
Cyprus	58,000	48,000	39,000
Czech Republic	2,116,000	1,763,000	1,411,000
Estonia	42,000	36,000	28,000
Hungary	1,070,000	892,000	713,000
Latvia	94,000	79,000	63,000

MS	PTE in sludge	OC in sludge	PTE in soil
Lithuania	286,000	239,000	191,000
Malta	-	-	-
Poland	1,985,000	1,654,000	1,323,000
Romania	327,000	273,000	218,000
Slovakia	397,000	330,000	264,000
Slovenia	48,000	40,000	32,000
EU-new	**7,169,000**	**5,975,000**	**4,781,000**
EU-TOTAL	**58,706,000**	**60,139,000**	**53,514,000**

6.6.2 Other Impacts

One other impact that was considered in the initial assessment was the effects on agricultural production. Consultation has revealed however that such impacts are expected to be negligible.

There may be some benefits in terms of amenity and public perception. These are highly uncertain however and have not been valued. One other benefit from this Option is that it will help meeting some other legislation objectives, such as WFD objectives. On the other hand, too stringent limits may compromise meeting some other legislation such as the Waste Directive. These impacts have been highlighted by the consultees but are difficult to put a monetary value on.

6.6.3 Distributional Analysis

6.6.3.1 Distributional impacts among MS

The impacts from the different option components will vary according to the MS. The following Table sets out the percentages of costs falling on the different MS according to their contribution to the total costs. As it can be seen, the main costs will fall onto the old MS. This is, as for Option 2, due to the fact that the projections from the sludge arising are more significant. Among those EU-15 that are likely to be the most affected are the UK, France, Germany and Spain; although the percentages vary according to the component considered. It is important to note here, however, that the zeros may be due to rounding and do not necessarily entail zero costs (but the costs would be small against the totals).

Table 94: Distributional Analysis

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
Austria	0%	0%	0%	0%	0%
Belgium	0%	0%	0%	0%	0%
Denmark	1%	0%	0%	1%	0%
Finland	0%	0%	0%	0%	0%
France	18%	10%	31%	14%	19%
Germany	17%	10%	13%	8%	9%
Greece	0%	0%	0%	0%	0%
Ireland	2%	2%	1%	2%	1%
Italy	8%	7%	5%	6%	7%
Luxembourg	0%	0%	0%	0%	0%
Netherlands	0%	0%	0%	0%	0%
Portugal	4%	4%	7%	2%	3%
Spain	14%	13%	10%	11%	12%
Sweden	0%	1%	0%	1%	1%

MS	PTE in sludge	OC	Pathogens	QA= Increased analysis	PTE in soil
United Kingdom	26%	43%	25%	14%	41%
EU15	**91%**	**93%**	**94%**	**60%**	**93%**
Bulgaria	1%	0%	0%	2%	0%
Cyprus	0%	0%	0%	0%	0%
Czech Republic	3%	2%	1%	10%	2%
Estonia	0%	0%	0%	0%	0%
Hungary	1%	1%	1%	7%	1%
Latvia	0%	0%	0%	1%	0%
Lithuania	0%	0%	0%	2%	0%
Malta	0%	0%	0%	0%	0%
Poland	3%	2%	2%	13%	2%
Romania	0%	0%	0%	2%	0%
Slovakia	1%	0%	0%	3%	0%
Slovenia	0%	0%	0%	0%	0%
EU-new	**9%**	**7%**	**6%**	**40%**	**7%**
EU-TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**

6.6.3.2 Distributional impacts among Stakeholders

As for distributional impacts among stakeholders, the main stakeholders affected are:

- sludge producers: operators of sewage treatment works would have to upgrade and replace current treatment plant equipment in order to meet the new standards of treatment set out in the regulations and dispose of the sludge that will not be recycled; and
- local authorities/municipalities: running the incinerators and/or landfills (and/or companies on their behalf or sub-contractors) that may need upgrading capabilities and/or setting new incinerator facilities and
- farmers: who are the sludge users, would have to comply with revised restrictions. Farmers would face costs for replacement of fertilisers (or treated sludge). However the consultation has revealed that they will use other organic fertilisers and not just mineral fertilisers which may be more expensive. The costs in terms of impacts on agricultural production are according to the stakeholders likely to be negligible. Hence unemployment impacts are expected to be negligible in this sector alone.

The exact distribution in costs is uncertain but sludge producers and waste disposal facilities will bear the greatest costs. Stakeholders have expressed concerns about the possibility that water companies may pass on the costs from complying with new standards. This is possible; in some MS, however, such price increases are regulated, e.g. the UK, and as a result such increases are not expected to be significant.

On the other hand, stakeholder have highlighted that strict limits on sludge may cause unemployment impacts on related sectors such as manufacturers of recycling machinery. These impacts need highlighting although their quantification is surrounded by uncertainty.

Environmental and social costs will accrue from increased incineration and landfill, as these will be the alternative routes for disposal to untreated sludge. These will accrue to all stakeholders through airborne pollutants.

7. Option 4: total ban on the use of sludge on land

7.1 Overview of Option 4

Option 4 will consist of a total ban on the use of sludge on land.

The main risks from this Option relate to the impacts from the alternative means of disposal for sludge, amenity impacts from landfill and public health risk from incineration (i.e. air emissions). Such impacts are quantified below. The main benefits relate to reduced risk to the environment and human health from application of sludge, but these will have to offset the costs of the alternative routes of disposal, which seems unlikely. There will be benefit from compliance with other legislation, such as the WFD. But these are very difficult to quantify due to uncertainty about the degree of implementation of relevant legislation at national level.

7.2 Impacts from Option 4

7.2.1 Step 1: Identification of MS affected by changes to the Directive

This Option will have significant implications in all MS, excluding parts of Austria (specifically two of its nine federal states) and the Netherlands (since there effectively is already a ban).

The countries most affected by the ban will be those where recycling is the greatest, i.e Luxembourg, Ireland, France, UK, Hungary, Spain.

7.2.2 Step 2: Impacts on Sludge Management

The only alternatives for the sludge failing will be incineration and/or landfill. The following Table summarises the assumptions in terms of disposal for sludge failing the standards.

Table 95: Disposal for sludge under Option 4

MS	Co-incineration	Mono-incineration	Landfill
Austria	50	40	10
Belgium	50	40	10
Denmark	40	50	10
Finland	50	50	-
France	40	50	10
Germany	50	50	-
Greece	25	50	25
Ireland	25	50	25
Italy	40	40	20
Luxembourg	50	40	10
Netherlands	-	-	-
Portugal	30	50	20
Spain	40	40	20
Sweden	40	40	20
United Kingdom	-	100	-
EU15	-	-	-
Bulgaria	50	-	50
Cyprus	50	-	50
Czech Republic	40	50	10
Estonia	50	-	50
Hungary	50	-	50
Latvia	50	-	50

MS	Co-incineration	Mono-incineration	Landfill
Lithuania	50	-	50
Poland	50	-	50
Romania	50	-	50
Slovakia	50	-	50
Slovenia	100	-	-

7.2.3 Step 3: Impacts from the component – Costs and Benefits

The following costs are calculated on the basis of the costs of the alternative disposal options. The unit cost presented in Section 3 are used for the analysis. It is important to note that owing to the nature of the unit costs, such costs include both environmental and human health costs in addition to financial costs. The environmental costs on the basis of the degree of quantification possible to date however represent around 10% of the total costs (although in the case of incineration the externality are closer to the 10% value of the total quantifiable costs). Estimates on the GHG for this component are presented at the end of the Section.

Table 96: Costs from Option 4 (EAC, €2009)

MS	Costs from mono-incineration	Costs from co-incineration	Costs of landfill	TOTALS
Austria	2,266,000	1,866,000	315,000	4,448,000
Belgium	1,387,000	1,135,000	194,000	2,716,000
Denmark	8,992,000	4,598,000	1,026,000	14,617,000
Finland	896,000	580,000	-	1,476,000
France	97,956,000	51,308,000	10,958,000	160,222,000
Germany	56,382,000	37,181,000	-	93,563,000
Greece	1,317,000	439,000	362,000	2,118,000
Ireland	11,507,000	3,715,000	3,256,000	18,477,000
Italy	35,398,000	23,318,000	9,848,000	68,564,000
Luxembourg	1,111,000	905,000	156,000	2,172,000
Portugal	17,894,000	7,231,000	3,906,000	29,030,000
Spain	63,694,000	42,390,000	17,562,000	123,646,000
Sweden	3,205,000	2,092,000	899,000	6,196,000
United Kingdom	210,540,000	-	-	210,540,000
EU15	**512,544,000**	**176,758,000**	**48,483,000**	**737,785,000**
Bulgaria	-	2,000	2,000	4,000
Cyprus	-	394,000	321,000	715,000
Czech Republic	12,221,000	6,748,000	1,304,000	20,273,000
Estonia	-	261,000	206,000	467,000
Hungary	-	6,170,000	4,734,000	10,903,000
Latvia	-	569,000	444,000	1,013,000
Lithuania	-	1,602,000	1,215,000	2,817,000
Poland	-	11,364,000	8,685,000	20,049,000
Romania	-	1,715,000	1,272,000	2,987,000
Slovakia	-	2,279,000	1,748,000	4,027,000
Slovenia	-	394,000	-	394,000
EU-new	**12,221,000**	**31,497,000**	**19,930,000**	**63,648,000**

EU-TOTAL	524,765,000	208,255,000	68,412,000	801,433,000

The impacts from Option 4 are expected to be more significant than for any of the other options. The above figures include the costs, internal and external, for alternative disposal options for sludge that will not be recycled due to the ban.

The benefits from the ban itself in terms of reduced risk to the environment and human health are not included above. This is because, as highlighted earlier such benefits are not subject to valuation (due to the lack of data on dose-response).

7.2.4 GHG from alternative disposal

The costs from GHG emissions are set out in the next table.

Table 97: Costs from Option 4 (EAC, €2009)

MS	**Landfill Costs**	**Mono-incineration**	**Co-incineration**	**TOTAL**
Austria	22,000	261,000	321,000	604,000
Belgium	13,000	152,000	188,000	353,000
Denmark	53,000	804,000	633,000	1,490,000
Finland	-	89,000	87,000	176,000
France	716,000	10,769,000	8,477,000	19,962,000
Germany	-	6,550,000	6,446,000	12,995,000
Greece	28,000	166,000	82,000	276,000
Ireland	187,000	1,126,000	554,000	1,868,000
Italy	678,000	4,079,000	4,014,000	8,771,000
Luxembourg	10,000	118,000	145,000	272,000
Portugal	320,000	2,411,000	1,423,000	4,155,000
Spain	1,315,000	7,912,000	7,786,000	17,013,000
Sweden	57,000	344,000	339,000	740,000
United Kingdom	-	25,492,000	-	25,492,000
EU15	3,398,000	60,274,000	30,496,000	94,167,000
Bulgaria	-	-	628,000	628,000
Cyprus	-	-	76,000	76,000
Czech Republic	-	1,917,000	1,509,000	3,426,000
Estonia	-	-	56,000	56,000
Hungary	-	-	1,405,000	1,405,000
Latvia	-	-	124,000	124,000
Lithuania	-	-	375,000	375,000
Poland	-	-	2,612,000	2,612,000
Romania	-	-	422,000	422,000
Slovakia	-	-	519,000	519,000
Slovenia	-	-	80,000	80,000
EU-new	2,227,000	1,917,000	7,807,000	11,950,000
EU-TOTAL	**5,625,000**	**62,190,000**	**38,302,000**	**106,117,000**

7.2.5 Distributional Analysis

7.2.5.1 Distributional impacts among MS

The table below provides the share of the total costs by MS. As it was noted earlier the countries most affected are the UK and France due to the greatest amount of sludge being recycled. The EU-15 will bear the greatest costs of the ban as opposed to newer MS (this also is due to the volume of sludge generated).

Table 98: Distributional Analysis

MS	**Share of total costs**
Austria	1%
Belgium	0%
Denmark	2%
Finland	0%
France	20%
Germany	12%
Greece	0%
Ireland	2%
Italy	9%
Luxembourg	0%
Netherlands	0%
Portugal	4%
Spain	15%
Sweden	1%
United Kingdom	26%
EU15	**92%**
Bulgaria	0%
Cyprus	0%
Czech Republic	3%
Estonia	0%
Hungary	1%
Latvia	0%
Lithuania	0%
Malta	0%
Poland	3%
Romania	0%
Slovakia	1%
Slovenia	0%
EU-new	**8%**
EU-TOTAL	**100%**

7.2.5.2 Distributional impacts among stakeholders

As before, the main cost will fall onto sludge and waste disposal operators and farmers currently using the sludge. The impacts on the sludge operators however are significantly greater than on the farmers.

There may be a possibility that the costs will be passed on to consumers. Price-elasticities for water services are fairly inelastic; on the other hand, regulation in some MS could stop water companies to pass all the costs in full. Information on price elasticities by MS is not available; hence these impacts cannot be evaluated in detail. However, owing to the greater costs, the possibility that these costs may be passed on is greater than for the other Options.

As before, there will be social impacts associated with the human health impacts stemming from the alternative disposal routes will fall on all stakeholders. These have been included in the above values however.

7.3 Summary of Costs and Benefits and Distributional Impacts from Option 4

This Option is likely to have significant impacts on the different MS. The main costs associated with this option will be related to:

- financial costs from increased incineration and recycling;
- environmental costs from increased incineration and recycling (i.e. from transport and emissions); and
- human health impacts derived from the above (increased incineration and landfill).

The total costs estimated in Andersen & Sede (2002), for the scenario where no sludge is able to meet the new regulatory requirements, could be seen as a check for this Option. This scenario led to costs of 1.2bn/year for the 15 MS of the European Union.

Another study calculated the value of sewage sludge in the EU to range from 0.5% to 1% of the total agricultural budget in the EU[45] (used to substitute mineral fertiliser). The agricultural budget for the EU in 2009 is €116bn. This would imply that the value of sludge is of around €0.58bn to €1.16bn per year.

Our estimates, annualised costs, are estimated to be of around €0.8bn. This is not very far off the estimate produced above.

[45] Kroiss H and Zessner M (2007): Ecological and Economical Relevance of Sludge Treatment and Disposal Options, Institute for Water Quality and Waste Management at Vienna University of Technology, Austria.

8. Option 5: Repeal of the Directive

8.1 Overview of Option

Option 5 will involve repealing the Directive.

8.2 Impacts from this Option

The impacts of this option will depend on two main issues: first, how Member States react and in particular whether they might change national legislation governing sewage sludge; and second, the extent to which other EC legislation might govern the sludge disposal and in particular the spreading of sludge on land. The future actions of the Member States in this situation in particular are difficult to predict.

8.2.1 Actions of Member States

As noted above, it is quite difficult to predict the actions of Member States were the Sewage Sludge Directive to be repealed. On the one hand, Member States with national legislation that is currently more stringent than the directive might keep this in place. However, Member States would also be free to remove all restrictions on sludge disposal (within the restrictions of other EC legislation).

Under this Option, however, we could assume that the national legislation will remain in place especially in the short term but changes may be introduced in the future. The greatest issue however is that in the case that some Member States lift all restrictions on sludge disposal. In this case, people could just apply sludge how and when they wanted (in line with national requirements). This may not guarantee a standard level of protection across all MS.

8.2.2 Influence of other EC legislation

Without the Sewage Sludge Directive in place, other EC legislation might influence the spreading of sludge on land. The following table presents an overview of other environmental protection legislation that might influence the spreading of sludge. (Note that such drivers also apply to the baseline scenario).

Table 99: Current EC environmental legislation that might influence the spreading of sludge on land if Directive 86/278/EEC were to be repealed

Directive	Potential influence
Directive 2008/98/EC	• sets the basic concepts and definitions related to waste managament and lays down waste management principles such as the "polluter pays principle" or the "waste hierarchy" thus recycling is a better options than disposal; • could lead to further recycling provided that standards are being met (will favour incineration versus landfilling)
Directive 91/676/EEC – Nitrates Directive	• Fertilizer application limited in nitrate vulnerable zones; also affects sludge application • No influence on other pollutants
Council Regulation (EC) No 889/2008 on organic production and labelling of organic products	• Ban on organic labelling of sewage sludge (Annex I to Regulation contains positive lists of fertilisers and soil improvers allowed in organic farming. Sludge is not included) • As organic production is a small share of all agriculture, any effects from this Regulation or Member State requirements likely to be negligible overall; perhaps some influence in restricted local areas
EC Decisions 2006/799 and 2007/64 on criteria for the award of a Community eco-label to growing media	• Growing media containing sludge shall not be awarded an eco-label • Same as above: likely to have negligible or mainly local effects
Environmental Liability Directive	• Environmental liability requirements may encourage private operators to

Directive	Potential influence
2004/35/EC	use good practice for sludge disposal – not all operators, however, may do so
Directive 2003/87/EC on greenhouse gas emissions	• Possible impact on ammonia production
Directive 2006/118/EC – groundwater protection against pollution and groundwater quality standards	• May influence spreading of sludge in local areas where groundwater exceeds quality standards
Directive 2008/105/EC – EQS for pollutants to achieve good surface water quality	• May influence spreading of sludge in local areas where surface waters exceed quality standards

The initial analysis suggests that these pieces of legislation may have some influence on the spreading of sewage sludge. However, they will influence only specific pollutants (the case for the Nitrates Directive) or local areas, for example where groundwater or surface water quality does not meet standards. While the Liability Directive might have a more broad-based influence, it may not affect all operators.

The European Commission's proposal for a Framework Soils Directive (COM(2006) 232) may have a more far-reaching effect. This proposal remains under discussion, however, and in the face of this uncertainty it has not been assessed.

A further question is whether EC food safety legislation would protect human health from indirect exposure, e.g. from fruits and vegetables grown using sewage sludge. Here, a broad and integrated framework of legislation has been put in place to ensure food safety (the framework is provided by Regulation (EC)178/2002 laying down the General Principles and requirements of Food Law). It is not clear, however, if this legislation and its implementation currently addresses potential risks from the spreading of sewage to land, as these are covered by the Sewage Sludge Directive. The repeal of this directive might require an adjustment of food safety legislation and its implementation in order to ensure adequate protection of human health.

8.3 Assessment of Option

8.3.1 Assessment of economic impacts

The marginal costs of this Option against the baseline are negligible.

The benefits will be in terms of costs savings from current monitoring, sampling and analysis accruing to the regulatory authorities. However, it is not certain that MS will change their regulation and practices. Indeed, it is unlikely that repeal of the Directive will lead to the adoption of less stringent quality standards for sludge in national legislation, especially in the short term. This is based on the results of the first consultation. So savings may not be large.

It is important to identify that such option may affect trade among MS depending on consumers' perception of risk from different products. Competitiveness and competition may be affected at EU level too; operators of wastewater treatment plants across the EU might find much greater divergences among Member State requirements than at present. While in some Member States they might realise savings, in others they would not. This could indicate significant distributional impacts.

8.3.2 Assessment of environmental and social impacts

In a worst-case scenario, a country could remove all restrictions on the spreading of sludge. This might create actual health impacts from contamination of food, and while sludge is not traded among Member

States, food is, making this a risk for the EU as a whole. The question is: does EU food safety legislation provide adequate safeguards against such an event?

In addition, as highlighted above, consumer perception and confidence are likely to play a key role on the social impacts (and likely macro-economic impacts) from this Option. It is important to identify that such option may affect consumer confidence as well as trade among MS depending on consumers' perception of risk from different products. The repeal of the directive could significantly reduce consumer confidence in the safety of food products, either from specific Member States or in general. In the consultations for this study, one stakeholder warned that the end result could be an end to all spreading of sewage sludge on land.

8.4 Summary of Costs and Benefits from Option 5

This preliminary review thus suggests that other EC environmental legislation would not provide sufficient protection of the environment in the event that Directive 86/278/EEC were to be repealed; nor would other legislation provide sufficient protection of human health from direct impacts of sewage sludge spread on land.

The responses from the consultation on this Option include the following:

> *Option 5 is not acceptable as it cannot guarantee protection of the environment. It will have an impact on stakeholders' confidence. This could lead to a sudden loss of the sludge to land outlet and Option 5 will have similar impacts to Option 4.*
>
> *86/278/EEC was the first soil protection directive and to a very large extent it still is. It would be very regrettable if it was repealed.*
>
> *Option 5 is unacceptable because there must be a legal instrument that provides protection of public health and the Environment*
>
> *In relation to option 5, any perceived savings are likely to be offset by the damage which might result to consumer confidence and the land bank for spreading.*

This tentative conclusion would appear to make this option unacceptable.

9. Sensitivity Analysis

9.1 Main sources of uncertainty

The main sources of uncertainty of this impact assessment relate to the following:

a. assumptions concerning the amount of sludge being affected and the different management routes for the sludge failing to meet the new standards;
b. unitary costs and benefits related to the different management options.

Sensitivity analysis is undertaken on the three aspects below.

9.2 Sensitivity on Amount of Sludge affected and disposal

The assumptions concerning the sludge affected were revisited on the basis of the responses provided by the consultees. Overall, it is expected that the consultees have taken into account responses on existing pollution prevention measures in their countries when answering the relevant questions. However, sensitivity analysis is still undertaken to account for the fact that more stringent analysis may lead MS to undertake further pollution prevention at source thus reducing the amount of sludge affected going to incineration and/or landfill as disposal.

Pollution prevention may be implemented through a variety of measures and can include individual regulatory, economic and voluntary and educational instruments. These instruments are consistent with an overall strategy of waste minimisation, polluter pays, and reduction at source. Examples of such instruments in the past are included in the following box. The effectiveness of such instruments however has been variable, with the waste water tax in Germany being limited but other such as the Danish eco-labelling of washing powders containing LAS being highly effective. In cases, however, the same instrument can have a varied impact depending on local conditions, e.g. a public campaign effectiveness may depend on the degree of public awareness at the time the campaign is out.

Box 1: Examples of Pollution prevention programmes

- Targeted waste collection in France;
- Charges on Cadmium fertilisers in Sweden;
- Provision of consumer information in France;
- Wastewater Tax in Germany;
- UK code of practice for the Dentist sector to reduce discharges of mercury to the sewerage system;
- Eco-labelling and LAS in Scandinavia;

Source: ICON (2001): Pollutants in urban waste water and sewage sludge,a report for the European Commission DG Environment.

Information on the costs and effectiveness of pollution prevention measures at source is limited by MS and moreover can be expected to vary significantly. The selection of measure or technology to pollution prevention and control will depend on the availability of resources but other aspects concerning perception. Examples of costs from pollution reduction measures are provided below.

Box 2: Targeted Waste Collection in France

This measure constitutes a specific drive and effort by authorities to collect dangerous and harmful waste from homes. While effective in its own terms it is not a long-term solution to the problem of discharges to UWW. It may be effective to deal with continuing risks of contamination from smaller and diffuse sources, and be used in connection with the adoption of a longer-term waste minimisation and collection strategy and public education campaign. One of the first targeted waste collection initiatives carried out in France was in 1989, where 11,500 kg of waste products were collected over 16 days, including solvents, paints, medicines among other waste categories. The costs of one such campaign in Boisset-Gaujac (Gard), conducted in 1994, was estimated at about 12,000 French francs . This consisted of two days of product collection.

Box 3: Costs of reducing mercury content in amalgams

Elements involving extra costs would be installation, maintenance of amalgam separators and training of personnel. On the other hand, there are reduced costs for; (i) special deposition of sludge because of high Hg contents, (ii) treatment and disposal capacity for Hg containing dental waste and (iii) environmental and health impacts of Hg released via sewage and waste.

Lassen et al (2008) concludes that it is clearly indicated that applying high efficiency filters and maintenance requirements is a very cost-effective measure. The costs to reduce one kg Hg is stated as being within the range of 1,400 to 1,800€. The benefits of reduced environmental and health impacts of Hg released from the entire life cycle of amalgam fillings were not assessed in this study. However, they are regarded as being significant.

Lassen, C., Holt Andersen, B., Maag, J., Maxson, P., 2008: Options for reducing mercury use in products and applications, and the fate of mercury already circulating in society, Final Report, September 2008

The following box provides an example of how pollution reduction measures can be effective in reducing discharges.

Box 4: **Awards for Company Innovation in Waste Management and Minimisation**

In 1996, the trophy ADEME "Economic and clean technologies" went to the STEN society, which is a metal finishing company which managed zero cadmium discharges by concentrating the cadmium-containing effluents through evaporation and recovered the metal through electrolysis.

Source: ICON (2001): Pollutants in urban waste water and sewage sludge,a report for the European Commission DG Environment.

Sede and Andersen estimated that if an efficient pollution prevention policy was implemented, the percentage of sludge failing could drop significantly (from 83% down to 25%). However in terms of costs, the difference between a scenario with pollution prevention measures and a scenario without pollution prevention measures was significantly less, and could range from 12% to 14%. This is because the costs of pollution prevention were also considered to be considerably large in comparison with other management options[46] thus offsetting the difference on amounts of sludge affected.

The following Table shows the result of a sensitivity analysis should other pollution measures be implemented, with these affecting the amount of sludge affected (based on the available information on costs from Sede and Andersen and our estimates on the amounts of sludge failing). This sensitivity analysis is given for illustrative purposes only and should take as an indication of the type of benefits that may accrue should the stakeholders decide to implement pollution prevention measures at source. As it can be seen from the Table, the savings will depend on the specific component under consideration but are not expected to exceed 7% of the total costs. However, other measures may be more effective in reducing the sludge failure level (although the costs of such measures will have to be considered against the benefits).

Table 100: Sensitivity to Pollution Prevention Programmes (PPP)

Scenario	Costs per tonne	Notes/Assumptions
PPP	229	Costs of PPP may vary significantly. Costs from Sede and Andersen reflect pre-treatment at industrial site. Only for heavy metals and organic contaminants.
No PPP		
Landspreading	126	Lowest costs taken as PPP will improve quality to minimise treatment costs and application
Incineration	371	Average mono-incineration and co-incineration
Net saving	245	As a result of the PPP now sludge will be applicable to land. Includes internal and external costs
Saving per tonne after PPP	**16**	

[46] The costs of pollution prevention were based on a single study and on average costs; but the same costs applied across a number of different pollutants, i.e. heavy metals and pathogens. Such costs were estimated at around €200/tonne and were based on ion exchange technology.

	Limits on Heavy metals	Limits on OC	% change in volume failing from 25% to 83% but assumes average of 54% fro calculation Assumes that all sludge will be applicable to land which may overestimate the savings.
Sludge to incineration without PPP (tonnes) – Option 2	2,391,858	16,722,805	
Volume of sludge not failing after PPP - Option 2	1,291,603	9,030,315	
Savings from PPP as sludge can be applied to land	21,147,000	147,854,000	
Main assessment costs	309,945,000	2,144,665,000	
As a percentage of totals main assessment	**7%**	**7%**	

9.3 Sensitivity on Unitary costs and benefits

The assumptions on the disposal routes were presented to the consultees and re-visited on the basis of their responses and more information available on the amount of mono-incinerators and co-incinerators. Similarly the disposal options have been chosen on the basis of technology known to data (as further development is uncertain).

Innovation and research is likely to develop overtime that could reduce the costs of treatment to deal with specific pollutants as well as disposal methods increasing the capacity for energy recovery. Such impacts are difficult to model but would suggest that the above estimates could be over-estimates of the total costs. This was highlighted by the consultees.

Sede and Andersen (2002) concluded that the costs of recycling routes and other disposal options were highly sensitive to the type and duration of storage and design capacities respectively. The impacts on internal costs of the routes could vary between ±30% and ±50%[47]. For sensitivity purposes we have assumed a 40% variation on the internal costs of incineration and sludge disposal. The results of our sensitivity analysis are shown in the next Table. This will imply a ±18-19% variation in costs. In relative terms therefore, even significant variation in internal costs may not affect the estimates of the cost from the Options to the same degree but the percentage change is still significant. However, this is not expected to affect the rank of the Options.

Table 101: Sensitivity to changes in unitary internal costs (€2009)

Main assessment			
PV	Option 2	Option 3	Option 4
EU-TOTAL	2,144,665,000	4,493,702,000	7,822,364,000
Annualised Costs	Option 2	Option 3	Option 4
EU-TOTAL	219,730,000	460,398,000	801,433,000
Sensitivity results			
PV	Option 2	Option 3	Option 4
EU-TOTAL (reduction)	1,764,439,000 (-18%)	3,651,475,000 (-19%)	6,406,784,000 (-18%)
Annualised Costs	Option 2	Option 3	Option 4
EU-TOTAL (reduction)	180,774,000 (-18%)	374,108,000 (-19%)	656,401,000 (-18%)

[47] On the other hand, transportation distance were not found to be significant as most of the costs seem to be related to loading and downloading of sludge.

10. Comparison of Options

10.1 Summary of Options

This Section presents a summary of the assessment, based on the assumptions presented above. The aim of the consultation was to refine our assumptions and the input of the stakeholders has been extremely valuable in order to do so.

A problem in order to comparing the options, however, is that the analysis of costs by component does not allow us to aggregate all the individual components to produce a total estimate for the Option. This is because should all the components be implemented together, double-counting will occur. In other words, the treatment plants may opt for incineration and/or landfill only once should the limits be too stringent.

The advantage of a component by component analysis, however, is that it allows the Commission services to account for the difference in costs among the different components and, as a result, make a decision on the individual aspects that may need changing in the Directive. This allows account to be taken of the consultees' varied responses with regard to the difference in impacts from the different aspects under analysis.

A comparison of Options however can be undertaken on the basis of different scenarios concerning specific changes to the Directive:

3. Scenario 1: the highest costs among the different options' components is taken as an indicator of the total costs for the Option. For both Option 2 and Option 3, the most expensive component concerns the new limits on organics, which is the component leading to the greatest costs (although the other component leading to similar magnitude of costs is the limits of PTEs in soil);
4. Scenario 2: the lowest costs among the different options' component is taken as an indicator of the total cost for the Option. This reflects a situation when only quality assurance and monitoring requirements are changed.

The following Table presents a summary of the Options for the above scenarios. As it can be seen, Option 2 and Option 3 are significantly cheaper than Option 4 for both scenarios.

Table 102: Scenario 1 – Summary of Net costs of Options (against Option 1)

PV	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	2,174,438,000	4,540,742,000	7,964,555,000
Annualised Costs	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	222,780,000	465,217,000	816,001,000
PV discounted at 4% covering period from 2010 to 2020			

Table 103: Scenario 2– Summary of Net Costs of Options (against Option 1)

PV	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	8,040,000	48,242,000	7,964,555,000
Annualised Costs	**Option 2**	**Option 3**	**Option 4**
EU-TOTAL	824,000	4,943,000	816,001,000

The following Table sets out the estimates from externalities related to GHG emissions from the different disposal route by Option and Option component (note that such values are included in the figures above). Again, and although the totals cannot be added, the Table shows how the greatest emissions (and hence externalities) are linked to Option 4.

Table 104: GHG Emissions Valuation – Annualised Costs (€2009)

Option Component	PTE in sludge	OC in sludge	PTE in soil	Option 4
Option 2	4,226,000	29,734,000	24,825,000	-
Option 3	58,706,000	60,139,000	53,514,000	-
Option 4	-	-	-	106,117,000

10.2 Interpreting the values and examining trade-offs

The above estimates do not include all impacts however. Importantly, the benefits to the environment and human health from changing the standards and reducing application of sludge to land have not been quantified. This is because the impacts from this are highly uncertain. The environmental and human health impacts have been quantified with regard to the emissions from the alternative routes of disposal and transport impacts. The following Table summarises the impacts valued in this impact assessment for the purpose of interpreting the results of the valuation.

Table 105: Impacts considered and approach

Economic impacts	**Stakeholder**	**Description**	**Quantified?**	**Qualitative assessment when no quantification/other comments**
Costs of alternative disposal	Water and sludge management operators	As sludge recycled will be ended, there will be internal costs from its disposal	Yes	-
Policy implementation and control	Regulators	There will be costs from changing legislation and consultation (not monetised)	No	These are expected to be moderate in comparison with total costs
Benefits/costs if meeting related legislation requirements (e.g. WFD)	Regulators	The total ban is likely to influence positively meeting the objectives of other legislation but may act against other	No	Depends on the level of changes. A ban may compromise objectives of Waste Directive
Loss of use of sludge as a fertiliser and fertiliser replacement costs	Farmers	As sludge is no longer available, they will have to be replaced by fertiliser (this could be organic and/or mineral)	Yes (included under net costs)	On the other hand, recycling is still a viable option to recover phosphorus which is a decreasing resource of the environment.
Loss of agricultural output/crops	Farmers	There could be impacts on crops in the short term and depending on availability of fertiliser as a replacement.	No	Impacts expected to be negligible as based on consultation responses
Environmental impacts				
Environmental benefits from end to application	General public	Impacts on biodiversity, ecosystems, quality of water and groundwater from an end to application.	No	Benefits are highly uncertain – lack of evidence on impacts from recycling
Benefits/costs from alternative routes of disposal including climate change	General public	Impacts from increase in use of landfill and incineration for sludge.	Partly	Values include externalities from air emissions (including energy recovery) but excludes impacts to the environment and human health through emissions to soil and water

Economic impacts	Stakeholder	Description	Quantified?	Qualitative assessment when no quantification/other comments
Social Impacts				
Human health benefits from end to application	General public	Owing to national practices and standards, benefits uncertain due to lack of evidence.	No	As above - Benefits are highly uncertain – lack of evidence on impacts from recycling
Human health from alternative routes of disposal	General public	Values include human health externalities from emissions (including energy recovery)	Yes	-

The main benefits could relate to reduced risk to the environment and human health from application of sludge from Option 2, 3 and 4. In order to make Option 4 cost-beneficial though, the benefits will have to offset the costs of the alternative routes of disposal. Based on the costs calculated, the implicit benefits should be equivalent to around 680 Value of Statistical Life (VOSL) saved[48] over the next 10 years. This is however highly unlikely on the basis of the current evidence.

There may be additional benefits in terms of amenity and public perception from more stringent standards and/or a ban. These are also uncertain however and could not be quantified in this assessment.

Other benefits from the Options include compliance with other legislation, such as the WFD. On the other hand, as highlighted by the consultees, putting restrictions on application that may deter from safe recycling (particularly with regard to Option 4) could work against the principles of the waste hierarchy within the Waste Framework Directive. Such balances need to be considered in order to make an informed decision.

10.3 Concluding Notes

The estimates produced here are subject to many uncertainties and as a result should be only interpreted as an approximation of the costs each option. This is due to uncertainties regarding the amount of sludge affected, disposal options and also the scope of the costs and the uncertainties concerning the unitary values as well as, more importantly, uncertainties concerning the baseline (i.e. percentile distribution of sludge pollutants by MS, level of treatment and background concentrations of heavy metals in soil by MS). The results nonetheless provide an idea about the order of magnitude of these costs. Moreover, they incorporate the information provided through the second consultation and as a result represent the best estimate possible based on the information available. It is important to remember that the following aspects were out of the scope of this study:

- scope of changes to the Directive: current changes include agricultural land use only. Consultees highlighted the fact the Directive should be extended to cover non-agricultural uses such as forestry but also included other industrial sources;
- changes should be consistent with a more general EU policy on soil fertilizers including the new directive on biowaste.

Based on the findings, the Commission may wish to include or exclude specific components from the Options or, alternatively, implement only the least costly components. Based on our analysis and the responses from the consultees, the most costly components appear to be the limits on organic compounds (in particular the limits on PAHs) and those on heavy metals in soil. The component with the smallest cost implications is that for quality assurance and/or increased monitoring (although the costs appear to vary significantly in range). The limits proposed under Option 2 concerning heavy metals in sludge seem to be achievable and most Member State and stakeholder responsdents called for this type of change on the basis

[48] Based on the NewExt values of Value of Statistical life of €1,213,000 (€2009).

that most national standards are already more stringent than the current Directive. As a result the costs of only introducing more stringent limits on PTEs in sludge (at levels such as those in Option 2) appear to be limited.

The above figures do not reflect all costs and benefits. In addition to the unquantifiable reduction in human health and environmental risks from reduced recycling, there may be additional benefits in terms of amenity and public perception from Option 2, 3 and 4. These are highly uncertain, however. One other benefit from Options 2, 3 and 4 is that in some geographical areas they could help meet other EU environmental objectives, such as those for the Water Framework Directive. A total ban, on the other hand, may act against the waste hierarchy set forth in the Waste Directive: this gives priority to the recovery and recycling of waste.

Such trade-offs will have to be borne into consideration in a decision on the revision of the Directive.

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Annex 1: Results of the Consultation

1. Introduction

This report is one of the outputs elaborated for the project "Study on the environmental, economic, and social impacts of the use of sewage sludge on land" (Contract Number: 070307/2008/517358/ETU/G4). It summarises the responses received to the Commission's consultation launched on 17th November 2009 for an eight week period regarding possible revision of the Sewage Sludge Directive 86/278/EEC and impacts from the different options for potential policy change. Responses received up to 26th January have been considered.

This document presents a summary of the responses, including a breakdown by type of stakeholder.

The report does not aim to provide a statistical survey of opinions. The consultants have responded to some comments with a short discussion but this is not intended to present a final view. The consultants do not necessarily agree with all the views expressed.

2. Scope and objectives of consultation

It is important to note that the lack of data led the consultant to make assumptions across the EU that may not always have been appropriate but were based on existing literature and on the 1st consultation on the evidence base. The aims of the consultation were to invite stakeholders to comment on the options and the assumptions undertaken by the consultants in relation to the impact assessment The Commission sought contributions from stakeholders which were structured around some general questions and nearly 20 specific questions.

Respondents were invited to comment if they disagreed with the findings and/or to submit alternative data to support the estimation of benefits and costs of the various policy options.

This report includes a list of respondents and a summary of their responses. These have been used to inform the revision of the Impact Assessment (see the main report), which is also based on discussions at a stakeholder workshop which took place in January 2010 and on other comments. See (see http://circa.europa.eu/Public/irc/env/rev_sewage/home for more information.

3. Facts and figures

A total of 39 responses were received in time to include in this report (more detailed information on respondents is provided in Tables 1 – 3[49]). Some were joint responses from several stakeholders and some originated from different organisations but reiterated the same comments. 14 were received from governmental bodies, 23 from the private sector or from associations with commercial interests, and two were received from non-profit making organisations.

Responses were not received from all the Member States (16 MS out of 27) but European representatives of commercial organisations from the agricultural, water and waste sectors as well as some of their national members were well represented. The highest number of responses originates from Germany, with respondents from the UK and France also providing three or more responses each. Due to the lack of response from certain organisations, the views of respondents described in this report do not necessarily represent the full range of opinions held by stakeholders within certain industrial sectors (i.e. food manufacturers) or societal groups (public citizens, environmental NGOs, etc).

[49] A last minute entry from Austria was received but this was not included here. On the other hand, a look at the response does not seem to entail significant changes to the report.

Some respondents provided general comments whilst others provided detailed responses to the questions and some additional material.

Table 106 Respondents to Public Consultation by Member State

Member State	**Responses received**	**Public authorities**	**Organisations**	**General comments**	**Specific response to 28 questions**
EU-15					
Austria					
Belgium	**2**	☺		☺	☺
Denmark	**2**	☺	☺	☺	
Finland	**1**		☺	☺	☺
France	**3**	☺	☺	☺	☺
Germany	**7**	☺	☺	☺	☺
Greece	**1**	☺		☺	
Ireland					
Italy			☺		
Luxembourg					
Netherlands					
Portugal	**2**	☺	☺	☺	☺
Spain	**1**		☺		
Sweden	**1**			☺	
United Kingdom	**6**	☺	☺	☺	☺
EU-12					
Bulgaria					
Cyprus		☺		☺	
Czech Republic	**2**	☺		☺	
Estonia					
Hungary	**1**	☺		☺	☺
Latvia		☺		☺	
Lithuania		☺		☺	
Malta					
Poland	**1**	☺		☺	
Romania	**1**	☺		☺	
Slovakia					
Slovenia	**1**	☺		☺	☺
EU			☺	☺	☺
Norway			☺	☺	☺

Table 107 Categories of Respondents

Respondent category	Total number	Sub-category	Number
Public authorities	**13**	National authority (MS)	8
		Regional authority (MS-R)	4
		Statutory advisor, agency, public institution (MS-A)	3
Organisations	**24**	International Professional association/federation (EF)	6
		National Professional association/federation (NF)	7
		Company/industry (IS)	8
		Consultancy	1
		Research/academic institute	0
		NGO	1
		Other	1

Table 108 List of respondents

Name	Type	Country
Official organisations		
Ministry of the Environment of the Czech Republic	MS	Czech Republic
Ministry of the environment and spatial planning	MS	Slovenia
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Ministry Environment)	MS	Germany
Ministry of the Environment	MS	Hungary
Hungarian Ministry of Environment	MS	Romania
Danish Ministry of the Environment	MS	Denmark
French Representation of the authorities in Brussels	MS	France
Department of Environment, Food and Rural Affairs (Defra)	MS	UK
Agencia Portugesa do Ambiente (Portugese Environmental Agency)	MS	Portugal
Municipal Enterprise for water and sewage of Patras	MS-R	Greece
Walloon Region Ministry of Agriculture, natural resources and Environment –Soil and waste department – soil protection direction (DGANRE-DSD-DPS)	MS-R	Belgium
Ministry of The Environment, Wasaw	MS-R	Poland
Bavarian Ministry for Environment and Health	MS-R	Germany
Centre for Waste Management	MS-A	Czech republic
OVAM - Flemish Waste Agency	MS-R	Belgium
Commercial organisations		
EUREAU (European Federation of National Associations of Water Suppliers and Waste Water Services)	EF	EU
EULA -European Lime Association	EF	EU
EFAR - European Federation Agricultural Recycling	EF	EU
EWA – European Water Association	EF	EU
CIAA - Confederation of the Food and Drink Industries of the EU	EF	EU
Ecosol (European producers of Linear Alkylbenzene)	EF	EU
FIWA (Finnish Water and Waste Water Works Association)	NF	Finland
Water UK	NF	UK
National Farmers' Union (Part of COPA-COGECA response)	NF	UK
COPA Cogeca - response from National Farmer's Union	NF	UK
DAKOFA (Danish Waste Management)	NF	Denmark

Name	Type	Country
Bundesverband der Deutschen Entsorgungswirtschaft BDE Federation of the German Waste, Water and Raw Material Management Industry	NF	Germany
The German Association of Energy and Water Industries (NDEW)	NF	Germany
3R Consulting	IS	Spain
Kemira	IS	Germany
United Utilities	IS	UK
SUEZ Environment	IS	France
REETRRA Service GmbH	IS	Germany
VEOLIA Environnement Europe Services	IS	France
Thames Water	IS	UK
Reciclamas Multigestão Ambiental S.A., from Águas de Portugal (AdP)	IS	Portugal
Others		
CIWEM (Chartered Institution of Water and Environmental Management)	Other	UK
Ren Aker Ren Mat	NGO	Sweden
Tim Evans Environment	Consultancy	UK

4. Summary of comments

Overall, the report was welcome although some of the respondents did not seem to agree with the options in its current form and have asked for more reasoning behind the selection of the options. Most of the respondents seem to agree that a revision of the Sludge Directive is needed:

> *We believe that the Sludge Directive 86/278/EEC needs an appropriate update for greater public and stakeholder confidence based on proven technological progress. Considering the environmental, social and economical advantages of recycling sewage sludge on land when appropriately treated, the Sludge Directive should be revised so to set standards and requirements that will ensure the public and environment safety without leading to its unnecessary banning (either direct or indirect).*

> *[…]the directive dating from 1986 does not reflect the present state of knowledge and technology.*

> *[…]the Directive is now 23 years old [..] it is thus necessary[…] to revise limit values in order to bring them to the average level of limit values set out in national legislations*

> *Option 1 is not satisfactory […] the current Directive does not properly take into account the distinction between sewage sludge of different quality (for municipal waste, industrial, small stations, etc)*

> *We appreciate a revision of the sludge directive (86/278/EEC) that would reaffirm the relevance of sludge land application and also guarantee a European-wide uniform approach to protect human health and the environment*

Only a few of them advocated for leaving the Directive as it is.

> *Option 1 is by far our preferred approach[...]Option 1 will allow Member States sufficient flexibility in their approach to regulating this activity*

The application of sewage sludge in agriculture based on the implemented system works satisfactorily [..] the most acceptable scenario is Option 1

However a few respondents noted that the revision should be undertaken in the context of other legislation, e.g:

For the moment, we miss a consistent EU policy about soil fertilizers. When we only deal with sewage sludge, the biggest part of fertilisers isn't included by law (like manure). Therefore we really hope this directive could be examend alongside other environmental proposals, for example on soils or on biowaste.

[..] the Sludge Directive, its baseline data and gap analysis needs to be extended to cover all biowaste under a biowaste directive, in order to establish a common set of standards for any biowaste applied to land and thus, to provide an even regulatory playing field and economic fairness.

It needs to be noted, however, that stakeholders' views are reflected clearly in their responses and the opinions vary from no change to a few stating their preference for a ban (e.g. Bavaria's ban on application of sludge on land and one NGO). Some others stated that they disagreed with the Options as they are currently proposed:

The proposals for revising 86/278/EEC are based on old thinking and do not take account of today's environmental priorities.

Most of the respondents seem to agree that Option 2 is the more realistic one. Overall, there is support for Option 2 but some issues have been highlighted (these are discussed below). Only a few respondents were in favour of Option 3 mainly on the basis that the national standards are more stringent than those in Option 2 but with also some shortcomings (e.g. no limits on organics or pathogens in Slovenia). Some respondents noted that Option 5 is unacceptable. Very few are in favour of Option 4.

Some respondents agreed with the data and assumptions used for assessing the impacts from the various policy options which were detailed in the consultation document forwared to them. Others disagreed and provided alternative figures instead. These are summarised by question below and they have been considered in drawing up the final report for this study.

Generally, incineration is not favoured by the consultees and amenity aspects have been highlighted but there are exceptions (e.g. NGO and some UK companies). Some respondents have also highlighted the lack of space for landfilling (e.g. UK); thus some of the estimates may need revising as for the destination of sludge failing. However, respondents seems to agree with sludge recycling hence the objective should be to utilise as much sludge as possible. This explains partially the main support for Option 1 and 2.

Generally, the respondents called for more information on the % applied, calculations and impacts included. Some data in the final report, some percentages have been revisited based on information provided. More specific comments are given below.

5. Summary of responses by component

Scope of the Directive	A call for extending the scope of this new/revised directive to all sludge that could be used on land (i.e. not only from the treatment of urban wastewater but also from pulp/leather/food industries wastewaters).
	Also the application on forestry should be considered.
	Nowadays,sewage sludge has a waste status on European level. If the directive would be changed significant with stringent requirements, which statute will sewage sludge get that meets the limits? Will it become a product? But then the Reachlegislation is applicable!

	The various quality and origin of the sludge should lead to a differential management system based on the classification of sewage sludge (e.g. four classes in the Walloon region), on requirements in term s of soil quality, and on differential traceability system given the origin of the organic material.
Heavy metals in sludge	Some respondents agree with limits proposed in Option 2; other have proposed the ones they have nationally. Other bodies acting across the whole of the EU have proposed the ones presented in the INERIS risk assessment study which are as follow (in mg/kg DS): Cd:10 Cr : 1000 Cu: 1000 Hg: 10 Ni: 300 Pb : 500 Zn : 2500 One other respondent noted that a revision should include more metals, e.g. Sb, Co, Mo and Se; also Arsenic.
Organic contaminants in sludge	There are different opinions with regard to the choice of OC in the Options. Some resposdents have argued that PCBs have legislative source control and PAHs are in decline due to cleaner engines. Oner respondent notes, with regard to LAS and Option 3: *In 2005, the Organization for Economic Cooperation and Development (OECD), approved the SIDS Initial Assessment Report (SIAR) for linear alkylbenzene sulfonate (LAS), concluding that LAS "is low priority for further work", and thus of low regulatory concern. The OECD acceptance of the LAS SIAR represents the culmination of nine years of collaborative efforts in researching, compiling and assessing the scientific information on the health and environmental properties of LAS, carried out by a consortium of 16 detergent and supplier companies, with the US Environmental Protection Agency as the sponsor country for the assessment*
Pathogens	The national regulations are very different when controlling pathogens and the percentages may need revisiting significantly. Some respondents have argued that E. coli is not an accurate indicator and recontaminations during storage may happen, and it will be very difficult to monitor proper sanitisation with this indicator. Others have argued that setting reduction limits is not feasible (as it implies that we can determine an entry value at the upstream treatment sludge process, which is inapplicable in certain sectors (eg lagoon ...). Others however have mentioned that a list of methods should be made available.
Provision of information on nutrients	Respondents did not provide a lot of information on this. However, one respondent noted that these were not stringent enough and proposed that in order provide guarantees to different stakeholders it is necessary to supply the information outlined below: ¾ Sludge analysis: - Agronomical value not less than 4 analysis per annum and at least one per 150t DS. - Heavy metal not less than 2 analyses per annum and at least one per 300t DS. - Organic compounds not less than 2 per annum and at least one per 500t DS. ¾ Soils analysis on agronomical parameter (every five years) and heavy metal (every ten years) per 20 hectares area. ¾ Establishment of a spreading forecast submitted to local authorities validation including: - Sludge and soil analysis. - Identification of the landbank which is going to be spread. - Information about the nutrient quantities spread on each plot of land and integration of other types of fertilisers (i.e. animal manure). ¾ Establishment of a yearly balance report integrating the record of all the data regarding the spreading campaign.

Heavy metals in soil	This is the component that lead to most comments. Many European areas have comparatively high natural concentrations of metals in much of its surface soil with background concentrations of metals already exceeding some of the proposed limits for sludge-treated soil, potentially restricting the land bank available for recycling biosolids in these areas. More data are needed to properly assess the impact of those limit values. A few respondents suggested alternative means like a total load application per annum (Limit values for PTE on the total load brought to the soil by the total quality of sludge spread, in order to limit the quantity of heavy metals spread on land from anthropogenic source) but most of the respondents suggested that flexibility was needed and that this component should be left out on the basis of subsidiarity.
Conditions on application and banning injection of untreated sludge	Here responses also varied significantly; some of the respondents noted that application of untreated sludge in not allowed hence they will not be affected. Others however noted that they could be significantly affected.
Quality and prevention	There was a general support for risk assessment aspects before application (in cases this may be preferred to the limits themselves) but HACCP is not yet widespread across Europe and other quality assurance systems have been highlighted (e.g. Industry in Germany has also sent a Manual on quality requirement and certification processes).

6. Other recommendations

Other recommendations for changes to the Directive and the quality of the IA include:

- reference to Health Risk Assessment by EFAR/INERIS (2007); the European Commission should launch a comprehensive Health Risk Assessment to be carried out by a panel of international experts, with the aim of setting up all limit values (PTE, OC without microbiological parameters);

- the development and implementation of sludge application rules should also be taken into account (e.g. a buffer zone between amended soils and rivers should also be proposed in order to prevent any impact of sludge spreading on the quality of surface waters). Such a double barrier approach will provide very good result as it has been observed in many countries without excessive costs;

- a study should be commissioned to assess markets and consumer confidence;

- authors should consider COST 68/681 programme on the Treatment and use of Sewage Sludge and Liquid Agricultural Wastes ran from 1972-1990. This programme brought together experts across Europe with the aim of developing the science and engineering base for recycling biosolids in agriculture. This work produced almost 1,000 papers and a number of other publications covering all aspects of the recycling options and a re-issuing of this work would certainly be valuable to everybody working in this field and help to provide information relevant to the areas of uncertainty outlined in summary report 1;

- Need to include a description of the benefits from the Options: some of the respondents noted that quantification was needed; however, there is a lack of quantification of benefits owing to the fact that there is not evidence base on any impacts from sludge application;

- a review of the estimated costs for the alternative treatment and disposal options, including additional options to the ones proposed such as thermal treatment;

- a review of alternative outlets and the availability of these for example non-agricultural land, reclamation etc;

- Consider the use of bio-fertilisers and other organic resources rather than conventional fertilisers as a replacement. Consider the Biowaste Directive; and

- highlight the positive aspects of sewage sludge recycling. In that respect nutrients have to be considered (e.g. copper and zinc that are important for plant growth and the soil), but also resources aspects (e.g. phosphorous - the availability of the primary resource is limited to approximately 120 years!) and the humus content of sludge used as organic fertiliser or soil improver. One of our suggestions includes developing a nutrient/pollutant-ratio in order to better recognise the positive impacts of organic fertilisers.

7. Responses to specific questions

The full copy of the responses is available on the CIRCA website http://circa.europa.eu/Public/irc/env/rev_sewage/home.. The responses to the specific questions in the report are summarised below.

Question 1: Do you have any comments on the Options as proposed?

The commercial stakeholders' responses are presented below.

Denmark **Option 2 or 3 seems the most realistic** and benefiting options for sewage sludge on land. More stringent standards will raise the public confidence and acceptance and also meet the standards many member states already adopted. Although stricted standards may be more costly Danish experience shows that it is only a matter of time before the sludge meets the standards and it is at the same levels. **Option 4 will not be in line with the Waste Directive** an also the general costs are too high. *Fertiliser replacement costs between 2010-2020 for Denmark is estimated to be 66m in this 10 years period and not 26m as stated in Table 46).* This is based on calculations of the amount actually used in agriculture, the amount of phosphorus in it and the actual plant uptake and utilisation.
Option 5 is not acceptable as the protection of the environment cannot be guaranteed.

Finland Al anternative treatement is incineration but they are objected on the basis of amenity. Strict limits on heavy metals and organics call for upstream approach. It is not only up to the waste water operators to limit the amount of pollutants entering the system (i.e. industrial sources and household chemicals). Waster water utilities have no opportunity to limit use of chemicals in the households. In case of strict quality criteria more pre-treatment will be demanded. In many cases technology is avilaible but it is expensive. Effect to industry may be considerable.

France The implementation of Option 1 and Option 5 would not lead to significant modifications of the current state of play of sludge management.
Option 4, which would consist in a total ban of sludge return to the soil, would lead to a huge modification and perturbation of sludge disposal in France and Spain where almost 70% of the total sludge national production is currently land spread. The implementation of this option in the 2 countries, and more generally in the EU at large, **does not seem realistic**. Member States indeed do not have sufficient capacities in alternative treatment solutions (incineration or landfill) for such important volumes, which are generally produced on a large number of small wastewater treatment works.
The adoption of options 1 or 5 do not present a sustainable way forward and should not be considered;
• As stated above, a total ban of sludge use on land (option 4) is unacceptable for environmental, technical and economic reasons;
• option 3 is unrealistic since it proposes more stringent values without justification on either environmental or health gains;
• option 2 should be favoured as long as the limit values for all parameters are determined on a scientific and sound basis.
Adoption of option 2 with revisited limit values for all parameters, on the basis of scientific evidences (global risk assessment) and pragmatic compromises.

Germany An option related to the relation of nutrients to heavy metals (phosphorus/Cd-relationship corresponding to mineral phosphorus fertilizers) is also recommended.
The restrictions made for cupper and zinc in Option 3 are from our point of view not comprehensible

and not acceptable.
The impacts on markets of mineral and other natural fertilisers could vary regionally, and could be more important than stated in Table 7.

One comment to the economic impacts in table 6: For **option 3 (significant changes) the impacts for Germany will be more like the impacts of option 4** (total ban). If we will get the stringent limits for copper (400) and zinc (600) in sludge and the strong pathogen standards we believe that most of German waste water treatment plant operators will give up agricultural use and turn to a safe incineration.
Altogether DWA votes for further developing the revision of the sludge directive on the basis of Option 2. It's not clear whether the scope of the options 2 & 3 is extended to non agricultural land. We call for a clarification on the basis of an enlargement of the current scope in order to take into account all the outlets using sludge as a fertiliser on all soils (agriculture, land reclamation, forestry, green areas, and landscapes).

Today in Germany voluntary QA-Systems are applied for about roughly 30% of the sludge recycled to land and we expect this rate to rise strongly during the next years, at least if legislation gives corresponding incentives. In Germany QA-Systems proved that they can provide a major contribution to improve sludge quality and that they are recognised positively by farmers and the food industry who are seeking for more confidence to trust the current practices. **Against the background of these experiences we strongly recommend that a revised sludge directive should take QA-Systems into account.**

Portugal

In Table 6 row Option 2 –"soil decontamination" (+) should be included under Economic Impacts
"Environmental benefits from reduced application" (+) should be included under environmental impacts;
Human health from alternative routes of disposal (+)
In Table 7: "amenity" –column quantified should say yes but highlighy variable but possible to be estimated. For energy recovery – should be yes, could be estimated depending on technology.
Environmental impacts – changes in risk from changes of recycled sludge – quantified yes, there are impacts from soil application
Social - human heal impact – yes – the use of contaminated sludge have an impact in human health.

UK

Some of the options proposed in the report would lead to a huge increase in 'non-compliant' sludge which is at odds with the majority of related Directives[..]Similarly some of the options do not reflect the best use of the beneficial properties within sewage sludge and the part that it can play in sustainable agriculture.
Option 2: We support this option in principle. We do however call for a review of the limit values proposed, specifically the PTE's for soils and organic contaminants
We think the EC could be in breach of the Waste Hierarchy provisions of Article 4 (1) of the Waste Framework Directive[..].Using the current Sludge Directive as a basis, the UK water industry has developed further plans to increase renewable energy generated from sewage sludge as a primary contribution to the climate change mitigation and the Renewable Energy Directive. We are keen to see that any revision to the Sludge Directive continues to support this policy and enables the residual sludge to be used are fertiliser and soil improver
The increasing level of investigation and application of risk assessment techniques has consistently shows that OCs in sludge amended soil have negligible impact on human health or the environment.
Option 2 (Moderate Changes) and Option 3 (Significant Changes) identify that most of the costs (E.g. Enhanced treatment costs, pollution prevention costs) will fall upon the water and sludge management operators. However the water companies and operators are likely to try to pass these costs to farmer users by increases in the prices of the sludge material. Many of the water companies here in the UK are charging farmers for biosolids and some farmers are happy to pay as they value the resource. But if the costs are increased too much then farmers may instead look to other material – as discussed above, in the future there will many other organic resources competing against sludge. Similarly, if there are more additional costs of policy implementation and control for the regulators, they too might try to recover these costs from farmers – e.g. charging farmers to have an environmental permit or licence to spread sludge material. So these costs that might be passed down to farmers also need to be considered and factored into the IA. Although the outcome will still remain the same = less farmers using sludge. "
Options 1 and 2 are the only supportable options. Option 1 is by far the favoured approach. Option 2 has the potential to increase stakeholder confidence in the sludge recycling route. However, the new organics and heavy metals in soil limits presented in this consultation document would need much

further consideration and scientific justification. **Option 3, 4 and 5 are unworkable and inappropriate and should not be considered.**
None of the options mentions odour which is known to be the root-cause of more than 95% of complaints.
The concept of "options" is flawed because it bundles changes together that are not necessarily associated

EU wide federation

Option 4 (ban on sludge recycling on land) would be the worst case: contradiction with the landfill directive, [..] **A total ban within the EU is not a viable possibility**.
Option 5 (repeal), without an other legal framework (Soil Directive e.g.), would be a bad scenario, with possible environmental impacts in countries with no national regulation ; this could lead to a possible loss of confidence on the use of sludge on land, prohibiting the possibility to develop in the future the possibility for recycling sludge
Option 1 ("business as usual") would be a missed meeting: since 1986, new scientific evidences have shown the need for a more accurate framework for sludge use in agriculture (pathogens, etc.), and farmers as the food industry are seeking for more confidence to trust the current practices. An accurate and sound regulation is the basis for developing sludge use on land in climate of confidence among stakeholders.
Option 3 is too expensive, and would be counter-productive with a low share of compliant sludges for a small increase in environmental/human health/soil protection level. We advocate for the abandonment of this option.
Option 2 is more realistic, providing a high protection for environment, human health, crops and soils, while needing reasonable costs. Nevertheless, we call for some modifications in the level of some specific requirements for this option 2.

In table 5, additional costs for increased scope of analyses in monitoring (more parameters as PCDD/PCDF e.g.) have been forgotten in economic impacts for water and sludge management operators.

We don't think that there could be "increased sales from reduced sludge linked to consumer demand" for food/retailers. Consumers are not aware of this issue and look for various labels (organic food, etc.), but the share of these label will concern a minority of cultivated areas, and will not hamper the sludge use in agriculture (e.g. 3-4% of arable land in France).

The more stringent will the requirements for sludges be, the more it will be necessary to get alternative outlets for non-compliant sludges (landfill, incineration plants). This could be in contradiction with the objectives of the landfill directive, and it will require additional treatment capacities (or new plants); this last point has been forgotten in table 5 for social impacts, because it's clear that extension of treatment capacities or new plants will lead to resistance of residents (NIMBY). This is not only a matter of "increased bill" for consumers.

It should be noticed that strict limits for heavy metals and organics call for upstream approach. It is not only up to the waste water operators to limit the amount of pollutants entering the sewer system. Many organics are entering waste water either through industrial sources or household chemicals. Waste water utilities do not have much opportunity to limit use of chemicals in the households.

In case of strict quality criteria for sludge industry will be affected since waste water treatment utilities will demand more pre-treatment for industrial effluents which are allowed to enter sewer system. According to the polluter pays principle, all the costs should be addressed to the original source of pollutant. Effects to industry can be considerable.
Option 2 appears to be the soundest option. However, as studies have shown that the contribution of sludge spreading to land to public health risk is low with regards to its heavy metal content and organic contaminants, we believe the main focus of the new standards should be on pathogen reduction. We therefore would like to suggest the introduction of:

- Classes of treatment for pathogen inactivation with: conventional treatments that have a residual disease risk and which requires a second barrier in the form of cropping and harvesting restrictions and advanced treatments that reduce disease risk to be similar to the soil to which the sludge is applied.
- A requirement not to cause odour nuisance, which is the root cause of most of the complaints about sludge.
- A mandatory quality management and good practice to comply with Hazard Analysis Critical Control Points (HACCP) of the different treatments methods to ensure for the public, safety and

reliability on a long term basis.

Also, any revised values should be set according to a risk based approach.

As already exposed several times before, EFAR is in favour of a potential revision of the directive on sludge land application in order to reaffirm the relevance of this disposal route while increasing the guarantees given to the different stakeholders.

Therefore **options 4 and 5 are not acceptable.** Regarding the options 2 to 4 EFAR maintains that any change in the limit values has to be based on a risk assessment. EFAR regrets that once again this is not the case and that there is no scientific justification to the different set of values mentioned in the scenarios 2 and 3.

Regarding Option 4, the reasons which could lead to a total ban of sludge land application need to be developed. It requires that the alternatives solutions have sufficient capacity to accept the whole sludge production which obviously is not currently possible.

EFAR also wishes that industrial sludges are being incorporated into the impact assessment which is not the case and which could have a significant impact on the final conclusion of the study.

Generally speaking EFAR believes that the different assumptions taken into account into the report are not sufficiently supported and documented particularly regarding the sludge failing rate to the proposed threshold limit values (before and after receiving further treatment).

CIAA thus recommends option 1 as first choice. Option 2 would require comprehensive further analysis of related benefits and costs. CIAA **does not support options 3, 4 and 5**.

[..]**favours Option 2** along the lines suggested in the Report. It is pleased to offer its services and far reaching knowledge base to the Commission in developing more elaborate criteria for the management of sewage sludge on land.

EWA is fully supportive of the practice of recycling sewage sludge to land as a safe and effective fertiliser and soil conditioner. We consider that where practice in accordance with appropriate standards (such as those which have been in place for many years in the UK and other countries), the practice is safe and also represents by far the most sustainable option, particularly in the light of future challenges including climate change and declining phosphate (P) resources.

The EWA agrees with the DWA that not all the disposal routes have been considered and the authors of the report should take account of the use of sludge in landscaping. This is important in a number of EU member countries as is the use of sludge for other land applications such as forestry.

The EWA would like to see more discussion of climate change not just in relation to Green House Gas emissions and energy re-use but also mention of the fact that sludge is an excellent soil conditioner and is absorbent so it could therefore act to reduce moisture loss during drought periods [..] there are issues in relation to heavy metals, organic pollutants and pathogens but contamination with organic pollutants and heavy metals contents have clearly declined substantially in the past two decades. The scientific evidence has not identified the need for statutory controls on organic contaminants at the European level to protect human health and the environment. Source control measures (e.g. REACH and WFD) will continue to have a positive effect on the chemical composition of sludge further reducing the risk of contamination with undesirable substances.
[…] the directive should be include all land-use applications for sludgeincluding for example forestry and land restoration. In reference to incineration the

EWA believes that it is important to distinguish between mono-incineration" and co-

Incineration", mainly because only mono-incineration makes it possible to recover phosphorous, from the ashes. Such recovery is increasingly important and the use of novel processes which also allow for phosphorous recovery such as super wet critical oxidation should be considered.

The EWA also considers that the reports authors should review the use of the term sewage sludge and bio-waste. Although the distinction is made between the two the EWA believes that is it better to use the terms 'bio-solids' and 'wastewater bio-solids' as these better reflect the matter that arises from commercial organic wastes and that from sewage treatment.

EWA considers that where sewage sludge has undergone suitable treatment, there should be no barrier to it being awarded an eco-label. Page 17 of summary document 1 refers to decisions by the Commission that products containing sewage sludge shall not be awarded an eco-label. The EWA considers that the presence of such a barrier discourages the recycling of suitably treated sludge to agriculture. This should be reviewed.

The answers of the official organisations are given below.

Belgium-Wallonia

Option 1 is not satisfactory[..]

Option 2 is not satisfactory but can become suitable provided that is modified [..]

Option 3 is not supported [..]

Option 4 is not supported [..]

Option 5 is satisfactory [..]

Belgium Flanders -

Option 1 and 2 positively evaluated. Option 3, 4 and 5 negatively evaluated. In Flanders, we have an additional limit value for As. Limit values for Sb, Co, Mo and Se are proposed for the near future. Arsenic for example is poisonous, Zinc is 'only' dangerous. Why don't you take into account the addition of some new?

The sludge production in 2008 was 105 kt (Table 8)

In our comments, we haven't made enough nuance between sewage sludge from plants treating domestic or urban waste waters and sewage sludge from the food industry. Sludge from domestic/urban waste waters aren't used anymore in agriculture in the Flemish region since 2006 because they are too heavilly polluted to use on the soil. On the other hand is sludge from the food industry a good fertilizer that can still be used. (nuance to our remarks on option 4)

As a general comment we stated that we miss a consistent EU policy about soil fertilizers. Therefore we advised to examen this revision alongside other environmental proposals. We would like to stress here that we really do not want to propose to 'integrate' several legislations into each other, like melting together the sewage sludge directive with a possible new directive on biowaste.

Denmark

Denmark has set up stringent standards for heavy metals, xenobiotics and the sanitary and treatment requirements. The limit values are based on the precautionary principle, focusing on long term protection of the agricultural soil. Due to the strict limits it is ensured that there will be no accumulation of metals and contaminants in soil due to application of sewage sludge. Like-wise, it is prohibited to use raw sewage sludge for agricultural purposes, and application of sewage sludge is restricted to the degree of treatment.

Option 2 and 3 are the most realistic. Option 4 seem to be in conflict with the waste hierarchy. Option 5 seem to be not a realistic option.

France

It is necessary to recall that the studies carried out in France during many years did not reveal any contamination due to the use of sludge when conducted in accordance with regulation. Although sludge contains many traces of unwanted compounds, exposure risks are in most cases known and considered as very low or negligible. A revision of Directive 86/278/EEC should it take place should therefore be based on scientific risk analysis.
Regarding the various "options" included in the report, France questions the criteria that led to retain PCDD / F (dioxins and furans), LAS (Linear Alkyl Sulfonates) and NPE (Nonyl-Phenols ethoxylates) as relevant substances as well as the assessments and assumptions used to define the proposed quality standards. The same questions concern the assumptions and

criteria leading to the development of quality standards relating to the suitability for land application.

c) Options 3 (major changes to the Directive) and 4 (ban on use) lead either explicitly or implicitly to the inability to develop the agricultural usage of sludge. This hypothesis is currently not possible for France. It results in a reduction of the possibilities to dispose of sewage sludge and actually leads to promote incineration as a method of treating these materials as the introduction of the landfill directive restricts admission to discharge of biodegradable waste. This is not an option for France on the commitments made at the Grenelle de l'Environnement.

d) Option 2 (limited changes to the Directive) would lead to adopt quality limits for sludge similar to those of the current regulations in France. The impact of changes in concentrations of metallic elements determining soil suitability for land application could not be determined because of the time needed to carry out the study. At first glance, some proposed values are however in the lower range of those known to the French soil and would lead to strongly penalise the agricultural sector.

Czech Republic

Prefers Option 2. In the case of approval of Option 2 there would be no the impacts on sludge recycled to land in the Czech Republic, the limits given by Czech legislation are more stringent than these proposed in Option 2. The increase of operational costs would not be significant; it would apply only to the costs of PAH determination.

The new suggested limits from Option 2 are from our point of view very moderate and for the Czech Republic does not means change. Different situation is with the limits on organic compounds. The Czech Republic has only one legislative limit for PCB (0,6 mg/kg) concerning to organics polutants. This issue should be solved widely because it is not obvious which organics and their limits should be observed in the future.

Chapter 4 – Option 3 (significant change) suggests much more stringent standarts than Option 2, but this standarts are closer to the legislative limits valid in the Czech Republic. We compared all new limits in report with our alredy valid limits. New limits according to the report are a little bit stricter at Cr, Cu, Ni and Zn. Stricter limits (especially for Zinc) raise the question, if it would be possible and economic to use the recycling of sewage sludge to agriculture.

We find Option 1,4,5 (of the Consultation report more or less counterproductive. Option 4 is also acommpanied with the highest cost. Therefore we suggest to use for finall review of the sewage sludge Directive the **Option 3, but with corrections** which will allows and retains recycling of sewage sludge on land (better to say on soil) at the present rate.

We would highlight potential extra cost in case of Option 5. For Option 5 the impacts are uncertain. We would hightlight potential extra costs araising from possible contamination of soil by the wrong usage of sewage sludge and from the consecutive remediation of demaged soil.

We highlight extra potential benefits in case if it would be used according to Option 4, but only in the case that European Commission find a some way of subvention for using compost. The ban of using sewage sludge on agricultural and other soil could be a chance for increased usage of the compost that can serve alternative quality fertilizer.

Greece

sludge should be used in forestry

Hungary

The application of sewage sludge in agriculture based on the implemented system works satisfactorily [..] the most acceptable scenario is Option 1.

Comparing all the costs and benefits Hungary is not in favour of modifying the existing legislation

Romania

In the revision process of Directive 86/278/EEC it is necessary to correlate its provisions with the provisions of other EU Directives: Water Framework Directive, Nitrates Directive, Directive 80/68/CEE on ground waters protection against certain hazardous substances and Directive 2006/118/CE on groundwaters protection against pollution and deterioration.

The EU Directives implementation has particular features for each Member State. In Romania, 55% of whole territory is declared as vulnerable zone at pollution with nitrates from agriculture activities. Thus, the use of sewage sludge with high nutrients content is restricted to the land of farms.

For the recycling of sewage sludge in agriculture, it is necessary a more complex knowledge of its composition, taking into account more advanced sampling and monitoring of sewage sludge for waste water operators. Those aspects can encourage the farmers in spreading sludge on land. In the process of waste water infrastructure development from Romania, there were noticed difficulties in farmer's perception regarding the use of sewage sludge.

Regarding the "Application conditions" Romania considers relevant the restriction of sewage sludge application in certain crops (fruits, vegetables) in order to prevent possible diseases among population.

Option 2 application will contribute to correlation with the provisions of other EU Directives (Water Framework Directive, Nitrates Directive, Directive 80/68/CEE on groundwaters protection against certain hazardous substances and Directive 2006/118/CE on groundwaters protection against pollution and deterioration). In this respect, the elaboration of a guide with good practice in sewage sludge recycling is necessary. The implementation of option 2 will have a moderate impact in Romania.

Option 3 involves high costs and big efforts for Romania, especially in endowment with high performance sludge treatment technologies, laboratory equipment and personal training.

Slovenia

In generally Slovenia has already set the most stringent restrictions on concentrations of heavy metals in sewage sludge for the use on agriculture land as proposed in Option 2 and even more stringent than in Option 3 (except for Zn in Option 3), wherein the estimated concentration of heavy metals are standardized on 30% organic matter. Slovenia has also set limits for heavy metals contents based on soil conditions as shown in the following table- table 1 (representative soil sample with pH between 6 and 7)

Table 1: Limit concentrations for heavy metals in soil

PTE	Soil (mg/kg DM)
Cd	1
Cr	100
Cu	60
Hg	0,8
Ni	50
Pb	85
Zn	200

The limit concentrations for heavy metals based on soil conditions are almost as stringent as proposed in Option 3. The analysis of recycled sludge must be carried out every six months or in distinct cases even more frequently. The analysis of soil on which the sludge should be implicated should be carried out, as well.

On the other hand Slovenia has not set any limits for organics either pathogens.

In Slovenia, 2007 approximately 25% of sewage sludge was exported for incineration due to the fact that Slovenia does not have any thermal treatment plant. Almost a half of produced sewage sludge was disposed to landfills. After July 15th 2009 there is a ban to dispose untreated waste and sewage sludge. Due to the stricter waste acceptance criteria for landfilling such as the total organic carbon content of less than 18% DM and the calorific value less than 6 MJ/kg the landfilling of sewage sludge will decrease.

The agricultural use is almost inexistent due to the low quality of sewage sludge due to high content of PTEs in sludge, especially zinc, copper, chromium and lead. The available arable land in Slovenia is limited to 36% as 60% of the country is covered with forests and woods. Application of sewage sludge in forestry is prohibited. Composting of dehydrated sewage sludge in Slovenia is most often performed in combination with biodegradable municipal waste and other structural materials. Composted sewage sludge is used in non-agricultural applications: for recultivation of closed landfill sites and land reclamation of degraded areas, public parks maintenance and other similar locations.

Germany	Option 1: do-nothing: keeping the Directive as it is; A revision of the sewage sludge directive with more stringent requirements would greatly contribute to establishing the stakeholder's confidence in agri-cultural sludge use. Option 2: introduce certain more stringent standards, especially for heavy metals, standards for some organics and pathogens, and more stringent requirements on the application, sampling and monitoring of sludge; In Germany the levels of pollutants in sewage sludge are far lower than existing legislation demands [..]This has been achieved by a number of measures such as minimising pollutants at the source. The proposed limits in option 2 would result in acceptable costs and also provide a high level of protection of the environment, human health and water and soil. **A revised directive based on option 2 seems the best option in every respect.** Option 3: In Germany the more stringent standards as described in option 3 would result in an extremely low amount of compliant sewage sludge in the range of about 10-20% at the most. As the necessary treatment if it is even possible would be extremely expensive and a probable result would be a de facto ban on sludge application resulting in incineration for all sludge. German legislation is quite prohibitive compared to a number of other EU member states so I would expect the impact to be similar in quite a few of these. The gain compared to option 2 seems small. The possibly slightly higher level of protection of the environment, human health and soil protection cannot compensate the EU-wide doubling of the costs. Option 4: total ban on the use of sludge on land; A total ban on the use of sludge on land would have a number of negative consequences without discernable advantages. As the report shows there would be a formidable economic impact. Further negative consequences are a reduction of recycling (organic matter, plant nutrients) and as a result long term sustainability, considerably higher GHG emissions and probable negative impact on the implementation of the landfill directive. The high costs of a total ban coupled with negative environmental impacts without discernable advantages rule out this option. Option 5: repeal of the Directive. **The repeal of the directive cannot be an option** as the possible risks if a member state has no legislation at all in place can not be quantified, i.e. use of untreated sludge from industry could have grave environmental consequences. A further assessment of this option does not seem necessary.
Germany - Bavaria	**The study does not consider sufficiently the drawbacks and risk of the use of agricultural use of sewage sludge**. When looking at incineration of sewage sludge though, mainly the negative and hardly the positive aspects are considered. A considerable deficit of this study lies in the fact that the environmental and human health benefits of a reduced use or rather ban of the use of sewage sludge are not quantified. In accordance with the Bavarian goal for a phase out of the use of sewage sludge on agricultural land, the precautionary principle should be accommodated with respect to the protection of water bodies, soil and consumers.
Poland	Existing legislation in Poland is stricter than Option 1; so this Option will ensure stability. Option 2 will increase expenses on sludge management. The objectives of the Polish plan is to extend sludge thermally treated. However, this is expensive. Option 3 will have adverse effect. Option 4 is not acceptable and Option 5 should be completely rejected. The benefits should include the impact of quality of water resources.
UK	- **Option 1 remains viable** in that it provides minimum standards and that member states are at liberty to adopt higher standards. However, as noted above, revisions to domestic standards relating to heavy metals and pathogens are under consideration at Defra and it may well be appropriate to consider updating certain standards. It should be recognised that doing nothing may generate impacts, for example in terms of the confidence of food purchasers. **- Option 2 provides an opportunity to consider updating standards but this should be on the basis of standards justified by sound evidence and experience and proposed only where necessary to protect human health and the environment.** It is not immediately clear that wholesale redrafting of the Directive would be appropriate in order to reinforce confidence in the use of sludge on agricultural land. - Option 3 envisages 'more stringent standards' across all substances and a 'ban on application of sludge to some crops'. **It is not clear why option 3 is necessary.** The notion of 'more' or 'less' stringent is irrelevant if any fresh standards are to be justified by the

evidence – they are either necessary or they are not. The same applies to the proposition of a ban on application to some crops although we are aware of no evidence which would justify such an approach.

- **Option 4, total ban, is wholly unsustainable from a UK point of view.** Such an approach would be the cause of major and disproportionate costs, and disruptive to the water industry and its customers. There is no justification for such a course of action.

- Option 5, repeal of the directive. Although it is possible for member states to make their own arrangements, **repeal would probably counterproductive in that the confidence of food purchasers could be damaged such that the route for recycling could be undermined.**

The answer of the NGOs are summarised in the next Table.

Sweden

EFSA has in a report from 2009 concluded that the cadmium load on the kidneys of people has to be *decreased*. The supply of cadmium has to be kept on the lowest possible level. As all sewage sludge is relatively highly contaminated by cadmium it should not be spread on agricultural land. That goes for every other fertilizer, that is highly contaminated by cadmium, as well.

Some examples of cadmium content in fertilizers

Humane urine	0,7 mg Cd/ kg Ph
Urine+faeces	10
NPK	3
Swedish sewage sludge 2006 (average)	37

An alternative way to handle the sludge is incineration, which is a growing trend in EU. By incineration you get energy and the possibility to extract a clean fraction of phosphorus.

Our organisation ”Ren Åker – Ren Mat” (“Clean Land – Clean food”) will strongly emphasize that the disposal of sewage sludge on land should be prohibited

Questions 2 – 10: Impacts from Option 2

Question 2- Would your MS be affected by any of the components considered under Option 2?

The commercial stakeholders’ responses are presented below.

Germany

The threshold values are high enough for giving an sufficient opportunity for implementing quality assurance system with quality standards for different sewage sludge types. It is also possible to set individual standards on member states level with take into account improving of sewage sludge by waste water control systems, better processing and quality control of the sludge. Moreover individual standards can be set and gives an approbate option for improving sewage sludge step by step for an good agricultural use

For Germany we think that we will have no bigger impacts by setting the new limits for heavy metals in the sludge. As in many ways Cadmium is surly most relevant for both, environmental protection and human health, DWA would advocate for further reduction to 5 mg/kg. This reduction could be implemented within 5 years after the revised directive comes into force. The same procedure could be intended for mercury (Hg) and lead (Pb) as these substances have a relatively high hazardous potential, too. On the contrary the limit values for copper (Cu) and zinc (Zn) should not be reduced much further as these substances count as micronutients for plants.

It is proposed, that all sludge must be treated by any process that ensures a reduction in Escherichia coli to less than $5*10^5$. According to our data, sludge which is treated by anerobic digestion will meet this standard. Regrettably we have no reliable data for E.Coli **in aerobically digested sludge**. But as E.Coli prefers aerobic conditions we doubt, whether aerobically digested sludge will comply with this requirement. Hence, we suggest that further information should be gathered on this issue or appropriate analysis should be made. If the use of sludge on land should not be hampered seriously, there must be the possibility to recycle **an**aerobically **and aerobically** digested and stabilised sludge without further hygienic treatment. Where appropriate, recycling of this kind of "conventionally treated sludge" can be carried out in combination with certain conditions on application or in combination with QA-Systems.

In this context we'd like to point out, that in Germany about 10.000 wastewater treatment plants are in operation and approximately about 8.000 plants have arobic digestion to stabilise the sludge. Of course these are the "small plants" and the corresponding bulk of sludge is about 20% of the total sludge-mass produced in Germany, which is about 2,2 Mio t DM.

It is proposed, that stabilisation (or pseudostabilisation) should be monitored by using the following methods:

- volatile solid reduction of 38% or
- specific oxygen uptake rate of less than 1,5 mg/h/g total solids.

We clearly support that all sludge recycled to land should be stabilised. To assess the degree of stabilisation there are a number of additional possible indicators. In our opinion it is important that analysis is safe and easy. Therefore we would prefer as indicators the ratio BSB_5/CSB or the ratio dry substance / ignition loss.

Germany As far as Germany is concerned, we believe that we will have no major impacts by setting the new limits for heavy metals in sludge. So we see Germany in line one of table 13, which means that 0 % of sludge recycled to land today will fail the new limits.

Regarding cost calculations **BDE** mainly discovered a problem for hygienisation (standards for pathogens). The report assumes that in Germany 0% of the sludge would need advanced treatment (Table 19). Consequently, the economic impact calculated no costs for hygienisation in Germany. It is true that German standards on good practice ensure a sufficient pathogen control, however, if - besides all - hygienisation would be required, basically all sludge applied to land would need a separate or advanced treatment. A recent study[50] published by our Federal Environment Agency (UBA - Umweltbundesamt) in 2009 indicates the following costs for hygienisation, depending on plant size:

- 207-1.100 € per ton of dry matter (lime hydrate treatment of wet sludge)
- 84-167 € per ton of dry matter (unhydrated lime treatment of dewatered sludge)

As a result, costs for hygienisation - especially with regard to wet sludge - are much higher than those calculated in the report (74-134 €/t DM, page 48). Another source (Schmelz, DWA-Conference 2007) indicates additional expenses of around 40% for obligatory sludge hygienisation. The calculations are based on the assumption that the sludge would then be treated thermally (no direct use on land anymore).

However, assuming costs of in average 200 €/t DM for 592.000 tons of dry matter (Table 8), Germany will face additional expenses of 118 million Euro per year, or even 148 million under the assumption of 250 Euro per ton dry matter. These costs might be slightly reduced considering other impacts estimated in Tables 31 and 32. **BDE** therefore recommends revising the chapter on economic impacts.

France The thresholds of Option 2 concerning heavy metals contenin sludge are very similar to the current French thresholds, and are slightl lower only for Lead and Zinc.

UK Yes, the Uk will be affected by the introduction of organics limits for sludge quality (PAHs) and by the changes to the heavy metal limits in soil.

UK company estimated that 5% of the sludge will not comply. The impacts on the disposal option are not realistic as they assume sufficient landfill (20% failing going to landfill). The only viable option will be incineration, pyrolisis, gasification. *They are very costly and incomplete solutions.*

The authors appear to misunderstand that a greater margin of safety does not represent a reduction in risk. If a limit value gives an acceptable level of risk then increasing the margin of safety by changing the limit value does not make it more 'safe'.

- The limit values for heavy metals in sludge should not be difficult to achieve provided that there is the legal framework and organisation to enforce control of discharges from industrial premises.

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[50]Texte 05/09: "Anforderungen an die Novellierung der Klärschlammverordnung unter besonderer Berücksichtigung von Hygieneparametern", March 2009, in German

- There is no scientific justification for changing the limit values for metals in soils. Results from pot trials have little relevance in testing soil limit values. The long-term field trials in the UK demonstrate that the current limit values protect crops and soil microbial function.
- There is no scientific justification for setting limits for PCBs and PAHs in sludges; to analyse for them routinely would be a waste of money, furthermore project HORIZONTAL has demonstrated that the reproducibility between laboratories is very poor so even when there are limits, the data from laboratories are questionable.
- In principle it would be an improvement to have standards for treatment provided they are sensible.
- Farmers need information on fertiliser replacement value so that they can use sludge to best advantage – this is essential.
- The conditions on application do not need to change, cross-compliance requirements under CAP should be sufficient.
- Monitoring for organic compounds (including dioxins) would be a waste of money. We still need standardised methods that have good reproducibility – HORIZONTAL has failed to produce these. Detailed probabilistic risk assessment has demonstrated that at the concentrations found in sludges there is no need for routine monitoring.

Portugal Yes, of course. The quality of sludge can vary significantly depending of the waste water source and waste water treatment plant (WWTP) lay out. A more restricted limit for heavy metals, organics and pathogen land application will have a big impact on SS management practices and costs, because at present agricultural valorisation and landfill are the only available final destination solutions for sludge, in Portugal. The data of Table 13 are not actual.

EU wide Detailed justifications of the sludge threshold values are required. Half lives of NPE and LAS in soils are of less than 6 months. Inclusion of these compounds into the list of PTE cannot be accepted without explanation. Regarding heavy metals the most important decreases between the scenario 2 and 3 are for chromium, nickel and zinc. As lead is the element which contributes the most to the risk increase EFAR would like to know how the decreasing rates for the different PTE have been determined between the two scenarios.

Regarding pathogens EFAR wants to stress the fact that there has never been a major sanitary crisis linked to sludge landspreading. In some countries like France where there is a specific survey cell very few incident have been reported and the conclusion is that the risk is very low. This has been confirmed by a recent epidemiological study carried ouby the SYPREA (French representative of EFAR) on workers directly in charge of spreading operation. Therefore applying very stringent constraints as the one proposed in option 3 is non sense. The use of E coli and C perfringens as treatment indicators needs to be justified (if C perfringens could be used as composting indicator this is surely not thecase for the other types of sludge treatments). Finally EFAR also believes that pathogens standards have to be defined in term of limit values per quantity of sludge (gram) rather than in percentage of reduction. This is particularly true for industrial sludge like paper or food industries sludges which have to be included in the scope of the directive revision asstated previously.

On the pathogen sensitive issue (more in term of public perception than in term of effective risks) another possibility is to ban at an EU level the landspreading of primary sludge and to leave to member states the choice to set up their own policies. Most of them have already specific disposition in their sludge regulations but unfortunately they are not convergent. Regarding the soil threshold limits EFAR said repeatedly that setting limits on three different classes of ph is totally inapplicable on the ground level. Indeed it is common that soil pH varies from more than one point in the course of an agricultural year. Moreover the set of data proposed are too stringent (even in option 2) and will immediately limit significantly or even practically stop for certain area the use of sludge on land. It is also well known that the major part of the heavy metals soils content is due to natural background level with very low availability rates. EFAR would also like to be informed of the justification of the particular limitation proposed for zinc between option 2 and option 3. Such restrictive value makes finally the option 3 equivalent to option 4!

The risk assessment study carried out by INERIS has demonstrated on the basis of the average levels of heavy metals in soils subject to sludge landspreading (database of 80,000 data provided by EFAR's members) that this activity does not lead to unacceptable risk to human health even using systematically the highest transfer coefficients. For the record the JRC study published in 2004 and which conclusion are obviously used to propose limit values per ph classes was registering only circa 6,000 data.

EFAR therefore proposes to set only two soil ph classes (less than 6 and over 6). For these two classes the soil threshold limit can be adjusted to the 90th percentile of the soil database for ph<6 which will automatically lower the average content of soil in heavy metal and therefore reduce the corresponding risk. On this basis the proposed values are as follow (in mg/kg using Aqua Regia extraction):

	Ph<6	Ph>6
Cd	1	1.5
Cr	100	140
Cu	50	100
Hg	0.5	1
Ni	50	70
Pb	70	100
Zn	150	200

Nutrients in soils: EFAR does not understand the difference between option 2 information only and option 3 nitrate vulnerable zones.

The answers of the official organisations are given below.

Belgium - Wallonia This option is not satisfactory but can become suitable provided that is modified. The main modifications relate to:

- OC: the PAH parameter is different from those we analyse in the Walloon region. The limits do not correspond either. MS should be able to determine the best parameter to analyse given their context. Guidance can be provided by EU but not obligation should be put forward.
- Treatment for pathogens: the conventional treatment proposed is not specified. In practice it will be easier to determine a list of treatments allowed to be used without considering supplementary analysis. The strategy here is to restrict the use and sanitary delay imposition and, if appropriate, a case by case approach.
- The limits proposed in soil for heavy metals should not be linked to pH and this should be taken by each MS given the quality of sludge to be recovered (pH is highly variable throughout the year and space). The limits proposed are similar to those in the region except for Cd which is lower; this would exclude a significant part of our soils due to the industrial history of our region. The limit should be raised to 2mg/kg.
- While setting periods for harvesting a 10 month compulsory will have no impact, the ban would highly impact the current sludge management. Currently liquid sludge can be spread on agricultural soild with restrictions: a storage of 6wk is required prior to spreading, a maximum volume per track,. This ban will affect sludge from small stations and from food processing industries. A ban is not acceptable neither to propose more restrictions on the use of liquid sludge.

Belgium - Flanders We wouldn't be affected at all by option 2. In the report, you mention that we would be affected for organiclimits, pathogens, etc. Please see chapter 'additional data' for a correction on these points

France over 70% of sewage sludge produced in France are valued on agricultural soils, 3 to 5% of the French agricultural area being affected by these practices.

Czech Republic Czech Republic would not be affected by any of the above components of Option 2

Germany Table 3: Some organic pollutants are regulated in German legislation. The wide range of chemicals used in industry and in households nowadays complicates the decision for which contaminants legislation is needed, especially as the only feasible approach is the control of pollutants at the source. A number of aspects must be considered for each substance i.e. toxicity, amounts discharged, persistence in the environment, possible health hazards before deciding whether binding upper limits are necessary. It would also be important to have comparable data for all member states as planned in the FATE-SEES project. In Germany PFT/PFC (perfluorated tensides) and benzo(a)pyren as an indicator substance for PAH will probably be included in the revised German sewage sludge legislation.

In Germany no cases of disease transmission from sewage sludge have been reported. Possible health risks are minimised as the use of sewage sludge in sensitive areas such as fruit or vegetables is prohibited in current legislation. As a result pathogen reduction has not been a major concern in the last two decades. In the revised sludge directive pathogen reduction will play a role. When defining standards for pathogen reduction it must be taken into account that the member states have different approaches and a binding pathogen reduction may result in costs, especially for smaller treatment plants, that render agricultural use of sludge as too costly compared to other options. A study conducted to analyse the imple-mentation of pathogen reduction treatments in Germany and estimate the costs, shows that small treatment plants (approx. 1.000 inhabitants) may have costs up to
59 € per inhabitant and year.

A flexible system combining standards for pathogen reduction with differing possibilities for application would be more appropriate.

Quality assurance systems specifically for sewage sludge have been widely established on a voluntary basis in Germany. As quality assurance leads to higher costs, at least during implementation, incentives for participation are important. In upcoming German sludge legislation quality assurance will be encouraged by easing a number of requirements such as sampling and reporting as proposed in the report. The report does not describe the scope and contents of quality assurance systems in detail but experiences show that again a flexible system is necessary to function well at different sewage treatment plants

Table 5/6:
- Water and sludge management operators will also have higher costs for the higher number of analyses per year and additional organic pollutants.
- Increased sales for food/retailers from reduced sludge use do not seem realistic. Costumer awareness is focused on other aspects, i.e. GMO or regional products.
- At least in Germany further social impacts in form of amenity impacts for incineration and depending on the necessity, the building of new incineration plants are to be expected.

Denmark

The introduction of PCB as a new parameter will affect Denmark in terms of analytical costs. Previous investigations have shown that PCB found in sludge was at a level below the porposed limit.The proposed limit value for zinc is not considered to have any impact because the Danish average level is significantly below the proposed limit.

In table 13 the percentage of recycled sludge failing new limits on heavy metals is 0 % for Denmark, but in table 14 you operate with 40% of sludge failing receiving further treatment and 60% of sludge of failing going to in-cineration with energy recovery. If zero percent of the sludge is failing (table 13), how is it then possible to operate with 40% and 60% in table 14?

Concerning table 25 it is difficult to see how the different costs have been calculated on the basis of the information in tables 13, 17 and 22. In Denmark's case the recycled sludge failing new limits on heavy metals is zero percent (table 13); the percentage failing new limits on OC is 10% (table 17) and the percentage of failing land will be 0% (table 22 and Q7). On this basis the costs mentioned in table 25 seem excessive. The parameters and the limit values mentioned in this option are very similar to the current Dan-ish legislation.

Romania

The implementation of option 2 will affect Romania in terms of institutional building capacity of environmental institutions and of improvement of sludge management in waste water treatment services.

UK

At table 3 [this table detailed the proposed standards under various options] the standards used are neither consulted nor discussed and cannot be taken as necessarily appropriate to the calculation of impacts. [Under] Option 2, any proposed changes to the limits on heavy metals should be justified by scientific evidence and should focus on soil quality.

Question 3: Do you agree with our estimate of recycled sludge failing the limits on heavy metals and the impacts on disposal and treatment?

The commercial stakeholders' responses are presented below.

UK	UK company estimated that 5% of the sludge will not comply. The impacts on the disposal option are not realistic as they assume sufficient landfill (20% failing going to landfill). The only viable option will be incineration, pyrolisis, gasification. *They are very costly and incomplete solutions.* As with report 1 and 2, comparing average metal values (Table 11 Page 17) is inappropriate because aggregations of internal company site-specific data are misleading and this is even more misleading at national level. Your estimates are almost certainly wrong because it is so long since we had a proper survey and reporting of sludge analysis. Even today, some MS (according to your report AT, SE, EE, MT) have not complied with the reporting requirements of 86/278/EEC. The MS that have reported will not have provided sufficient detail to estimate the amounts of sludge that would fail the limits. The limit values for heavy metals in sludge should not be difficult to achieve provided that there is the legal framework and organisation to enforce control of discharges from industrial premises but some MS do not have these necessities.
Finland	Proposed limits less stringent that in Finland so this Option will not affect the sludge use.at the moment only very small fraction is incinerated. In the future, this situation may change.
France	According to our sludge analysis data bank, out of 1129 heavy metals analyses that comply with the French regulation, only 3 analyses for lead and 1 analysis for zinc would not comply with the thresholds considered in Option 2. If we refer to our internal data bank, the proportion of sludge that would be affected by this parameter threshold would be way under 5% and would not affect more than 1% of french recycled sludge.
Portugal	For Portugal it will be more than 5% and less than 15%
Germany	We agree with the estimates made in the report. Germany will not be concerned by setting the limits for the mentioned organic contaminants.
EU wide	No comment on new thresholds for PTE in sludge since most of the sludge will be compliant with those proposed thresholds. Impacts may vary among MS, but this will concern a low share of sludge quantity. Only few MS, if none, get accurate data to confirm or change the proposed ratio of non compliant sludges proposed in table 13. But it seems to be more or less to reflect reality. What are the "further treatment(s)" in the first column of table 14? Is it economically (and technically) feasible to take into account such alternative treatments? We think that the main routes for non complaints sludges will be incineration and/or landfilling with the proposed share; so the first column would have to be deleted. The estimation of €200/tDM for reduction of PTEs in sludge (p. 19) is probably not an annual cost but an investment cost for the 1st or 2 first years when setting up campaign for industrial PTE discharges in the sewage network. The following years, this cost is falling down. The EWA would argue that there is a case to simplify the controls on PTEs in sludge and sludge-amended soil as concentrations of many of the elements that were important contaminants in sludge in the 1980s have declined below critical risk thresholds. The statutory regime could include Zn and Cu and possibly Cd, but, whilst it would be desirable to monitor other elements (eg Ni, Pb, Cr, Hg) for quality assurance purposes, in Member States where the concentrations in sludge are below risk thresholds, there specific regulation is no longer necessary. The EWA believes therefore believes that the maximum permissible values applied to today in relation to organics and heavy metals are extremely safe and demonstrate that every precaution is being taken.

The answers of the official organisations are given below.

Czech Republic	Czech Republic would not be affected hence 0%
Germany	The proposed heavy metal limits for option 2 will not have a significant impact in Germany, only a small percentage of the sludge will not comply with the limits. The impacts on disposal and treatment (table 19) are unclear and possibly not correct. A sewage sludge failing to comply with legal limits will be incinerated. I do not understand which treatment could lower the heavy metal content apart from mixing it with better sludge, something I would not call a treatment.
Portugal	Decree law 276/2009 of 2nd October establishes limit values for concentration of heavy metals in sludge identical to the limit values indicated in option 2, except for Cd and Hg.
Romania	The Romanian legislation (Ministerial Order no 344/2004 transposes the Directive 86/278/EEC) establishes limits of heavy metals and organic substances in sewage sludge more restrictive that provided by the Directive, so no different impact on disposal and treatment will be expected.
UK	It is not clear why the UK would fail as postulated in table 14 [disposal routes for sludge failing limits on heavy metals as proposed under Option 2].

Question 4: Do you agree with our estimate of recycled sludge failing the limits on OCs and the impacts on disposal and treatment?

The responses of commercial stakeholders are given below.

UK	Same UK company said that 10% of the sludge production will not comply with the OC limits. Disposal other than landfill is the only option. We believe the case for setting OCs has not been made and justified on the basis of sound science. It is likely that the % recycled sludge failing new limits on OC's for the UK of 40% is an underestimate, data from 2007 (Smith and Riddell-Black) suggests the majority of sludge has PAH's greater than the 6 mg/kg limit. We believe that 40% figure for sludge in the UK failing the new organic limits under Option 2 could be an under estimate. We are disappointed that no justification has been provided as to the limits for PAHs and PCBS given in Table 16. Research for Defra indicate that present levels are not of concern. Labs could not measure 6 mgPAH/kgDS or 0.8 mg PCB/kgDS reproducibly in the HORIZONTAL interlaboratory trial. The results from 16 laboratories that analysed a sludge sample ranged from 7.49 to 20.86 mgΣPAH/kgDS, mean 12.3, standard deviation 3.5 mgPAH/kgDS. When experienced laboratories report results like this for an ideal sample it is very unlikely that your estimates are correct because the base data are not comparable.The fact that some MS have chosen to set limits for OCs is no reason to impose them on all MS. For example the basis of the LAS limit in DK has been demonstrated to be wrong and that there was no need for a limit. The other limits are not justified by risk assessment, which as a matter of policy should be the basis for EU legislation [CEC (2000) Communication from The Commission On The Precautionary Principle COM(2000) 1 final Brussels, 2.2.2000].
Finland	At the moment there are no limits in organics. Not possible to make reliable estimates of how limits would affect Finland. New limits will increase amount of analysis and costs. Laboratories do not make these analysis at the moment. PAH is not a suitable parameter to regulate since PAH is mainly formed by incomplete burning and deposition is difficult to control by waste water utilities.
France	For organic pollutants, out of 700 analyses, 2 PAH analyses and 1 PCB analysis would not comply with the Option 2 thresholds. For PAH, we do not have any internal data bank available regarding the 6 new compounds that should be taken into consideration. However, if we refer to the 2002 ASTEE study led on 60 different French waste water treatment plants for 11 different PAH compounds content in sludge, the average value was only of 2,3 +/- 2 ppm on dry matter, to be compared to the proposed threshold of 6. If we refer to our internal data bank and to the ASTEE 2002 study, the proportion of recycled sludge that would be affected is not theoretically null, but remains very low (about 1% ?). A little incertitude remains on PAH due to the global 9 compounds approach of the Option 2. Following the INERIS risk assessment released in 2007 for EFAR, we propose to implement

	limit values only for PAHs and PCBs due to insignificant contribution to global health risk for other OCs (as DEHP, LAS or NPE). For PAHs and PCBs, the following limit values should be: - 2 ppm DM for benzo(a)pyrene (that should be considered separately from other PAHs), - 4 ppm DM for other PAHs, - 0.8 ppm DM for PCBs
Germany	In the current German sludge ordinance, there is no regulation for PAH. Thus we do not have sufficient data for this parameter. But we are quite confident that due to the improvements in sludge quality, which has been achived during the past, most sludges will comply with the proposed limit value. For PCB in Germany there is already a limit value in force which is 0,2 mg/kg for each of six congeners. As most German sludges clearly go below this limit, we expect the new limit $PCB_{(Sum\ of\ 7)}$ will be no major problem. Altogether Germany should not to be too much concerned by setting the proposed limits for the mentioned organic contaminants ($PAH_{(Sum\ of\ 9)}$: 6 mg/kg DM and $PCB_{(Sum\ of\ 7)}$: 0,8 mg/kg).
Portugal	For Portugal it will be more than 30% and less than 50%
EU wide	EFAR suggests setting up limits only for PAH with a maximum of 4 mg/kg DS for the sum of Fluoranthene + Benzo (b) fluoranthene and of 2 mg/kg for benzo (a) pyrene which is the most poisonous. The limits mentioned in the table 15 for France are the specific case of sludge spreading on grassland. For the general case other values are to apply. EFAR is really doubtful with the content of the last § page 20 which could be summarized by " As there were no common view on the OC issue the author has arbitrarily set the limit values mentioned in table 16" !!! Once again EFAR wonders how the different country classes have been set. For example how is Portugal in the same group as Italy and Ireland and not with Greece, Spain, Luxembourg and UK? How the 12% failing rate for the EU 12 has been determined? It's not clear what the 6 mg/kg DM for PAH is covering: is it a limit value for each congener (and which ones?) or is it a limit value for a sum (and the sum of which congeners?). According the answer, the failure ratio will change, and the list of MS not affected might change.

The answers of the official organisations are given below.

Belgium Flanders	We have no legislative limits in organics – please correct!
Czech Republic	Small water treatement plants and small localitites in the Czech republic could comply with the limits proposed in Option 2. In the Decree of the Ministry of Environment of the Czech Republic No. 294/2005 Coll., on the conditions of landfilling of waste and use of waste on surface and below the surface and amendment of Decree No. 383/2001 Coll., on details of waste management are in Table No. 4.1. maximum allowable concentrations of PAHs and PCBs given for wastes (therefore also for sludge), which may not be accepted in a landfill group S-inert waste. The maximum allowable concentrations for PAH is 80 mg/kg and for PCB 1 mg/kg. Further the maximum allowable concentrations for PAH in dry matter of waste, used on surface is 6 mg/kg of dry matter. In the Decree No. 382/2001 Coll., of the Ministry of Environment of the Czech Republic of 17th October 2001, on the conditions for using treated sludge on agricultural land, the value for PCB is determined only, and that is 0.6 mg/kg of dry matter of sludge. The values for PAH are not given. Decree 341/2008 Coll. (Decree on Details of Management of Biologically Degradable Waste) gives concentrations of PCB and PAH for outputs from facilities for recovery of biologically degradable waste. For PCB is limit 0.02 – 0.2 mg/kg of dry matter and for PAH 3 – 6 mg/kg of dry matter.

Germany	As stated in the report we do not believe that the suggested limits for PAH or PCB will have any impact in Germany.
Poland	Table 18 contains incomplete criteria. It should also include other parameters such as Ascaris eggs, Trivhuris SP and Toxocara sp.
Portugal	As far as organic compounds are concerned, Decree law 276/2009 of 2nd October establishes limit values for concentration identical to limit values illustrated in the option 3.
UK	Para 3.2.2 assumes the at OC controls are desirable but it is not clear what the evidence for such an assumption would be.

Question 5: What percentage will be affected by the new limits on pathogens and will receive further treatment? Would this treatment consist of adding lime?

The response of the commercial stakeholders is given below.

UK

The estimate of 40% of sludge failing the conventional standard for pathogens is in our opinion an over estimate. There has been significant work in the UK by Water companies to meet the requirements of the Safe Sludge Matrix (SSM). The standards set in the SSM however remain non-statutory guidance parameters.

The addition of lime to non-compliant sludge represents an option for re-treatment, there are however other options, for example, further digestion, use on alternative outlets or disposal. The addition of lime to 40% of UK sludges would have a significant impact on the carbon footprint of the water industry. Any alternative treatment option would need to be verified to the same levels as the primary treatment source.

The estimate of 40% of sludge affected is likely to be a little high as significant investment in advanced digestion is occurring across the UK.

The reliance upon lime addition as a main treatment process or a 'back-up' process for achieving pathogen compliance is predicted to significantly reduce over the coming 5 years as companies responsible for sludge treatment are aiming to maximise the energy value associated with sludge and moving towards anaerobic digestions as the predominant treatment process.

We think the costs of liming seem rather low. For example we estimate that 22Euro per tds would only cover the material costs, and would not cover impact of labour, power and maintenance. Our estimate (based on Ofwat July Return data) would be closer to £150/tds for lime treatment OPEX.

Option 2 is likely that the suggested limit for PAH at 6 mg/kg dry matter will preclude a significant amount of biosolids from application to soils.

The utilisation of landfill will diminish in the future as either the costs significantly increase (gate fees and escalating landfill tax) or availability becomes an issue, as an example it is suggested that the Southeast of England has only 3 years of landfill life left. It is likely that current incineration capacity will need to be increased to accommodate such volumes of sludge.

The UK water industry treats the large majority of sludge to a conventional standard and the estimated % should be lower, closer to 20%. The reliance on lime stabilisation is one that adds to the carbon foorprint and increasing the mass for transport. As such it is an unsustainable process and one tha the UK water industry is moving away from.

As with organic contaminants, the percentages of sludge that will require additional treatment are almost certainly unreliable. For one thing the point of sampling needs to be defined closely because numbers of organisms enumerated can increase or decrease depending on conditions.

Lime is easy to deploy and is very effective for reducing the numbers of pathogens and has been used for this purpose for centuries but it has two drawbacks a) the treated sludge can be very malodorous and b) lime has a large carbon footprint (it is produced by burning limestone at 825ºC).

The reality of public acceptance is that odour by far the most important consideration, much more than pathogens – not causing odour nuisance should be one of the requirements if the directive is going to be revised.

Finland In Finland advance treatment is required. Thus, it will not affect the use of sludge in agriculture. The percentage of sludge affected will be 0%. Lime treatment is not usual in Finland, majority of sludge is composted. Pathogen reduction is also done by thermal treatment before digestion. In Oulu sludge is treated by Kemicond reduction.

Germany But the new requirements for sanitation /reduction of Escheria coli to less than 5x105 have to be proved also for anaerobic-mesophilic processes, so that we cannot make any statements on these issue. In a worst-case-examination we don´t believe in a 0% sludge rate for Germany affected under these new treatment duty

(question 5), but approximately about 40 %? (Question 5,6)

Today we have no requirements for pathogens in sewage sludge going to agriculture in Germany. Most of the sludge bulk in Germany is treated by mesophilic anerobic digestion. We are relatively sure that digested sludge will meet the suggested standard (less than $5 * 10^5$ colony forming units of E. coli).

On the other hand –as already mentioned above- we are not sure, whether aerobically stabilised sludge can observe the standard. **This is significant for a huge number of smaller wastewater treatment plants in rural areas (in Germany about 8.000 plants!) where usually the sludge is used in agriculture,** mostly as liquid sludge.

France For Escherichia Coli, as this parameter is not analyzed in France, we do not have any reference data on raw product that could help us appreciate the impact of this new parameter and threshold. It can be only mentioned that this threshold would probably mainly affect liquid sludge or pasty sludge for direct land spreading without further treatment (AD, liming or composting). These sludge recycling solutions are less and less frequent in France as they bring about logistic and environmental difficulties (important restrictions on parcels slope and on calendar of use for liquid sludge; odour problems for pasty sludge storage and land spreading).

It is impossible to say that 0% of French recycled sludge would be affected since the E.Coli numeration threshold is not applied in France, and since the “boues hygiénisées” status mentioned in the French regulation is not mandatory.

We can only assume that the implementation of this threshold could affect (in DM proportion) between 5% and 20% of French recycled sludge without having any guaranty on the sanitary risk due to pathogens

Portugal The new Portuguese legislation already establishes new limits for the following organism: E. coli: <1,000/g. Salmonella spp: not detected in 50g.

Almost all WWT in Portugal are not prepared to promote higienisation. Therefore the % of sludge that needs advanced treatment will be much higher than 40%, probably around 90%. Adding lime is one of the simplest ways to obtain the expected results, although plants are not prepared to do so.

EU wide EFAR regrets that his previous comments regarding maximum concentration for pathogens have not been taken into account. Once again for France the limits mentioned are only applicable for hygienezed sludge and for specific uses.

Pathogen controls in the revised Directive could be developed to include different levels of microbiological quality according to treatment status and end use.

Agricultural use of untreated sludge should not be permitted and is no longer regarded as acceptable practice. Waiting periods for sludge treated to eliminate pathogens are unnecessary and would increase the flexibility in end-uses of sludge processed to this standard. Agricultural use of sludge treated to significantly reduce pathogens (but necessarily to eliminate them) coupled with suitable land use restrictions, following the well established multi-barrier approach, is an acceptable and safe practice and should be maintained by the revised Directive.

The answers of the official organisations are given below.

Belgium Flanders	We do have standards on pathogensAdding lime is common used treatment to reduce the risk of pathogens in Flanders
Czech Republic	Waste water treatment plants, which have set up new technologies including hygienization of sludge outputs, produce sewage sludge complying with the limits given in the Czech legal regulation. Waste water treatment plants greater than 100 000 EI are concerned. Treatment consisting of adding lime has been introduced in some Waste water treatment plants after the Decree No. 382/2001 Coll., on the conditions for using treated sludge on agricultural land entered into effect. At present adding lime is decreasing due to the problems with NH3 and problems with homogenization. In final phase the treatment consisting of adding lime did not prove to be suitable treatment of sludge.
Germany	As explained in Q1 Germany has minimised health risks by prohibiting sludge use if risks can be expected, i.e. sludge use in vegetables is not allowed. Normally specific treatments to reduce pathogens are not applied. Anaerobic digestion is the usual procedure, but according to the study this may not reliably achieve standard. Some sewage treatment plants have processes integrated for other reasons that would reduce the amount of pathogens as a side effect, i.e. in some areas the farmers prefer sewage sludge treated with lime.
UK	At 3.2.3 we would draw attention to the use of the SSM in the UK in respect of pathogen standards.
Romania	According with Romanian propose regarding 2020 scenario for the sewage sludge disposal, 30% of sludge will be affected by the new limits on pathogens and will receive further treatment. In principle, this treatment will consist of adding lime.

Question 6: Do you have and can you provide costs data on HACCP? Please provide estimates of the number of staff or time required per installation if feasible.

The responses of the commercial stakeholders are below.

UK

We do not have any specific cost data at this time, however, in order to ensure that we meet the requirements of HACCP we have:-

- trained site staff at all of our wastewater treatment facilities
- created a compliance manager and compliance reporting role within operations to manage this specific requirement
- developed in-house procedures, data collection processes and sampling regimes to ensure we are compliant
- invested in complex digestion and liming processes to ensure compliance
- invested in contingency process to manage non-compliant products
- invested in R&D to understand issues including re-growth/re-activation.

Clearly these actions have significant costs associated with them.

It is estimated that HACCP monitoring is in the region of £5000 - £8,000 per treatment site/year.

Having done a lot of HACCP training and HACCP analysis and plans, I would say that it is impossible to answer this question because it is inadequately defined. However HACCP is the best way to design a process, if it is done honestly and properly. Undertaking HACCP need not take a lot of time. It is the best way to assure and to demonstrate that standards are achieved. If a lot of work is required to bring a works into HACCP it is because it was not doing the job it was supposed to be doing in the first place. For a works that is achieving good treatment without short circuiting, etc. should comply with HACCP easily.

Neither of the suggested measures of stabilisation have proved effective in practice.

Finland

We do not have information about HACCP costs. We are of the opinion that methods and liits of stability measurement should be decided locally since different methods are in place already.

Germany

No experiences and cost data exists to the HACCP processing currently, because it is not carried out yet. A comparable tool might be the voluntary Quality Assurance System (e. g. QLA) that controls the raw materials, the treatment process and the application in agriculture. We welcome the opportunity for implementing quality assurance systems in order to get more transparency in the process and in the quality of the end-product. We calculate just now only for the new quality assurance system of sewage sludge 2- 3EURO/t DM and huge costs for

the demanded additional analyses. Just now we calculate of about 600 €/ analysis (inclusive sampling).
The increased quantity of analysis will bring more than doubling of analysis costs and additional costs for quality assurance – beginning with waste water register testing, process and product control, as well as checking the good agricultural fertilization (question 9).
HACCP is unusual in Germany, hence we can not provide cost data.
As far as we know, HACCP originates from the food industry. For the following aspects, we would like to put for discussion, whether it is wise to try to carry forward the principles of HAACP to sludge recycling:
HACCP is based on **accurate definition of the control points** (measured variables) which correspond with **definite actions** that have to be taken, whenever any discrepancy occurs. In our opinion the whole process of wastewater- and sludge-treatment, as well as sludge recycling does not fit very well into this system, because control points and corresponding actions can not be defined that stringent. To ensure "state-of-the-art" recycling of sludge, we would prefer a Quality Assurance System which is particularly designed according to the complex and often "fuzzy" context of wastewater treatment and sludge recycling. To give an example for such a system, we enclose the "Qualitäts- und Prüfbestimmungen Klärschlamm" of the German QA-System "Qualitätssicherung Landbauliche Abfallverwertung (QLA)" in Annex 1.

France Even if the categories of waste water treatment plant sizes differ in the French regulation and in the Option 2, we can consider that the frequency of analyses required in Option 2 (and option 3) is twice lower than in the current French regulation. In that case, the implementation of Option 2 would not impact the current quality control of land spread sludge in France. By limiting the test duration to 4 days, the approximate cost of practicing this test with the SUEZ ENVIRONNEMENT BIODEC apparatus (equipped with 4 cells of ten liters each) would be about 200 € by sample with a minimal number of 4 samples to be analysed simultaneously. A new apparatus comprising 8 to 10 cells and automatically monitored could allow for a decrease in costs.

EU wide Stability of sludge is difficult to define and different practices and methods are used for this purpose. Nationally, there might be different requirements for stability as well. Thus methods and limits for stability measurements should be decided locally.
There are numerous different quality control methods used in different countries. HACCP is one of them. EUREAU is of the opinion that there should not be any rigid requirement for HACCP in all plants but it should be based on decision in each country how to implement quality control.
As Stated in our general comments, we advocate for flexibility. Flexibility has been a relevant tool in the 1986 directive, and this should be kept as a warranty for success
The EWA would like to ask the authors of the report to review the Quality Assurance Systems (QAS) in Germany and Sweden. In Germany expert organisations from agriculture (VDLUFA) and waste water treatment (DWA) have developed a QAS that now applies to approximately 10% of the sewage sludge used in agriculture. In Sweden a quality assurance system (ReVAQ) has been designed by all stakeholders and it incorporated aspects of the DIN ISO certification standard. This scheme is being rolled out across the country. Quality assurance schemes are also used by some water utilities for example Anglian Water from the UK adopts aspects of the ISO standard and uses them in combination with concepts from the food industry such as Hazard Analysis & Critical Control Points (HACCCP). The EWA has taken the initiative in establishing a task group to determine if it is possible to create a common European QA framework and once complete the organisation is happy to share the findings with the commission.

Portugal Portugal does not have experience in this area

The answers of the official organisations are given below.

Czech Republic No data

Germany As stated in Q1 pathogen reduction has not been a major concern in Germany, as a result HACCP is not applied and no data is available.

Romania Presently, Romania cannot provide costs data on HACCP.

Question 7: What do you expect the % of total agricultural land to be failing to comply on the new limits of heavy metals in soil? Would production be maintained through the application of fertiliser?

The responses of the commercial stakeholders are below.

UK

We estimate a 15% - 65% loss of available land (best case to worst case from 3 years of data). N.B. This does not account for all agricultural land in our region.

In regard to potential loss of production, UK wide the water industry accounts for approximately 5% of all organic manures applied to land, as such, loss of sludge as an alternative is unlikely to impact significantly on food production as farmers would turn to readily available alternatives. The question should perhaps be directed at the lost opportunity to utilise a low carbon, sustainable supply of valuable plant nutrients.

We believe that the data provided by WRc for the UK to be a reasonable estimate of the land not available for biosolids recycling. It is probable that production would be maintained through the application of commercial fertilisers.

The maximum presimissible limts under Option 2 are lower than the current UK ones. However research for Defra shows that immediate changes to permissible soild limits calues for Zinc, Copper and Cadmium are unwarranted at this stage.

While it is likely that production will be maintained through the use of commercial fertilisers, sludge is more sustainable. These are often imported from Europe or beoun and are less sustainable.

There are probably few, if any, MS that can answer this question with any degree of accuracy because few, if any, MS have sufficiently detailed national soil inventories [for all of the elements] with data held in a relational database where it is possible to make multiple compound queries.

High geogenic concentrations of metals in soils seldom coincide, thus, for example, some soils might exceed the new Ni but others exceed the Pb. If a field exceeds a single pH/metal limit it will be excluded from sludge application. For the UK (which has no map for soil-Hg) the percentage of the total agricultural land that would fail almost certainly exceeds 40%.

The long-term, multi-site field trial in England, Scotland and Wales has found that the ceiling soil limits in the UK are adequately protective of crops and soil microorganisms and their functions.

The EU is supposed to be committed to science-based policy; there is no evidence from field trials that the soil limits values need to be changed; pot trials cannot replicate field conditions.

Agricultural production would of course be maintained through the application of fertiliser but the opportunity to conserve and recycle phosphate would be lost, which would be a scandalous dereliction of responsibility. The world's phosphate is being exhausted; EU policy should aim to conserve phosphate. Furthermore, soils would not benefit from the organic matter, nitrogen and trace elements.

Finland

New limits will not affect sludge use in agriculture.

Germany

In Option 2 also the new regulation of soil heavy metal concentrations could have an greater impact of the fertilization of sewage sludge especially on sandy soils as the estimated 10% "failing land rate" for Germany. In east Germany a lot of sandy soils are under cultivation and could be affected by the new soil heavy metal limits. We think that the percentage land considered under Option 2 could be regional much more than the estimated 10%.

We don't have enough data to give an exact answer. As the proposed limits fall clearly below the existing German limits for soils with 5<pH>6 and 6<pH<7, our estimation is that considerably more than 10% of the total agricultural land will not comply with the new limits. We expect this share to be in the range of 25% to 35%.

We do not have a sufficient amount of data available to give an exact answer to this question. But we agree with the estimation made in table 22, which means that about 10 % (or less) of the total agricultural land will not comply with the new limits.

France

Only 2 to 3% of the soils will be affected.

Portugal

The new Portuguese legislation states the same limits mentioned in Table 21. 30% will be correct for Portugal.

EU wide

The proposed limit values on PTE for soil will cause significant impacts on sludge recycling and do not appear to take into consideration:

▫ The EU's complex soil variety.
▫ Natural background values in soil
▫ The difference of behaviour for PTE in soils ; scientific evidence show that PTE from anthropogenic sources (contamination) are more bio-available) than background concentration (geogenic origin) for plant uptake
▫ Thresholds based on risk assessment
▫ The evolution of soil pH with the agricultural practices (liming, fertilising, etc.), the natural microbiological soil activity and the growth of the crop

Due to a possible huge impact of this PTE limit values in soils, we think that it should be the matter for a separate and specific study, aiming at collecting more data on soils per country, and doing a proper assessment of the expected impacts. Most of the stakeholders responding to the consultation are not experts on this issue.

Furthermore, doing comparisons require that methods for analysis should the same or should be similar; but it seems not to be the case, comparing PTE extraction with aquae regia or HF acid.

Such an important issue should not be solved without an accurate assessment (more data, health risk assessment, peer review for soil analysis methods). We consider that the current impact assessment for this issue is not accurate.

Production will be maintained through the application of fertilisers since the farmer will get the same crop yields and incomes, but with a less favourable economic balance (price of fertilisers), and a worse environmental balance (GHG, consumption of natural resources).

The answers of the official organisations are given below.

Belgium Flanders	0%
France	The issue of limits in concentration for metals determining soil suitability for land application will take the following developments. The geochemical background varies greatly from one region to another. It is thus important to be able to waive these limits where appropriate. The French approach of granting an exemption provided that the exceedance is of natural origin and that the metal concerned is neither moving nor bioavailable could be accepted.
Czech Republic	The limits for sludge are stated in the Decree No. 382/2001 so that not to affect the quality of soil. The Decree (see section 1) gives in addition to concentrations of metals also technical conditions for using treated sludge on agricultural land as for example doses, which can be used similarly as fertilizers.
Germany	The limits on heavy metals in soil seem acceptable. As the classification of soil by the pH-value is not normally used in Germany appropriate data to estimate effects is not readily available. Production would be maintained by the application of other fertilisers.
Portugal	In relation to the options 2 and 3, Decree law 276/2009 of 2nd October establishes less restrictive limit values for concentration of heavy metals in soil. It is thus considered that the adoption of limit values for heavy metals established in the option 2 implies significant impacts, namely reduction in terms of percentage of the soil available for sludge application. So being, it is considered that this point requires a more in-depth approach, and that specific soil characteristics of the different Member States are taken into account when establishing limit values.
UK	Evidence is required for the PTE standards set out at table 21.
Romania	The heavy metals concentration in soil from Romania complies with national limits. In Romania, the production will be maintained through the application of fertilizer.

Question 8: What % of total agricultural land do you expect will be affected by Option 2 conditions on application?

UK	This would be limited as the UK already works to the application requirements detailed in the SSM, including the banning of untreated sludge application, harvesting and grazing intervals. The banning of liquid sludge injection would have minor impacts as this practice has already been significantly curtailed by the implementation of the Nitrates Directive and Nitrate Vulnerable zones. This impose extended closed periods for readily available N organic manures It is expected that such a ban will have a negligible effect on the % of total agricultural land in

	the UK. There is really no objective reason to ban injecting untreated sludge and/or liquid sludge into the soil; it is effective, avoids the problem of odour, prevents run-off and is used extensively for manure. If MS chose to do it, that should be a matter for subsidiarity, it does not need to be harmonised across the whole EU.
Finland	All sludge must be treated. This ban is not expected to affect the agricultural use of sludge.
France	Much lower than 30%, elss htan 5% of French soils that receive or could receive sludge.
Germany	It is not clear to us what is meant by "*untreated sludge and/or liquid sludge*". If "untreated" means "not stabilized" this part must be divided from liquid sludge. In Germany it is forbidden to use unstabilised sludge in agriculture. All liquid sludge used in agriculture is stabilized and mostly spread on land and rarely injected into soil.
Portugal	Since most of the WWT have only conventional treatment of sludge, operators will need to invest in higienisation systems to remove pathogens. The costs will be probably much higher. (Table 24) Environmental impacts from reduced application should be changed to comply with the precautionary principle. There are impacts os using sludge in agriculture that must be quantified. The impacts of sludge application should be included with the impacts from incineration and landfill.
EU wide	This percentage is quite variable among EU countries, since untreated sludge will concern the small size and a lot of medium WWTP (< 10,000 p.e.), and thus the rural areas. But for some countries, it could concern a large share of WWTP that won't have the financial capacity to set up more advanced treatment to produce dehydrated sludge. We would like to highlight that requiring the immediate injection in soil for liquid sludge would de facto ban all recycling in mountainous areas (where arable crops are very rare) and large areas where cattle farming and grassland are predominant, since the injection in soil destroys the pasture. Because spreading dehydrated sludge is difficult on grassland, this would get to a huge decline of recycling ratio while requiring dehydrated treatment for incineration as alternative outlet (not to say about the cost of building up new incinerators). As a result, it would be better to set allowable periods for grazing, rather than prohibiting the use of liquid sludge. Figures are at least wrong for France where lot of liquid sludge coming from long term aeration processes is spread on land. Why as for the heavy metal issue is there no column for sludge receiving further treatment? The definition of untreated sludge needs to be given. Does this term refer to primary sludge or also to biological sludge with only aerobic treatment? Considering that untreated sludge is primary sludge and due to the lack of sanitary crisis linked to sludge landspreading EFAR believes that the restrictions proposed page 27 are appropriated. However it is necessary to pay specific attention to sludge landspreading on grassland and forage crops. For these types of crops a compulsory six weeks period between spreading and grazing or harvesting is suitable. This could be limited to three weeks for advanced treated sludge and for sludge direct injection.

The answers of the official organisations are given below.

Belgium Flanders	0% of untreated sludge because this is forbidden by law. We have a lot of liquid sludge from the food and paper industry. This will have an extra costs implication (if it cannot be applied without being injected or immediately worked into the soil)
France	using liquid, untreated sludge has the advantage, for small wastewater treatment plants (it is recalled that France has about 5200 stations handling capacity less than 1000 population equivalent of a total of about 11,800 stations with over 200 population equivalent), to reduce the investment required for sludge treatment while using the nutrient content available in it. The issue of odour is an important component in public acceptance of such usage. Strict usage rules, such as the requirement of rapid burial and the respect of minimum distances between areas of application and houses, implemented in France are an appropriate response to this issue.
Czech Republic	Czech Act No. 185/2001 Coll. on waste states in Section 33 (1) that: A legal entity and a natural person using soil shall be obliged to use **only treated sludge**

taking into account the nutritional requirements of plants, under the conditions stipulated in this Act and an implementing regulation and in accordance with the sludge use program stipulated by the producer of sludge so that the quality of soil and the quality of surface waters and groundwater is not impaired.

Germany The use of untreated sludge is prohibited in Germany. Liquid sludge used in agriculture is stabilized and spread on land. It is very rarely injected into soil. The no relevant amount of land used for agriculture would be affected.

Portugal Decree law 276/2009 of 2nd October already contemplates the conditions indicated in option 2.

Romania In Romania, according to the water management national legislation, the direct discharge of waste water in groundwater is forbidden. Due to this provision, the practice of injecting of untreated sludge and/or liquid sludge into soil is not in operation.

UK At paragraph 3.2.7, it is unclear what evidence there is for the amendment on current restriction on spreading. The UK is considering further controls over the spreading of untreated sludge to land.

Question 9: What are the costs implications of these new monitoring requirements? Please explain (e.g. number of additional FTE, administrative costs, etc.)

UK Option 2: Increased sampling requirements will lead to additional staffing levels (a small number per company, for example 3 staff). Overall this cost is considered modest in comparison to the capital costs identified in the report.

Some additional costs may be more significant, particularly the organic contaminants and pathogens analysis in sludge as these would require new methods and additional sampling requirements e.g. refrigerated vans for pathogens.

It is likely that the sampling requirements will increased staffing levels, with sampling and administration adding a probable 2 FTE posts (per Company) resulting in up to 30 additional posts in the UK. The analysis is likely to be contracted out to a service provider and as such will not impact on FTE's to the Water Companies but increase current opex costs by a suggested 10 fold.

As discussed above, there is no objective reason for monitoring organic compounds and dioxins routinely; it would be a waste of money and have no benefit. If MS chose to do it, that should be a matter for subsidiarity, it does not need to be harmonised across the whole EU.

Regrettably it is delusional to think that the analytical methods produced by CEN/TC 308 [or HORIZONTAL] give results that are reproducible between laboratories as the international interlaboratory evaluation exercises have demonstrated.

Finland The proposal will increase the amount of analysis. OC and dioxins are not analysed at the moment and these analysis would increase the costs. Amount of heavy metals will increase. Micro-organism are followed according to the monitoring plan of the sludge management operator. Amount of analysis will probably increase.

Germany The suggested number of analyses per year is much higher than it is required in Germany today (Heavy metals, AOX and agronomic parameters 2 times per year; Dioxins and PCB every two years). The frequency proposed in is higher and in addition there will be new parameters (PAH, microorganisms). This will considerably increase the costs for sampling and analysis. For example the analysis of Dioxins costs about 500 € per analysis. Usually sludge quality from a certain plant moves within a certain band width that can be recognized by relatively few analyses. Therefore increasing the number of analyses does not automatically lead to a much better knowledge of the sludge quality. Hence, we think the number of analyses should be reduced substantially, particularly with regard to the sludge directive giving a standard for whole Europe. Memberstates still can set up stricter requirements if this seems adequate due to special conditions in the state.

The suggested number of analyses per year is much higher than usual today in Germany. The frequency is higher and we will get some new parameters (pathogens). This will increase the costs for these monitoring requirements.

For example, costs for the analysis of dioxins amount to about 500 € per analysis. According to the valid German sludge ordinance, dioxins in the sludge for use in agriculture must be analyzed every two years, independently of the size of the WWTP.

EU wide It will depend on the current monitoring situation of each country: see appendix on national data.

The answers of the official organisations are given below.

Czech Republic We have no available data.

Germany Compared to current legislation (agronomic parameters and heavy metals twice a year) the necessary number of analysis is far higher. The draft of the revised Ger-man sewage sludge directive requires more analysis, comparable to the proposal, but it is planned to reward participants of quality assurance systems by requiring less analyses per year. The frequency for the organic compounds seems extremely high, in Germany Dioxins and PCB are analysed once every two years and this seems to be sufficient, particularly as the costs are high.

Romania The Romanian legislation (Ministerial Order no 344/2004 transposes the Directive 86/278/EEC) establishes a minimum number of analyses per year higher than monitoring requirements proposed by Option 2, so no cost impact will be expected.

Question 10: Do you agree with our assessment of Option 2? If not, please expand. Feel free to add comments on the benefits and costs from Option 2 as well as any data that could influence the assessment.

UK We suggest that further work is undertaken on the estimated failure rates in order to refine the overall impact assessment. We also suggest alternative treatment/disposal options are considered rather than simply rely on landfill to solve a significant proportion of non-compliant sludge problem as this is not considered realistic or sustainable.

The estimates for non-compliant sludge with more than one parameter exceedance will need to be explored to fully understand the impacts, for example some sludge may fail individual metals and a different sludge may fail the organics limits. The total non-compliant sludge volume could therefore be significantly higher if no overlap assumed (worst case v best case).

We propose the following revisions to refine the risk assessment:

• a separate study on the PTE limit value options and the development of the most appropriate methodology to administer the approach ensuring protection of human health and the environment;

• a review to look at the distribution of low pH soils across Europe as this will be the most significant factor in terms of future landbank availability for option 2 or 3;

• a study to quantify the potential benefits for example a CBA of the different options; and

• an assessment of market and consumer confidence impact

In general the assessment is reasonable. However we consider the benefit of this option to implementation of the Water Framework Directive (WFD) is overstated and unlikely. For example use of biosolids on land is not even considered a risk to meeting the WFD objectives in the recently published River Basin Management Plans in the UK. There are definitely no measures identified in the RBMPs relating to the Sludge Directive.

The total cost of all of Option 2 is estimated in Table 25 at €4.5bn but no evidence has been given for the benefit that would be achieved for this huge investment nor evidence of risk that needs to be reduced.

The “environmental costs (to incineration)” in Table 26 almost certainly do not take account of the fact that sludge is burnt in coal fired power stations in Germany (and possibly other MS) without the power stations complying with the Waste incineration Directive.

Squandering phosphate by burning or landfilling sludge brings forward the day when agricultural production will be phosphate limited and the geopolitical issue of relying on Morocco for supply [e.g. Dery & Anderson (2007) Peak Phosphorus. Energy Bulletin http://energybulletin.net/node/33164 and Vaccari, D. A. Phosphorus Famine: The Threat to Our Food Supply. Scientific American Magazine - June 3, 2009].

The proposed revised soil limit values are the particular issue because, whilst controlling contaminants at source is practicable, there is no means of getting around the distribution of geogenic metals. Unless there is evidence of adverse effects it would be irresponsible and reckless to change the soil metal limits.

Germany In table 27, we are surprised by the huge impact for 2 countries, UK (1.1 – 1.3 billions €) and Spain (0.7 - 0.8 billion €), with some disproportion compared to other countries: e.g. for UK

	and Spain 10 times more than Germany on a €/Mg sludge used in agriculture basis. Those data should be checked.
Finland	Influence in FInalnd is estimated based on the assumption that only 3% of sludge is used in agriculture. This was the case in year 2007 but the use has increased. We suggest that at least 15-20% of sludge generated in Finland in 2020 is assumed to be used in agriculture in the impact assessment.
France	Should the thresholds concerning pathogens (E coli) proposed in Option 2 not become mandatory, the overall impact of Option 2 on the current French legal framework on the use of sludge in agriculture would be very low. It would thus be acceptable for the major stakeholders who want to maintain a high rate of return to soil for sludge of good quality in the future.
Portugal	In our opinion, there weren't considered all the impacts associated with the use of sludge in agricultural valorisation.
EU wide	In table 27, we are surprised by the huge impact for 2 countries, UK (1.1 – 1.3 billions €) and Spain (0.7 - 0.8 billion €), with some disproportion compared to other countries: e.g. for UK 40 times more than Finland on a €/inhabitant basis (20 times vs Belgium, 10 times vs France). Those data should be checked.
EU wide	EFAR would like to understand how the different failing rates have been determined. Is it statistical analysis or expert point of view (if it is who are they?)? It is obviously a mistake to consider that all the sludge disposed by incineration will be treated in facilities with energy recovery equipments. Methodology which has to be applied to answer the question 3 has to be presented other wise how could it be possible to validate the data received in return? The amount of 200 €/t DM is extremely high. Indeed to meet the new quality criteria you will have initially to carry out a network policy to identify the industrial discharges to the sewer. This will generate the main part of the costs. Further actions will then be limited to the control of the pre-treatment effectiveness by a yearly analysis campaign. EFAR would appreciate if EUREAU could comment this figure. It is absolutely necessary to generate here a recapitulative table mentioning clearly what are the impacts of the different restrictions proposed on the tonnages which are currently spread on land. It is also essential to take into account the cumulative impacts (i.e. sludge compliant with heavy metals limit values but failing for pathogens or OC). EFAR wants also to stress that in comparison with the 33 potential impacts listed in table 4 only four are totally integrated and three partially. Taking into account the uncertainties related to the different assumptions it is evident that the conclusions of the impact assessment should be considered with great caution. How can one imagine that it is possible to validate the figures presented in table 25 without a calculation example provided to the reader! It also seems that where there is no data available the costs are supposed to be nil which is surely not the case. Having a look in annex 2 table 55 it appears that the same disposal costs are applied for all of the member states and that the figures are in fact a simple update of the 2002 ones! This approach is not acceptable. EFAR does not understand from where the 320 to 380 million € per year comes from. Indeed economic impacts already represent 450 million € per annum. Moreover is there a link between table 27 and table 25 and 26?

The answers of the official organisations are given below.

Czech Republic	Data provided with different recovery rates – the national decree sets stringent standards so no impacts from Option 2 expected.
Germany	It is noticeable that Spain and the UK bear nearly 70% of the costs for all of the EU-27. This seems quite high and is surprising, especially in comparison to the costs Germany for example will have. It is not possible to understand the basis of calculation with the given information.
Romania	Romania agrees with your assessment.

Questions 11 – 19: Impacts from Option 3

Question 11: Would your MS be affected by any of the above components?

The commercial stakeholders' comments are presented below.

UK

Option 3: The proposed tightening of existing standards and limit values and the introduction of 'new' standards in this option would be 'equivalent to a ban', given the large volumes of sludge impacted (for the small perceived environmental protection benefit). **We advocate the removal of this option**

Option 3 will preclude a significant amount of biosolids from application to soils due to the proposed standards for copper, nickel, PAH, PCDD/F5, LAS6 and NPE7.

Yes, the UK will be affected by the changes to the heavy metal limits and new limits in pathogens. In additiona, it will be affected by the changes to heavy metals in soil and the introduction of organics limits for sludge quality.

All MS would be affected, except possibly NL, which set limits such the sludge use in agriculture is hardly possible in order that farmland would be available for manure.

When sludge is treated to "advanced treatment" status it is essentially free of pathogens and therefore there is no objective reason for restricting the crops on which it can be used.

Finland

See below

Germany

The thresholds for heavy metals content in sewage sludge set in Option 3 are very restricted, and will lead not only to an significant reduction in sewage sludge material use, but to its total ban from use in agriculture.

Due to the fact that zinc and copper are micronutrients it is not comprehensible, why the limits of theses parameters in the sludge are so low. In spite of that, the content for the real pollutants Pb 250 ppm, Cd 5 ppm, Hg 5 ppm) are very high. From our point of view we see a urgent need for clarification!

As described above, we are of the opinion that **Option 3** would be **counter-productive** with a low share of compliant sludges for a small increase in environmental protection level.

We advocate for the abandonment of this option.

All factors considered **BDE** believes that Option 3 will lead to a complete stop of sewage sludge used on land. We found especially the following reasons:

Table 28 includes very strict requirements for heavy metals and **BDE** wonders on which scientific research work these assumptions are based on. Assumptions should be reasonable to represent an option for European sewage sludge management. For instance, we believe lead (Pb), cadmium (Cd) and mercury (Hg) to be relatively high compared to extreme low limiting values for micro-nutrients such as copper (Cu) and zinc (Zn). How does that correspond to each other? Applied to Germany these assumptions would definitely have a higher impact than to half of the sludge, which is given in Table 31, as the German average-value for zinc is already above the limiting value of 600 ppm (713 ppm; Table 12).

The report further estimates that 20% of the land will fail to comply with the new limits for heavy metals in soil (Table 38). **BDE** is familiar with the discussion in Germany as well as a similar approach is used in the revision of the Sewage Sludge Regulation (working document 2007): clay, loam/mud/silt, sand. However, again values given for the micro-nutrient zinc deviate a lot from the German approach. Measurements in the Federal State North Rhine-Westphalia show an average of 67 mg Zn per kg soil and a 90%-percentile of 119 ppm. Population areas with higher density even result to 219 ppm (90%-percentile). In these areas no sewage sludge could be used on land and as a result we believe that above mentioned 20% are underestimated.

Finally, **BDE** doubts that the requirement for hygienisation affects 0% of the German sewage sludge (Table 36). As earlier stated we believe there is no danger by sewage sludge after appropriate treatment and handling according to good practice rules. However, measurements that include

- a 99.99% reduction of *Escherichia coli* to less than $1x19^3$ colony forming units per gram (dry weight) of treated sludge

- no Ascaris ova
- not more that $3x10^3$ spores of *Clostridium perfringens* in a sample of 1 gram
- no *Salmonella spp* in a sample of 50 grams and
- a 99.99% reduction in *Salmonella senftenberg*

will definitely lead to mayor impacts. Furthermore, the HACCP has to be considered. As a result also cost calculations (see calculations given under Q1) should be adjusted.

France Option 3 tresholds concerning heavy metals content in sludge are significantly lower (between 2 times for Cadmium and Mercury and 5/6 times for Zinc and Chromium) than current French thresholds. The overall impact of Option 3 on sludge quality is very high and that it compromises the future of sludge recycling in France and more generally in the European Union.

Portugal Yes. A more restricted limit for heavy metals and rest will compromise the application of sludge. SS will be landfilled.

EU wide EUREAU is of the opinion that Option 3 is too much expensive, and wouldbe counter-productive with a low share of compliant sludges for a small increase in environmental/human health/soil protection level. We advocate for the abandonment of this option.

EFAR refuses to comment this option because the need of such stringent limits is not clearly supported. For simple comment the proposed limit values for zinc (20 mg/kg for ph<7) in soil will immediately declassified more than 90% of the existing land banks! The percentages mentioned in table 38 are totally wrong for information the10th percentile for Zn in our soil database is over 40 mg/kg. The same considerations apply for the PTE limits proposed in sludge for copper and zinc.Table 36 as also to be reviewed because at least for France and Germany there is a significant part of the sludge production which is not achieving the proposed standards for pathogens.

Thus ***ERASM*** doesn't support the proposed limit values for LAS in sludge, as mentioned in option 3 of the report "Environmental, economic and social impacts of the use of sewage sludge on land", developed by prepared by RPA, Milieu Ltd and WRc for the European Commission, DG Environment.

The answers of the official organisations are given below.

Belgium - Wallonia This option is not supported as the conditions are more stringent than for Option 2 and would therefore be far away from an integrated strategy that can be implemented for the management of organic material.

Czech Republic we would be affected by all components mentioned on page 37 of the Consultation report.

Denmark In this option Denmark may be affected by the new limits for copper and zinc in sewage sludge. Danish research has shown that the Danish average level for copper is lower than the proposed limit and for zinc it is about the proposed limit.

The introduction of PCDD/F, an additional limit and the introduction of fur-ther standards for pathogens and advanced treatments may have an impact for Denmark.

The estimated percentage at 50% sludge affected under new treatment seems to be very high. In Denmark there already exist strict requirements about the treatment of sewage sludge and its application on agricultural land.

Romania Option 3 involves high costs and big efforts for Romania, especially in endowment with high performance sludge treatment technologies, laboratory equipment and personal training. In this respect, Romania will not support this option.

UK At table 3 [this table detailed the proposed standards under various options] the standards used are neither consulted nor discussed and cannot be taken as necessarily appropriate to the calculation of impacts.

Question 12: Do you agree with our estimates of sludge failing the limits on heavy metals and the likely percentages receiving further treatment or going for incineration/landfill?

The commercial stakeholders' comments are presented below.

UK	We estimate a minimum of approximately 60% non-compliant sludge (limiting metal typically Zinc) The utilisation of landfill will diminish in the future as either the costs significantly increase (gate fees and escalating landfill tax) or availability becomes an issue, as an example it is suggested that the Southeast of England has only 3 years of landfill life left. It is extremely likely that current incineration capacity will need to be increased to accommodate such volumes of sludge. No. The percentage is likely to be higher for sludge to incineration. Imposing these limits could prevent approximately 42% of the sludge to being recycled to land. There is no incineration capacity for 50% of the UK's sludge. There is neither capacity for landfill. As noted on page 38 the data "are national (weighted) averages so they do not show the effect of different distributions" – the detailed information is simply not available because the EC has not been insisting on reporting and not at this level of detail.
Finland	Chromium, copper and zinc limits are lower that current limits in Finland. Proposed limits on Zn and Cu may be demanding. Heavy metal information is not generally available and thus it is not possible to estimate consequences accurately. Our estimate is that even though most of the sludge will fulfil criteria it is likely that some will fail.
Germany	In spite of the assessment of the report, which estimate for Germany an 50% recycling sludge failing the new limits, we think the quota much higher and near by 100%. We also don´t believe, that 40% of sludge failing limits would receive further treatment. We assume that in these cases the waste water treatment plants decide to incinerate all their sludge directly, if the limit values are fulfilled near by 90% of one parameter already by a few analysis. We guest that also great investment costs for sewage sludg treatment plants would not carried out (Question 12). An evaluation of data from more than 1.800 German waste water treatment plants shows that more than 80% of the plants would fail to comply with the suggested limits. In addition, one has to keep in mind that this share is a computed value. That is to say that for example a sludge with Zn 599 mg/kg passes for the computed share, whereas in practice the operators will need a safety margin of about 20% to cover variability in sludge quality. Therefore we expect that practically no German wastewater treatment plant would continue sludge recycling to land if these limit values come to force. We don't see possibilities to make a further sludge treatment to reduce the amount of heavy metals in the sludge. The only possible way would be to mix different loaded sludges to come to a dilution but from our point of view this is no solution and has to be declined. We are relatively sure that about 100% of German sludge failing the suggested limits on heavy metals will go to incineration. We do not see any possibilities of further sludge treatment to reduce the amount of heavy metals in the sludge. The only possible way is to mix different loaded sludges to come to a dilution; but from our point of view this is no solution and has to be declined.
France	20% of analyses would not comply with the Copper threshold proposed in Option 3, and 40% would not comply with the Zinc threshold. the proportion of sludge that would be affected by this parameter threshold would be of about 50 %, as mentioned in the report. For France, about 30% of samples do not comply with the limit values (estimation). But such percentage is largely due to high "geogenic" concentrations that will be met on large areas (e.g. Trias on the east borderline of the Bassin Parisien). So it means that it will concern more than 30% of national amount because the distances for transportation (in order to find PTE concentrations "complying" with the limit values) will be too expensive, and sludges will be incinerated. Thus an estimation of 50% of sludges that couldn't be used on land is more probable. We propose to use risk assessment methodologies for setting the PTE limit values. In 2008, the INERIS risk assessment released for EFAR concluded that the proposed limit values in CEC 2003 were relevant except for lead, where the limit value should be 500 ppm DM. So there is no need to go further with more stringent limit values, as it would be counter productive for achieving a high level ratio of sludge recycling on land.
Portugal	By year 2012, the % of sludge failing receiving further treatment and % of sludge failing going

	to incineration with energy recovery will be 40% and 60% (instead of 30% and 50%).
EU wide	There's no use to set more stringent PTE limit values in sludges if there are no gain for environmental and/or health reasons proved by a proper risk assessment.

The answers of the official organisations are given below.

Czech Republic	we suppose in case of stricter limit that %of sludge going to incineration with energy recovery will increase and in future will be higher.
Germany	In the study the estimate was that about 50% of the sludge from Germany would fail. It is to be expected, that a higher amount may be affected as about 60 % (Cu) respectively only 20 % (Zn) of the sludge will be able to comply with the proposed values. It is also extremely important not to forget that there will not only be sewage treatment plants with only high values so the 60% and the 20% mentioned above may add up to 70%. All sludge failing would go to incineration, a possible further treatment suitable to extract Cu and Zn from sewage sludge without huge costs does not seem feasible.

Question 13: Do you agree with our estimates of recycled sludge failing the limits on organic contaminants and the impacts on disposal and treatment?

The responses of the commercial stakeholders are below.

UK	The UKWIR organics in sludge report (Sutherland, Comber 2009) estimated that up to 95% of sludge in the UK would be non-compliant (limiting factor typically NP/NPE) It is likely that the % recycled sludge failing new limits on OC's for the UK of 50% is an underestimate, data from 2007 (Smith and Riddell-Black) suggests the majority of sludge has PAH's greater than the 6 mg/kg limit. See detailed comments in Section 2 above. No, we do not agree. Increasing investigation in recent years has not identified ecotoxicological significant of organic contaminants on the soil-plant-water system and in the food chain. The question is fatuous because we have even less information about the concentrations of organic contaminants than we do for metals. There is no evidence to support a requirement for these limits. The cost of monitoring and analysis would be a waste of money because there would be no benefit from the limits. Even asking the question gives strength to the companies selling incinerators and other options that will squander phosphate.
Finland	At the moment there are not limits in Fi. We assume that 50% is a safe approximation. It is possible that the limits will have a dramatic effect to the sludge use in agriculture in Finland.
France	For organic pollutants, PAH and PCB thresholds of Option 3 are the same as those of Option 2 and would not have any significant impact on the rate of compliant sludge. The concentration of organic micro pollutants measured in sludge is low and generally below the proposed thresholds. the proportion of recycled sludge that would be affected by the new parameters and thresholds is low (about 5 % ?), and in any case much lower than the 50% mentioned in the report. We can say that more or less 80 % of French recycled sludge would be affected because the thresholds asked for E.Coli, Salmonella, Ascaris eggs, and Clostridium Perfringens correspond to composted or thermally dried sludge that could eventually qualify for a product status. In this view, we can say that Option 3 is not dealing with a waste status of sludge any more, but rather with a product status, which can currently only be reached by a minority of sludge feedstocks. In that case, since the "boues hygiènisées" status is not mandatory in the current French regulation and is generally not applied, the rate of non-compliant French sludge would not be 0 as it is mentioned in the report, but rather about 80% !
Germany	We are not really sure because there is a lack of data. But we think the estimation given in table 34 might be a realistic scenario.
Portugal	It is possible that % of recycled sludge which may fail the new OC limit will be bigger than 50%
EU wide	Organic harmful compounds have been studied widely. We support that all the possible

limitations to the quality of sludge are based on sound science and risk analyses. So we regret the absence of justification for the specific organics chosen in option 3.

Moreover, we call for strong upstream control with these substances. Both PAH and NPE are substances which are also listed in the Environmental Quality Directive 2008/105. We think that long lasting solution is to limit use of these substances in the first place and thus prevent them entering both into sludge or water courses.

Strict levels for sludge are not a comprehensive solution.

The answers of the official organisations are given below.

Belgium Flanders No, we do not agree. The estimate of the Flemish region is less than 50%

Czech Republic We agree with your estimates.

Germany A number of organic pollutants are listed which are not regularly analysed in Germany, i.e. LAS. In connection with the voluntary quality assurance system benzo(a)pyrene is analysed instead of the PAH. As a result the impact of the new limits cannot be estimated precisely. It could be helpful to await the result of the FATE-SEES project to see the EU wide results and perhaps discuss the chosen pollutants regarding their relevance. In Germany i.e. PFC (perfluorated tensides) are widely discussed and limits for this extremely persistent pollutant seem more important than LAS, especially as a report from the commission to the European parliament (KOM (2009) 230 final) came to the conclusion that at the present there is no evidence that would justify legislative measures at EU level, such as regulatory limit values for LAS in sludge.
The most important aspect is limiting use of extremely toxic and/ or persistent substances and prevent them entering wastewater, water and sewage sludge.

Portugal As far as organic compounds are concerned, Decree law 276/2009 of 2nd October establishes limit values for concentration identical to limit values illustrated in the option 3.

Question 14: What percentage of sludge will be affected by the new limits on pathogens and will receive further treatment? What is the preferred treatment? Please specify the costs of this treatment if possible.

The responses of the commercial stakeholders are presented below.

UK Option 3: We do not have any data on the specific pathogens other than E.coli and Salmonella. The option would require all sludge to be treated to an advanced standard or with full pasteurisation (even the latter may be insufficient for *clostridium perfringens*). We currently treat approximately 13% of our sludge production to an advanced standard. To increase the level of treatment at our remaining sites would require significant investment **>£100M**
The introduction of Option 3 will lead to a figure as high as 70% of sludge that would not be compliant with the proposed standard and therefore require additional treatment. The additional treatment is likely to be advanced digestion, probably thermophilic anaerobic stabilisation and possibly some thermal drying.
The UK water industry currently produces only 24% of its sludge make to an advanced treatement standard (based on the UK Water Industry Sludge Summary) so the estimate that 70% of sludge would be affected is correct. Our company has the capability to produce advance treated sludge at three of our 37 STC wich will increase to eight sites in the period 2010-2015. The preferred treatment to meet new limits on pathogens would be a form of enhanced digestion, e.g. Thermal Hydrolisis Process (THP). We would however question that Table 36 which implies that all sludge in Austria, France, Germany and Holland and Sweden meets the advanced treatment standards set out in 4.2.3 Our understanding is that not all of these countries treat 100% of their sludge to an advanced standard.
There is sense in establishing two classes of treatment on the basis of the level of pathogen inactivation that they achieve: Conventional treatment that is partnered by restrictions on cropping and harvest intervals and Advanced that essentially has no pathogen risk and for which no cropping or harvest interval restrictions need be required. There is no objective

reason to require all sludge to be Advanced treated any more than there is objective reason to require treatment for all manure. The production of manure is at least two orders of magnitude greater than sludge and manure carries a greater pathogen load. Cropping restrictions and intervals to harvest provide an effective barrier to disease transmission.

Finland Only salmonella and E colli are used as parameters. It is important that operators are allowed to decide which technology is used for the treatment as long as results are acceptable.

France For new pathogens parameters integrated in Option 3, as Escherichia Coli,Clostridium Perfringens, Salmonella and Ascaris eggs numeration, we lack internal data enabling us to appreciate the impact of the proposed thresholds as these parameters are not analyzed in France -except for the product status that can be reached by some sludge composts that comply with the French quality standard U44095. We can however underline that these thresholds can be only reached after thermal treatment, as sludge in vessel composting or sludge thermal drying would greatly lower the rate of non-compliance of urban sludge (thermal treatments are currently applied to only 15- 20% of the total French production of sludge).

Germany The preferred treatment in Germany is the mesophilic anaerobic digestion (about 80 % of sludge mass; which is treated by roughly about 20% of the wastewater treatment plants) and simultaneous aerobic digestion (roughly 80% of the wastewater treatment plants; 20% of sludge mass). Normally we have no further treatment to reduce pathogens because there are no requirements in the valid German sludge ordinary. With the usual sludge treatment on WWTP's it will be impossible to meet the suggested limits. Only a few sludges with thermal drying or lime-conditioning may observe the limits. We think that more than 80 % of the German sludges can not meet the limits without additional treatment, hence in Table 36 Germany has to be moved from the first line to the third line (70 % affected).

Costs :

- Thermal treatment of liquid sludge (70 °C, >30 min): Costs: ca. 120 €/Mg DS
- Adding quicklime Costs: ca. 200 €/Mg DS

Portugal The WWTP in Portugal aren't prepared to make advanced treatments to eliminate pathogens. The % of sludge needing additional treatment will be probably be higher than 90% of the global production of Portugal.

EU wide The % reduction is not a relevant method for pathogens since it depends on original concentration in sewage (raw material); furthermore, some methods (e.g. spiked sludges with microorganisms) are complex and expensive (andnot developed in a routine way). A simpler approach to assess advanced treatment should be found.

There are very many criteria for advanced treatment. For practical follow up only very few indicative parameters should be used. Theses parameters should be easy to monitor all over Europe. For example Clostridium Perfringens does not exist in all sludges. Thus it is not suitable as a limit parameter.

The answers of the official organisations are given below.

Czech Republic we expect a little bit less percentage of sludge which will be affected the new limits on pathogens (50%). The preferred treatment of sewage sludge in Czech Republic is anaerobic digestion and sewage sludge composting.

Germany As described in Q5 there are no legal requirements concerning pathogen reduction to date. About 80% of the sewage treatment plants use a mesophilic anaerobic digestion which will not be sufficient to meet the suggested limits. In Table 36 Germany would belong to the member states where 70% (or even more) of the sludge is affected.

Portugal In terms of *Escherichia coli* and *Salmonella* spp, Decree law 276/2009 of 2nd October establishes limit values identical to the limit values indicated in the option 3.

Question 15: What are the costs of HAAP?

The responses of the commercial stakeholders are below.

UK	We do not have any specific cost data at this time It is estimated that HACCP monitoring is in the region of £5,000-8000 per treatment site/year The costs of HACCP depend on how well processes are designed, instrumented and managed. For example, if there is by-pass or short-circuiting, HACCP should identify this and there will be investment to correct the deficiency, but actually the process was not compliant anyway, so is that a cost of HACCP of merely correcting a deficient process? As another example, if the temperature probes in a digester are not working or if they are not being recorded, HACCP would reveal the deficiency and it would have to be corrected, but in the prior condition there was no traceability or record that treatment had been accomplished. If processes are deficient then HACCP should reveal the deficiency, which will have to be corrected, but that is merely correcting a delusion about the treatment. Where processes are designed, instrumented and managed properly HACCP will cost very little.
Finland	Information not available.
Portugal	Nol costs data
EU wide	This information is not available.

Question 16: What do you expect the % of total agricultural land to be failing to comply on the new limits of heavy metals in soil set by Option 3? Would production be maintained through the application of fertiliser?

The responses of the commercial stakeholders are below.

UK	We estimate that >82% of the monitored agricultural land may exceed the proposed metal limits (with Zn being responsible for the majority of this figure). We believe that the WRc estimate of land not available for biosolids applications due to PTE's in the soil, in particular chromium, mercury and zinc levels would be the critical elements. . It is probable that production would be maintained through the application of commercial fertilisers. The soils of England and Wales were sampled on a 5 km square grid, only 7% of samples had <20mgZn_{tot}/kgDS and only 28% of soils had pH>7.0(McGrath, S.P. and Loveland, P.J. (1992) The soil geochemical atlas of England and Wales. Chapman & Hall, London). Clearly, around 70% of soils would fail the pH tiered limit for zinc. The estimates of the land failing are wrong for England and Wales and almost certainly wrong for other MS as well. It is not uncommon to find herbage that is deficient in zinc as regards animal nutrition. Zinc is a very important micronutrient, which plays an important part in soil fertility. One role is in the creation of over 100 enzymes in plants and over 300 in livestock animals and humans. The proposed limits are misguided. As discussed earlier, changes such as those proposed should be considered only where 86/278/EEC has been demonstrated not "to prevent harmful effects on soil, vegetation, animals and man" sufficiently.
Finland	However, consultation report does not indicate what is the standard method for analysing heavy metals.Correlation between used methods in literature and standard methods for proposed limits should be clarified before results can be interpreted correctly.
France	*As this threshold is very low, it leads to the non-compliance of 500 analyses in our internal data bank, and to the elimination of 50% of French soils currently receiving sludge. According to our internal data bank on soils, the proportion of French soils that would be affected by Option 3 thresholds is of about 50%, similar to the rate of non-compliance indicated in the report (40%).*
Germany	As the limit for Zinc is extremely low (20mg/kg DS, maybe a literal mistake?) we guess that the percentage of failing land will be considerably higher than 20%. We are sure that the agricultural production will be maintained trough the application of mainly mineral fertilisers. Because of a lack of data, we cannot give an exact answer to this question. So we agree to the estimation made in table 38 (20 % failing). We are sure that the production will be maintained through the application of mainly mineral fertilisers.

Portugal	40% to Portugal is probably correct. The production will be maintained through the application of fertiliser.
EU wide	This is too stringent. See answer to Q7.

The responses from official organisation are presented below.

Germany	The limits on heavy metals in soil seem acceptable. As the classification of soil by the pH-value is not normally used in Germany appropriate data to estimate effects is not readily available. Production would be maintained by the application of other fertilisers.
Portugal	In relation to the options 2 and 3, Decree law 276/2009 of 2nd October establishes less restrictive limit values for concentration of heavy metals in soil. It is thus considered that the adoption of limit values for heavy metals established in the option 2 implies significant impacts, namely reduction in terms of percentage of the soil available for sludge application. So being, it is considered that this point requires a more in-depth approach, and that specific soil characteristics of the different Member States are taken into account when establishing limit values.

Question 17: What % of total agricultural land do you expect will be affected by application conditions considered under Option 3? What are the costs and implications?

The responses of the commercial stakeholders are presented below.

UK	Option 3: Banning sludge application to grassland would be catastrophic for United Utilities as this accounts for the majority of agricultural landbank in the Northwest of England If biosolids are applied to fruit or vegetable crops it is only a minimal amount and therefore the ban is unlikely to have any significant financial impact. In respect of Section 4.2.7, we are very concerned about proposed ban on use of grassland and salad crops. In some areas in the UK around 20% of biosolids application is through these routes. Some 78% available landbank in these some areas is grassland (unlike other largely arable areas in the UK). A ban would have a severe affect in this area. Restrictions on cropping and harvest intervals are only needed when a second barrier to transmission is required to prevent transmission of harm. In the case of Advanced treated sludge, the pathogen risk has been reduced to ambient, i.e. the risk from the sludge is no greater than the risk from the soil in which the crops are grown, consequently the first barrier (treatment) is all that is required. 86/278/EEC did not include the concept of Advanced treatment but if a revised directive were to include it, there would be no reason to have cropping and harvest interval restrictions when Advanced treated sludge is used.
Finland	According to the Finnish legisltation sludge cannot be used for fruit and vegetables or grassland. Thus this ban will not affect sludge use in Finland.
Germany	This ban will have no consequences for Germany because the application of sludge for fruit and vegetable crops and grassland is already forbidden in Germany.
Portugal	In Portugal, the main crops that use SS are: fruit, vegetable crops and grassland. At least for these crops the fertilising process costs will raise by the ban.

Official organisations' responses are presented below.

Germany	In Germany the application of sewage sludge on fruit, vegetables and grassland is prohibited as procedures for the reduction of pathogens are not compulsory. There would be no additional cost. In the revised sewage sludge directive this may be different; at the moment it is not possible to quantify effects.

Question 18: What are the costs implications of these new monitoring requirements? Please explain (e.g. number of additional FTE, administrative costs, etc.)

The responses of the commercial stakeholders are presented below.

UK	Option 3: Increased sampling requirements will lead to additional staffing levels (a small number per company, for example 3 staff). Overall this cost is considered modest in comparison to the capital costs identified in the report. Some additional costs may be more significant, particularly the organic contaminants and pathogens analysis in sludge as these would require new methods and additional sampling requirements e.g. refrigerated vans for pathogens. Increased sampling requirements will lead to additional staffing levels (a small number per company for example 3 staff). Overall this cost is minimal in comparison to the capital costs identified in the report. The additional analysis costs could be more significant particularly the organic contaminants and pathogens in sludge as these would require new methods and additional sampling requirements (refrigerated vans for pathogens as an example). It is likely that the sampling requirements will increased staffing levels, with sampling and administration adding a probable 2 FTE posts (per Company resulting in up to 30 additional posts in the UK). The analysis is likely to be contracted out to a service provider and as such will not impact on FTE's to the Water Companies but increase current opex costs by up to 10 times. Routine monitoring of organic compounds and dioxins would be a waste of money because at the concentrations present in modern sludges the risk is within acceptable limits. Furthermore the methods of analysis do not give reproducible results. Occasional surveys to check the situation are useful but routine monitoring would be a waste of money, which could be spent better on other things.
Finland	The proposal will increase amount of analysis. Organic analysis is not currently undertaken and they are expensive.
Germany	The proposal would increase the amount of analyses and costs. See answer to Q 9.
Portugal	Advance treatment – to achieve hygienisation by adding lime we need a dosage of 300kg lime/ton DM. Since lime value for money is about €100/t, we have a value of €30/ton DM. This value does not include investment costs. Monitoring costs – each OC set of analysis cots over €1,000/analysis. Other costs like investment costs on additional treatment, microorganism' analysis, sludge transportation and so on must be calculated on a case by case basis. The costs will raise significantly
EU wide	Proposal would increase amount of analyses and costs.

Question 19: Do you agree with our assessment? If not, please expand. Feel free to add comments on the benefits and costs from Option 3

The responses of the commercial stakeholders are below.

UK	We feel that the assessment is reasonable. 4.3 states "Similarly, benefits are expected to be greater." but nowhere have benefits been discussed or monetised. Having less of a hazard is not necessarily a benefit if the concentration (limit value) was already such that the risk was within tolerable limits. The disbenefit to the planet and to future generations of squandering phosphate because of unnecessary restrictions that prevent the recycling of P have not been considered. This is not just a matter of today's fertiliser prices but the fact that the global resource is being exhausted unacceptably rapidly. The objective of the Directive is to control risk; if you are serious about controlling risk you must have quality assurance (QA) so implementing QA is not a cost, it should be there already, where there is no QA (informal or formal) the idea that risks are being controlled effectively is probably a delusion.

The total of Table 40 for EU27 is a cost of €10.56bn, which as discussed above is almost certainly an underestimate, for no apparent benefit (at least no benefit has been monetised) and this to modify a directive that is thought to be a success already.

DEHP is readily biodegradable in a standard OECD test for assessing biodegradation potential. If DEHP is present in soil in a bioavailable state, it will degrade rapidly, it will not accumulate. DEHP has an extremely low water solubility (order of 1 ug/l) and a very high octanol water partition coefficient therefore DEHP will bind very strongly to the organic matter in soil and hence leaching to water or significant uptake by plants or other soil organisms is not expected. Experimental evidence confirms this, it shows that DEHP has a low potential for transfer from soil to both plants and to earthworms. DEHP is virtually non-toxic to mammals. The negative evidence about mammalian toxicity was obtained using very high doses rodents. These effects occur through a mechanism which appears to be rodent specific and not relevant to other mammals: humans are not rodents. A limit value for sludge use in agriculture is not justified.

Some very important uncertainties in the data are listed at the end of 4.3.2. 86/278/EEC is declared to have been successful. Before contemplating investing €10.56bn plus €7bn operating costs these uncertainties should be clarified with objective data at the very least.

Germany	We are not able to assess the assumption for the different costs which a made in the report. It is a very complex issue, that depends very much on the regional situation, the quality of the sludge, the acceptance of the product and the guidelines of the authorities on the basis of the waste water and fertilizer law. With the requirements and limits made in Option 3 we think that in the same extent costs as in Option 4 (total ban) could be calculated.
France	Implementation of Option 3 would thus not impact the current framework of quality control in France, but it would increase the cost of quality control due the greater number of additional parameters to be analyzed. SUEZ ENVIRONNEMENT regrets that the strengthening of limit values and the introduction of new parameters should not be based on sound scientific justification. The benefits of such modifications on health and the environment are therefore questionable, while additional costs are very high. Should the Option 3 thresholds on sludge and soils quality become mandatory: - more than 50% of sludge (and up to 80 % if we consider new pathogens thresholds) would not comply with these thresholds - about 50 % of soils would not comply with the Zinc specific threshold (which is extremely low, probably under the original Zn content of numerous “natural” soils without anthropogenic inflows of Zinc) In these conditions, sludge agricultural recycling (and many agricultural effluents like treated pig slurry) would become impossible to manage. This would lead to a very important loss of organic matter and of sustainable nutrients that are increasingly demanded by European farmers. Making three classes for the pH of soil is not workable due to the changing nature of pH values in soil during any one year (pH can also vary by more than one unit in a short period of time). We believe that PTE limit values in soils are the most sensitive issue, since it could de facto limit sludge use (including those that provide a very high agronomical value as well as harmless sludges) on very large areas all over Europe. This key issue should be described through a more accurate and detailed study for each Member State, with soil databases. Such a study ought to be launched by the European Commission.
Portugal	The report does not consider the advantages in the E associated with sludge incineration with energy recovery and the economic, social and environmental impacts associated to the use of sludge in agricultural valorisation. Both options have positive and negative impacts that should be considered at the same detail.
EU wide	Safe use of sludge should be achieved with reasonable costs. The costs for this option are more or less 10 times higher than costs for option 2 without real (and proved) gain for health and/or environment. This option is non cost effective and has to be abandoned. Advanced treatment methods typically increase energy use at the sludge treatment plant. Hygienisation requires high temperatures and especially in cold climate this is causing both high investment costs but

also increased use of energy for the whole running period of the treatment plant.

The answers of the official organisations are given below.

Czech Republic	In general we agree with changes provided in the assessment.
Germany	As the absolute amounts cannot be judged without more information on the basis of calculation it is neither possible to agree nor disagree. As remarked in Q19 the absolute amounts cannot be judged at this stage. It is to be expected, that an option 3 will be much more expensive than option 2. See also the remarks concerning table 5/6 at the end of Q1.
UK	At section 4, what is the justification for 'more stringent standards' over and above what can be justified on the basis of sound science and the evidence of practical experience and impacts? Para. 4.3.2, the statement that 'there could be benefits in terms of reduced environment (and human health) risks', and later references, is vague in the extreme and does not justify the inclusion of such standards. What are the risks referred to here and how do they play in an evaluation of costs and benefits?

Impacts from Option 4

The responses of the commercial stakeholders are below.

UK	The estimate on percentages going to landfill and incineration are incorrect. A total ban is likely to lead to nearly 100% of the sludge going to incineration in the UK as the landfill route is unsustainable in the longer term. The increased storage of sluge at Sewage Treatment works would also present a public health issue and may give rise to nuisances such as odour and flies.There will be increase transport costs and hence carbon dioxide, road traffic, nosie and other disruptions to local communities and potential environmental damage.The additional costs will be passed on to the consumers. This will have consequences too for metting national targets for recycling and sustainability. The statements "The main benefits relate to reduced risk to the environment and human health from application of sludge" and "There will be benefit from compliance with other legislation, such as the WFD" are fallacious because (a) there is no benefit from reducing risk below that which considered "safe" already and (b) the requirements of the WFD will have to be satisfied irrespective of sludge use in agriculture or any other activities. Combustion facilities that comply with the Waste Incineration Directive (2000/76/EC) do not increase the risk however this is not true for co-combustion in facilities that are not regulated under the WID, such as the coal fired power stations in Germany that burn sludge. The disbenefit of squandering phosphate has not been considered. The climate change impact of landfilling sludge has not been considered or monetised.
Finland	Banning of sludge in agriculture would cause much pressure to find alternative uses. Another uses will demand different treatment facilities and equipment which would increase the costs for waste water utilities and their customers. Incinerators are objected on the basis of amenity. In Finland many incineration plants do not even plan to incinerate sludge due to amenity. Most of the sludge is composted at the moment. In the future use of sludge as a landfill cover will come to an end. It is up to the farmers to decide if they use sludge or not. This Option would reduce their possibilities to choose.
EU wide	No comment on this option without a clear demonstration of its relevance.

Official stakeholders' responses are presented below.

Belgium - Wallonia	This Option is not supported
Belgium Flanders	When no sludge can be used on the land anymore, you do not have to send it to 100% to

	incineration or disposal. You have other treatment like composting and digesting of sludge from food industry! Why did you not take these treatments into account?
UK	Option 4 does not respect the flexibility which we understand it is the intention to preserve and is not regarded as feasible. No further comment is made at this stage. However it should be noted that the costs (table 43) will always affect the general public at every level since they pay water charges and costs will feed through as a consequence of this (and all) options. Overall a more 'joined-up' approach in relation to other EU legislation is to be commended. In relation to the comment at 5.2.3 that consumer confidence is difficult to value, this is nevertheless one of the most important beneficial impacts to be gained.

Impacts from Option 5

The responses of the commercial stakeholders are presented below.

UK	Option 5 is not acceptable as it cannot guarantee protection of the environment. It will have an impact on stakeholders' confidence. This could lead to a sudden loss of the sludge to land outlet and Option 5 will have similar impacts to Option 4. Table 49 does not mention the cross compliance obligations for the Single [farm] Payment Scheme (SPS) under the Common Agricultural Policy which require good agricultural practice, preventing soil erosion, etc. which apply to all the options. Neither does it mention the Water Framework Directive. 86/278/EEC was the first soil protection directive and to a very large extent it still is. It would be very regrettable if it was repealed. The vacuum that would be created if it were repealed would probably be filled by the immensely powerful food industry that buys the produce from farms and which for its own sake would impose conditions. Most likely they would refuse to buy produce from land that had been treated with sewage sludge unless it was regulated by government legislation and the companies had confidence in the policing, which is currently part of the SPS.
Portugal	Option 5 is unacceptable because there must be a legal instrument that provides protection of public health and the E, from SS land application in the MS.
EU wide	No comment on this option for which EFAR is not in favour of (please refer to our general comments).

Official stakeholders below.

Belgium - Wallonia	This Option is satisfactory. If Option 2 modified as suggested is not implemented, this Option will allow the region to implement its integrated management of various organic materials including sewage sludge.
UK	In relation to option 5, any perceived savings (6.3) are likely to be offset by the damage which might result to consumer confidence and the land bank for spreading.

Questions 20 – 21: Comparison of Options

Question 20: Do you have any comments on the Options as proposed, especially in terms of the ir impacts?

The responses of the commercial stakeholders are below.

UK	Option 1 remains viable given that biosolids recycling to agriculture under the current regulatory framework has a proven record as a low risk environmental activity that does pose a risk to public health. The introduction of HACCP regulations would be a logical step however and this should perhaps be evaluated before the existing Regulations are amended or the

tighter options introduced. An alternative would be to introduce HACCP Regulations separately.

Options 2 updating of the current Regulations would be useful if it led to an increase in consumer/retail confidence.

Option 3 will significantly increase costs to the MS without any proven material benefit.

Option 4 should not be considered as a viable proposition based on risk analyses and given the overall benefits of sludge recycling.

Option 5 should not be considered as a viable proposition as Regulations prevent poor practice and assists in engendering confidence.

Option 1 is the most viable and allows MS sufficiently flexibility in their approach to regulating sludge to land activities. Sludge use has been safe in agriculture for 40 years. Sound science should be used and not individual MS areas of concern. Option 2 might lead to an increased stakeholder confidence in the sludge recycling to land route. However, the new organics and heavy metals in soil limits presented in this consultation would need further consideration. Option 3 is completely unworkable. Both Option 2 an dOption 3 would require further work and may well require a detailed study for each of the countries involved. Options 4 and 5 should not be considered as viable options.

The report admits several times that the data on which assumptions have been based are very uncertain. It also says "The Sewage Sludge Directive (86/278/EEC) could be said to have stood the test of time in that sludge recycling has expanded since its adoption without environmental problems". The phosphate crisis has not been acknowledged in any of the impact assessments. EU policy is supposed to be based on science and risk assessment. No evidence has been presented that changes to the metal limits in 86/278/EEC are required or for introducing limits for organic compounds.

Introducing two classes of sludge treatment (Conventional and Advanced) with appropriate cropping and intervals-to-harvest based on risk of pathogen transmission, compared with the ambient risk, would be an advance and would be welcomed by the food industry.

Introducing an obligation not to cause odour nuisance would also be an advance because it would control the factor that is the root of 95% or more of complaints from the public.

Reinstatement of interest by the Commission in the reporting requirements of 86/278/EEC would reduce the uncertainty in the data. It is scandalous that some of the EU15 are still not reporting; it reflects the Commission's lapse of interest in the past few years, which is also manifest in the way that project HORIZONTAL was allowed to slip.

Finland Advanced treatment method typically increase energy use. Hygienisation requires high temperatures and especially in the cold climate this is causing both high investment costs but also increased energy use. In Finland, costs of treatment have increased fast. Traditionally windrow compositng has been used but in cold climate it is challenging to maintain high temperatures all year round.

Germany The data given in the assessment shows a clear result. Even if the expected changes and the estimated costs may be corrected for some MS, the finding will be the same. Option 3 and option 4 will become very expensive. Option 2 is the most realistic scenario that ensures a high level of environmental protection with tolerable costs.

Official stakeholders' responses are presented below.

Belgium - Wallonia We cannot comment for Belgium as a whole so data should be dissagregated by region.

Portugal Compared to Decree law 276/09 of 2nd October with the numerous options identified in the report, we verify that the diploma already contemplates most of the components of option 2, and some of the components of option 3.

It is thus considered that at a national level the adoption of the option 2 does not imply significant impacts seeing that Decree law 276/2009 of 2nd October mainly contemplates the stipulated conditions in the option 2. The adoption of limit values of heavy metals in soil established in the option 2 is the only situation that could have an impact at a national level.

Nutrients in sludge:
Decree law 276/2009 of 2nd October establishes that in quantity definition of nitrogen (N), phosphorus (P) and potassium (K) to be applied by sludge on a cultivated soil, the quantities of these nutrients supplied by other fertilizing materials, namely livestock effluents and fertilizers, are taken into account, as not for the necessary quantities for crops to be exceeded. So being, a fertilization plan is drawn up in which it is shown that only the N, P and K quantities needed for the crops are applied. The options 2 and 3 establishes that information should be facilitated related to the quantities of N, P and C supplied by sludge. It is concluded that this component is already contemplated in Decree law 276/2009 of 2nd October.

Nutrients in soil:
Decree law 276/2009 of 2nd October establishes that analyses should be done to the soil agronomic parameters (N and P). The sludge application in nitrate vulnerable zones, is restricted to what the different action programs stipulate. Thus, the conditions of options 2 and 3, are already covered by the Decree law 276/2009 of 2nd October.

UK

The comparison of options (at 7) suffers, as already pointed out, from the major disadvantage that it relies on unconsulted standards for which evidence of justification has not been put forward.

UK policy takes the view that the use of sludge in agriculture represents the current best practicable environmental option in many circumstances whilst soils can benefit from the addition of good quality biowastes. We could not, therefore, support options which prevented their use or unnecessarily restricted such use.

At the same time it is recognised that the unsustainable spreading of sludge can be harmful and revised standards, provided that they can be justified, can be considered. More stringent standards than in the Directive are already employed, including the 'safe sludge matrix.' Defra is currently considering revision of the current Use of Sludge in Agriculture Regulations, subject to government clearance of policy, and UK experience would provide a valuable contribution to a proper discussion if more stringent standards are to be considered.

We would therefore wish to raise awareness of UK evidence of costs, benefits and risks of sludge use on land and its sustainable management. We would wish to draw your attention to UK experience if it your intention to work up a proposal.

Question 21: Do you agree with our costs data and assumptions presented in this report and the overall estimates presented in Table 51? Please expand, provide us with your data and estimates if possible.

The responses of the commercial stakeholders are below.

UK

The costs against the total ban are an underestimate. For example based upon the most recent data within the industry, a capital cost of £2500/tds is estimated for the construction of incineration plant.

Applying this data to the construction of incineration plant with a capacity of 1,050,000 tds (currently applied to the landbank) gives an immediate total capital costs of the order of £2.6bn.

The estimates in Table 51 are flawed because they are based on flawed data, as the authors admit in the report. Member States simply do not have the detailed knowledge of their soils or their sludges to estimate effects. The "benefits" in Table 51 are spurious; if 86/278/EEC has prevented environmental problems, how can its revision generate improvements in environmental or human health? Even these spurious amounts are greatly outweighed by the costs. Nobody would make a business investment based on such a poor return. The report has failed to consider the phosphate crisis.

Finland

Costs of Finland should be corrected to correspond to the more realistic amount of sludge used in agriculture.

Official stakeholders's responses are presented below.

UK At various points in the report (and at 3.3.2) there is reference to the potential use of landfill in place of spreading. Such an approach would be at variance with EU policy to restrict the use of landfill and is therefore not, in practice, a viable option. Similar comments could be made in respect of the alternative of incineration because of the implications for increased carbon emissions, including increased transport movements. The recycling of sewage sludge is in fact one of the lower carbon emission options. The impact assessment appears to overlook this critical dimension to assessment.

At table 7, too much remains unquantified to make meaningful assessments.

The paper is predicated on the basis of a large number of new standards for which no scientific or practical evidence is presented. Furthermore the standards presented have not been consulted or discussed amongst experts and to all intents and purposes appear arbitrary. Proposal for new standards must recognise the variety of conditions under which sludge is applied in various member states in order to preserve the flexibility which currently exists. This step is crucial to the formulation and negotiation of any new directive. The use of these standards for anything other than for purely illustrative purposes would be unacceptable, particularly if conclusions as to costs and benefits, and cost-effectiveness, are to be drawn in support of a new proposal.

It follows from this that the standards and practices incorporated in this paper remain to be properly discussed and justified by scientific evidence prior to any formal discussions in relation to a new directive. To this extent any conclusions drawn in the Impact Assessment are spurious in the absence of fully-justified, discussed and agreed standards which are essential components of any Impact Assessment.

We note that the study confines its interest to entirely traditional considerations pertaining to the use of sludge in agriculture. There is scope for development of treatment processes to extend to anaerobic digestion and the treatment of other wastes. Whilst there is no need for an EU directive on the subject, some might see this study as unduly restrictive in its scope.

Annexes

Annex 2 1 Assessment of economic impacts

Table 55 What is the justification of the higher cost of landspreading of solid in comparison with landspreading of semi solid? Does solid mean dried? Please clarify.

As mentioned previously it is not acceptable to use the same costs within the whole EU. Landspreading of liquid sludge has also to be taken into account with the necessity of a initial dewatering operation to have access to disposal outlets like incineration or landfilling.

Table 59 Please provide the detail of the capital costs. EFAR would like to understand how the liming operating costs can vary from simple to double and finally being comparable with the incineration operating costs mentioned in table 56.

2 Assessment of environmental impacts

Table 62 As energy recovery seems to have a significant impact on the final balance EFAR would like to get the calculation details as sludge even at 25% DS is just self combustible.

Annex 3 Need to include CHP generation

Concerned about the data given in highly uncertain. Section 1.1. omits to mention that in addition to GHG there will be emissions from the lorry movements. This will depend on geographical location. Equally this assessment does not reflect the GHG emissions associated with replacement of sludge by man-made fertilisers,w hich we believe gives a very limited and unrealistic impression of the actual carbon impact.

Once again it is a copy and paste of values coming from other reports dating from 2002! It is important to consider that the methodology for establishing carbon footprint balances has evolved considerably since then.

The origin of the data and methodology used are insufficiently documented.

EFAR is therefore unable to comment the values provided, but informed the Commission that it has launched a study of the comparison of the carbon footprint of the different sludge disposal routes which conclusion will be available by the end of the first quarter of 2010.

The authors admit they have limited information about the percentage of sludge treated by anaerobic digestion; this is another example of lack of base data, which should be collected in order that a proper assessment of this important treatment can be made. Information should also be collected about biogas use; about plans to upgrade digestion to increase biogas yield (which is a very current topic in the industry) and about co-digestion if it were enabled by legislation.

Gasification, even when it is developed to be operationally viable, is unlikely to yield very much net energy because of the high water content of sludge. For a similar reason the net energy from incineration is low. These thermal processes squander phosphate.

Energy recovery is already a key aspect of sludge management but at present the only sensible contribution is from anaerobic digestion; especially advanced AD, i.e. phased digestion and thermal hydrolysis. The digestate could be disposed by incineration but there will be little additional net energy produced.

Smith et al. included carbon sequested when compost was used on land; this was accepted by the EC and published; it could be extrapolated to sludge. [Smith, A., K. Brown, S. Ogilvie, K. Rushton, and J. Bates. 2001. "Waste management options and climate change: Report to the European Commission." http://ec.europa.eu/environment/waste/studies/pdf/climate_change.pdf]

CO_2 from sludge or from burning biogas is "biogenic" [short-cycle] and therefore has no climate change impact. I think there must be a mistake in Table 3 CH_4 high estimate. All the table that include CO_2 and therefore wrong and also the climate change cost tables derived from them.

When accounting N_2O, allowance should be made for the N_2O that would have been released from the mineral fertiliser that the sludge replaces.

Annex 4

Table 1 suggests that landfills have the ability to leach to soil and/or water, as 'modern' landfills are lined and controlled. –

Table 2, we are surprised to see the 'value' of CH4 the same as CO2 as it is 20x more harmful.

Table 3, should the table match Table 2 and include Emissions from transport? Also similar comments to operation of a 'modern' landfill

Table 5, should the table match Table 2 and include Emissions from transport?

Table 6 , we are surprised to see no 'value' against CH4 as the industry (through the workbook) suggests significant levels of CH4 associated with biosolids application to land.

Annex 4 is hugely uncertain because it is based on uncertain data. It does not consider the consequence of not recycling P on the depletion of the world's phosphate resource.

Other comments

Company operating in France but with offices elsewhere stated that:

In Spain, where SUEZ ENVIRONNEMENT is present through Agbar, the current legal framework on the land spreading of sewage sludge is very similar to the provisions of the Directive. The impacts of Option 2 and 3 would thus be greater than the ones we expect in France.

In Germany, where SUEZ ENVIRONNEMENT is active in sludge land spreading through Eurawasser, the legal framework at the federal level is slightly more restrictive than in France. However, some Länders have decided a ban on sludge land spreading. The impacts of the two Options considered in this document would thus be a little less significant.

In the Walloon region of Belgium, where SITA practices sewage sludge land spreading, *the current legal framwork is slightly more restrictive than in France as to the maximum heavy metal contents. There is however no threshold for organic mico-pollutants. We can thus infer that the potential impacts of Options 2 and 3 would be equivalent to the ones expected in France.*

Some other respondents also were uncertain about the distributional impacts as presented.

Environmental, economic and social impacts of the use of sewage sludge on land

Final Report

Part III: Project Interim Reports

milieu ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by Milieu Ltd, WRc and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r.

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Part III of the final report consists of the project's interim reports:

1. The Assessment of Existing Knowledge
2. The Baseline Scenario and Analysis of Risk and Opportunities
3. Interim report describing the first consultation

Delivered on the 10th of February 2010

List of abbreviations

AD	Anaerobic digestion
AOX	Total adsorbable organo-halogen
APD	Acid phase digestion processes
BAT	Best available techniques
BOD, BOD5	Biochemical oxygen demand
CBA	Cost-benefit analysis
CEN	Comité Européen de Normalisation
CHP	Combined heat and power plant
COD	Chemical oxygen demand
CoGP	Code of good practice
DEHP	Bis(2-ethylhexyl)phthalate
DG ENV	Directorate General Environment of the European Commission
DM	Dry matter, or dry solids, or total solids
DS	Dry solids, dry matter, total solids
ECJ	European Court of Justice
EEA	European Environment Agency
EoW	End-of-waste
EPA	Environmental Protection Agency
EQS	environmental quality standards
EU 12	The 12 Member States that joined the EU in 2004 and 2008
EU 15	The 15 Member States that joined the EU before 2004
EU 27	All 27 Member States since 2008
FAO	Food and Agriculture Organization
FWD	Food waste disposal
GHG	Green house gas
GWP	Global warming potential
HACCP	Hazard analysis and critical control point
IA	Impact Assessment
IPPC	Integrated pollution prevention and control
LAS	Linear alkylbenzene sulfonate
LCA	Life-cycle analysis
MAD	Mesophilic anaerobic digestion
MBT	Mechanical biological treatment
MS	Member State of the European Union
MSW	Municipal solid waste
Mt	Million tonnes
ND	Nitrate Directive
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
NP/NPE	Nonylphenol/Nonylphenol ethoxylate
OC	Organic compounds / Organic contaminants
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PCDD/F	Polychlorinated dibenzodioxins and polychlorinated dibenzofurans
pe	population equivalent
PPP	Public private partnerships
PTE	Potentially toxic elements; refers to heavy metals
QA	Quality assurance
QMRA	Quantitative microbial risk assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RED	Renewable Energy Directive
SEPA	Scottish Environmental Protection Agency

SSM	Safe sludge matrix
TD	Thermal Destruction
tDS	Tonnes of dry solids
THP	Thermal hydrolysis process
TOC	Total organic content/carbon
TRF	Toxicological reference value
TS	Total Solids, dry matter, dry solids
TSP	Total sludge production
UBA	Umweltbundesamt
UWWTD	Urban waste-water treatment
VOSL	Value of statistical life
WFD	Water Framework Directive
WI	Waste incineration
WWTP	Wastewater treatment plant

Environmental, economic and social impacts of the use of sewage sludge on land

Summary Report 1

Assessment of Existing Knowledge

milieu
ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by Milieu Ltd, WRc and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Anne Gendebien. Additional expertise was provided by Bob Davis, John Hobson, Rod Palfrey, Robert Pitchers, Paul Rumsby, Colin Carlton-Smith and Judith Middleton.

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EXECUTIVE SUMMARY

Milieu Ltd is, together with partners WRc and Risk & Policy Analysts Ltd (RPA), working on a contract for the European Commission's Directorate General Environment, entitled *Study on the environmental, economic and social impacts of the use of sewage sludge on land* (DG ENV.G.4/ETU/2008/0076r).

The aim of the study is to provide the Commission with the necessary elements for assessing the environmental, economic and social impacts, including health impacts, of present practices of sewage sludge use on land and prospective risks/opportunities and policy options related to the use of sewage sludge on land. This could lay the basis for the possible revision of Community legislation. This report summarises information on sludge recycling to land. It is the first deliverable of the study on "Environmental, economic and social impacts of the use of sewage sludge on land" for the European Commission (DG Environment). The report focuses on work reported since 2000 but taking account of important earlier studies. The aim of the report is to identify key information that would be relevant for updating the Directive 86/278/EEC (hereinafter, the "Sewage Sludge Directive") which is the principal legislation underpinning the control of sludge recycling to land in the EU.

Topics covered in this report include: sludge production, legislation, economics and some social considerations but the emphasis is on environmental factors. In this way, the report has identified, from the very extensive literature on sludge recycling to land, the key factors on which the review of Directive 86/278/EEC needs to focus. The topics covered are:

- Current sludge Production and Disposal in the EU
- EU and Related Legislation on the Use of Sludge on Land
- Economics of sludge Treatment and Disposal
- Agricultural Value
- Contaminants and Pathogens
- Water and Air Pollution
- Greenhouse Gas Emissions and Carbon Footprint
- Stakeholder Interests and Public Perception
- Future Trends
- Monitoring, Record Keeping and Reporting
- Summary of Areas of Uncertainty and Knowledge Gaps

1 Introduction

The Sewage Sludge Directive 86/278/EEC was set up to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. To this end, it prohibited the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. The Directive also required that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.

Directive 86/278/EC on sewage sludge was based on the knowledge available at the time, including the evaluation of the risks provided by the COST 68 programme during the early 1980's. Since its adoption, many Member States have, on the basis of new scientific insight in the effects of sludge use on land, enacted and implemented stricter limit values for heavy metals as well as for contaminants which are not addressed in the Directive.

The most recent estimates reported to the Commission by the Member States suggest that more than 10 million tons DS were produced in 26 EU Member States (no estimate for Malta), of which approximately 36%, almost 3.7 million tons DS, was recycled in agriculture. In the last 10 years, the total amount of sludge produced has increased in most of the 15 EU Member States, due primarily to the implementation of the Urban Waste Water Treatment Directive 91/271/EEC. The quality of the sludge has also improved quite substantially in the EU 15. The proportion of waste recycled to land has also changed dramatically. For example, in Finland, Slovenia and Flanders quantities going to land has decreased significantly in recent years while they have increased in countries like Bulgaria.

2 Current Sludge Production and Management in the EU

This section reviews recent information on the production and disposal of sewage sludge in the EU. In particular, it presents information that can be used in the next stage of the study to develop a baseline scenario for future production and disposal.

2.1 Sludge quantity and disposal

According to the figures provided to the European Commission for the period 2003-2006 (personal communication, 2009) (Table 1), about 10 million tons DM of sewage sludge were produced in the EU; 8.7 million t DM in the EU-15 and an additional 1.2 million t DM for the 12 new Member States. This is probably underestimating the total quantities produced as not all of the Member States had provided up to date figures for the latest Commission survey (2003-2006) and figures from the previous survey (1999-2002) (EC, 2006) or from other sources were included in the Table. No data was reported for Malta.

According to the same sources of information, 37%, about 3.6 million t DM, was recycled in agriculture (Table 1). However, the proportion of sludge recycled in agriculture varies widely between different Member States and regions. In the Walloon Region (Belgium), Denmark, Spain, France, Ireland, and the UK, 50% or more of the sludge generated is applied to agricultural land while in other Member states there is less than 5% (i.e. Finland, Flemish Region of Belgium) or no application (Greece, Netherlands, Romania, Slovenia, Slovakia) of sewage sludge to land (EC, 2006; Alabaster and LeBlanc, 2008).

Compared with figures (Table 2) provided in the previous Commission surveys for 1995-1997 and 1998-2000 (EC, 2006), sludge production has steadily increased between 1995 and 2006 in most Member States. This can be attributed mainly to the implementation of the Urban Waste Water Treatment Directive 91/271/EEC (CEC, 1991) and also, in some cases (i.e. Italy and Portugal), to better reporting. However, in some Member States (i.e. Germany, Denmark, Finland, Sweden), although sludge quantities had increased since the 1980's, sludge production appears to have stabilised or even slightly decreased over the last 5 years. This has been attributed to a reduced consumption of water and an increased treatment of sludge (Jensen 2008). In 2004 and 2007, there was also the enlargement of the EU with the accession of 10, then 2, more new Member States, which added another 12% to the total sludge production in the EU. For the next 5 years this trend should continue with further investment in sewer connection and wastewater treatment capacity, especially in the new Member States.

The proportion of waste recycled to land has also changed dramatically in recent years (Tables 1 and 2). While in some Member States, such as France, Portugal, Spain and the UK, quantities recycled to agriculture have continued to increase, agricultural application has effectively been banned in some countries, e.g. the Netherlands and some regions of Belgium (Flanders), of Austria and of Germany, due to growing public concerns about the safety of the outlet and competition with other organic materials going to land such as animal manure. The Global Atlas (Alabaster and LeGrand 2008), however, estimates that there is more than a 50% chance that the benchmark sludge in a European city would be treated and recycled to land.

Incineration and landfilling are the main alternative methods to agricultural recycling for sludge management. Most Member States treat a proportion of their sludge by incineration and the residual ash is usually disposed of to landfill. The amount of sludge that is incinerated significantly increases when recycling is discouraged or banned. In Flanders (Belgium), for instance, more than 70 % of sludge production is now incinerated (Table 3). In the Netherlands, about 60% of sewage sludge is incinerated (Smith 2008) and in Austria, Denmark and Germany approximately 40 % of sludge is incinerated. Slovenia dries and then sends 50% out of the country to be incinerated.

The total amount of sludge destined for landfills is relatively small overall, and as the Landfill Directive 99/31/EC (CEC, 1999) sets mandatory targets for the reduction of biodegradable waste to landfill, landfilling of sewage sludge will be effectively banned. Some countries (mainly in the new Member States), however, still depend heavily, or entirely on this outlet as a means of sludge disposal (e.g. Greece, Hungary, Poland – see Table 3).

Table 1 Recent sewage sludge production and quantities recycled to agriculture in the 27 EU Member States (Doujak 2007, EC, 2006, EC, personal communication, 2009, IRGT 2005)

Member State	**Year**	**Sludge production**	**Agriculture**	
		(t DS)	**(t DS)**	**(%)**
Austria (a)	2005	266,100	47,190	18
Belgium				
• Flemish region	2006	76,254 (b)	1,981	3
• Walloon region	2003	23,520	11,787	50
• Brussels region (c)	2002	2,792	878	31
Denmark	2002	140,021	82,029	59
Finland	2005	147,000	4,200	3
France	2002	910,255	524,290	58
Germany	2006	2,059,351	613,476	30
Greece	2006	125,977	56.4	0
Ireland	2003	42,147	26,743	63
Italy	2006	1,070,080	189,554	18

Luxembourg	2003	7,750	3,300	43
Netherlands	2003	550,000	34	<0
Portugal	2002	408,710	189,758	46
Spain	2006	1,064,972	687,037	65
Sweden (e)	2006	210,000	30,000	14
United Kingdom	2006	1,544,919	1,050,526	68
Sub-total EU 15		***8,649,848***	***3,462,839***	***40***
Bulgaria	2006	29,987	11,856	40
Cyprus	2006	7,586	3,116	41
Czech republic	2006	22,0700	8,300- 25,400	4- 12
Estonia (d)	2005	nd	3,316	?
Hungary	2006	128,380	32,813	26
Latvia	2006	23,942	8,936	37
Lithuania	2006	71,252	16,376	23
Malta		nd	nd	nd
Poland	2006	523,674	88,501	17
Romania	2006	137,145	0	0
Slovakia	2006	54,780	0	0
Slovenia	2006	19,434	27	< 0
Sub-total for EU 12		***1,216,880***	***190,341(f)***	***17***
Total		**9,866,728**	**3,653,180**	**37**

a) Austria has not submitted figures to the Commission for the last two surveys. Figures presented above are from Doujak (2007) from UBA: total sludge production amounts to 420,000 t DM in 2005. This includes 238,100 t DM municipal sewage sludge + 28,000 t DM exported and 155,000 t DM of industrial sludge (mainly from cellulose and paper industry.
b) Figure for previous year (2005) as for total sludge produced no figure was provided for 2006.
c) No figures submitted to the Commission. Figures from IRGT 2005. In the Brussels Region, there are now 2 STEs; wastewater treatment started in one STW in 2000 for 360,000 pe and a second STW was commissioned for 1.1 M pe and started operating in 2008. In 2002, sludge production in the Brussels Region amounted to 2800 t DM.; 66% was incinerated, 32% recycled to agriculture and 2% was sent to landfill.
d) No figures reported for total sludge production.
e) Estimates
f) Taking into account the highest figure for the Czech Republic.

Table 2 Past (1995 and 2000) Sludge production in the EU-15 (EC 2006)

Year	**1995**		**2000**	
Member State	**Sludge production (t DS)**	**Sludge used in agriculture (%)**	**Sludge production (t DS)**	**Sludge used in agriculture (%)**
Austria (a)	390,000	12	401,867	10
Belgium				
• Flemish region	73,325	13	80,708	0 (b)
• Walloon region	14,311	75	18,228	59
Denmark (c)	166,584	67	155,621 (1999)	61 (1999)
Finland	141,000	33	160,000	12
France	750,000	66	855,000 (1999)	65 (1999)
Germany	2,248,647	42	2,297,460	37
Greece	51,624	0	66,335	0
Ireland	38,290 (1997)	11 (1997)	35,039	40
Italy	609,256	26	850,504 (d)	26
Luxembourg	nd	nd	7,000 (1999)	80 (1999)
Netherlands (f)	nd	0	nd	0

Portugal (e)	145,855	30	238,680	16
Spain	685,669 (1997)	46 (1997)	853,482	53
Sweden (e)	230,000	29	220,000	16
United Kingdom	1,120,00 (e)	49	1,066,176	55
Total EU-15	**6,664,781**	**42**	**7,306,342**	**40**

a) Includes sludge from municipal treatment plants (60%) and commercial/industrial treatment plants (40%) (especially from cellulose and paper industry)
b) Since December 1999, municipal sewage sludge is no longer used in agriculture.
c) Since 1994, annual sludge production in Denmark has been between 150,000 – 160,000 t DM with a drop to 140,000 t DM in 2002.
d) Data not complete for all regions
e) Estimates
f) Figures reported to the Commission in 1995 and 1999 only covered sludge produced by private treatment plants (220 t DM and 242 t DM respectively as since 1995), as since 1995 municipal sewage sludge was no longer used in agriculture in the Netherlands

Nd no data

Table 3 Disposal methods for sewage sludge in EU Member States as percentage (AMF 2007, Doujak 2007, Eureau 2006 reported by Smith 2008, IRGT 2005, Leonard 2008, COM personal communication, 2009)

Member State	**Year of data**	**Agriculture**	**Landfill**	**Incineration**	**Other**
Austria (a)	2005	18	1	47	34
Belgium					
• Flemish Region (b)	2005	9		76	14
• Walloon Region (c)	2005	32	6	62	
• Brussels region (d)	2002	32	2	66	
Denmark (e)	2002	55	2	43	
Finland	2000	12	6		80 (f)
France (g)	2002	62	16	20	3
Germany (h)	2003	30	3	38	29 (i)
Greece (j)			>90%		
Ireland	2003	63	35		3
Italy		32	37	8	22 (k)
Luxembourg	2004	47		20	33 (l)
Netherlands (m)	2006	0		60	40
Sweden		10-15		2	90-85 (n)
UK	2004	64	1	19.5	15.5 (o)
Bulgaria (p)	2006	40	60		
Czech republic (q)	2004	45	28		26
Hungary (r)	2006	26	74		
Poland (s)	2000	14	87		7
Romania (t)		0			
Slovenia (u)	2006	>1	50		49
Slovakia (v)	2006		17		83

a Figures from Doujak (2007) from UBA. In 2005, municipal sewage sludge production amounted to 238,100 t DM + 28,000 t DM exported. Sludge used in agriculture has to meet specific legal requirements which differ from federal state to federal state. In several federal states, there is a ban on sewage sludge application in agriculture. The legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are much less stringent; therefore an increasing part of sewage sludge is used for this purpose. Since 2001, thermal treatment has increased from about 30% to nearly 50% . While in 2001, 11% of municipal sewage sludge was sent to landfill, by 2005, this outlet represented only 1%. Sludge disposal to landfill was basically banned in 2004 as new legislation required that only material meeting the following criteria be allowed for landfill disposal: ≤ 5 % TOC related to total dry solids and ≤6000 MJ/kg dry solids. These criteria cannot be met by conventional sludge treatment. Only the ashes after incineration are meeting these requirements. Out of 91,700 t DM disposed of by others routes - 77% are composted, 12.3% used in landscaping, 2.4% in temporary storage and 8.2% in unknown outlets.

b The Flemish Region has discouraged the recycling of sewage sludge to land through stricter limit values due to the large volume of animal manure produced in the region. While in 2005, 31% of 76,250 t DS were still used in agriculture, land spreading of sludge in agriculture was stopped in 2006 due to increasing costs of complying with the recent regional restrictions. Other means landfill cover.

c While landspreading in agriculture (82% in 1998, 56% in 2001) and landfilling (18% in 1998 and 37% in 2001) have been the preferred options for years, these outlets have now been supplanted by incineration which was first used in 1999 (2% , 7% in 2001) (IRGT 2005, Leonard 2008).

d According to IRGT (2005), in 2002, 66% of sludge in the Brussels region was incinerated, 32% recycled to agriculture and 2% was sent to landfill.

e Denmark has a target for 2008 to sent 50% of sewage sludge to agriculture, 45% to incineration corresponding to 25% incineration with recycling of ashes in industrial processes and 20% “normal” incineration. Agriculture includes sludge mineralisation plants, composting, long time-storage. Incineration includes recovery, e.g. cement or sand blasting agents (58% of incinerated sludge is recovered by alternative methods). Sludge recycling to agricultural land has been encouraged as a way of recycling nutrients. From 1995 to 2002, however, the relative fraction of sludge recycled to land has decreased from 70% down to 60%. Since 1994, the relative proportion of sludge incinerated has stayed fairly constant at around 20%, while landfilling has decreased to less than 5% (Jensen, 2004).

f While in 2004, there was still 9% of sludge recycled to agriculture, it was down to 3% in 2005. In 2000, other outlets include 27% as landfill cover and 53% for landscaping

g From AMF 2007 (Data from Agences de l’Eau for 2002/2003)

h Three of 16 federal states intend to stop agricultural sludge use.

i 26% as landscaping and 3 % as other

j No recycled to agriculture. Stated that most goes to landfill due to joint ownership of WWTP and landfills by municipalities.

k Includes 19% as composting, no final outlet given.

l As composting no final outlet given

m Since 1995, in the Netherlands, municipal sewage sludge is no longer used in agriculture. In 1996, the majority of municipal sewage sludge was sent to landfill (82%). Now, most sewage sludge goes to incineration in the Netherlands or in Germany, some of it after composting or heat drying.

n Including 60-65% as construction soil and 10% as vegetation material.

o Including 11% for land reclamation and 4% as compost and industrial crops

p While there was no recycling to agriculture in previous years (in 2004 and 2005), 40% of sludge was reported to be used in agriculture in 2006.

q In the Czech Republic, in 2001, 42-48% of sludge was recycled to agriculture, in 2002 and 2003, there was no sludge sent to agriculture and in 2004, 16% of 206,000 t DM was again recycled to land.

r Recent legislation regarding maximum water content of landfilled sludge (at least 25% DM) could limit this outlet. No incineration of sludge.

s Data from Twardowska 2005

t From the literature review (Crac 2004) although Romania does not yet recycled sludge to agriculture, is intending to do so in the near future as well as other recovery methods such as co-incineration in cement kilns

u In the past, the majority of sewage sludge was disposed of in landfills; however, following the adoption of a Decree on landfilling of waste, the volume should slowly be reduced as the landfilling of sludge from 2008 is only authorised for waste with TOC < 18% d.m. and calorific value < 6 MJ/kg d.m. In 2001, 2002 and 2003, Slovenia recycled 6%, 16% and 9% respectively to agriculture. Since 2003, the quantities of sludge recycled into compost and on agricultural land have been reduced down to about one per cent due to concerns about the content in hazardous substances when produced from combined wastewater treatment plants in urban and industrial areas. The remaining sludge is exported for the preparation of artificial soil and other recovery methods (not specified but could include co-incineration).

v Figures reported are estimates. In Slovakia, in 2004, 23% of sludge was directly spread on land, 54% was composted and another 3% was used in land reclamation, 9% was landfilled and 11% were placed in temporary storage. In 2006 there was no direct land spreading in agriculture but 61% was composted (no final outlet mentioned) and 10% was used in land reclamation, 17% landfilled and 11% placed in temporary storage. No suitable incineration capacity for sewage sludge, but potential co-incineration in cement plants.

2.2 Sludge quality

Member States have to provide information to the Commission on the average quality of sludge recycled to agriculture regarding PTEs (Potentially Toxic Elements) and nutrients (Total nitrogen and total phosphorus). The information submitted during the latest survey for period 2004- 2006 is presented in the Table 4 below. The following comments can be made:

- The three highest values for each metallic elements have been highlighted;
- There are some large differences in quality between 18 Member States which have provided information depending on the elements;
- Cyprus, Italy, Latvia, Poland have the sludge containing the highest concentrations for at least 3 elements.

Sewage sludge contains potentially toxic elements (PTEs), including heavy metals, which are from domestic (i.e. plumbing, body care products, etc.), surface run-off and/or commercial and industrial origins (see chapter 6 below). It has been confirmed by several studies (Smith 2008) that since the mid 80's concentrations of heavy metals in sewage sludge has steadily declined in the EU due to regulatory controls on the use and discharge of dangerous substances, voluntary agreements and improved industrial practices; all measures leading to the cessation or phasing out of discharges, emissions and losses of these PTEs to the environment.

Table 4 Quality of sewage sludge (on dry solids) recycled to agriculture (2006) (CEC, personnel communication 2009)

Parameter	**BE a,b)**	**DE**	**ES**	**FI b)**	**IT**	**PT a)**	**SE**	**UK**	**BG**	**CY**	**CZ**	**EE b)**	**HU**	**LT**	**LV**	**PT**	**SI**	**SK b)**
Zinc	337	713	744	332	879	341	481	574	465	**1188**	809	783	824	534	**1232**	996	410	**1235**
Copper	72	**300**	252	244	283	12	**349**	295	136	180	173	127	185	204	**356**	153	190	221
Lead	93	37	68	8.9	**101**	27	24	**112**	55	23	40	41	36	21	**114**	51	29	57
Nickel	11	25	30	30	**66**	15	15	30	13	21	29	19	26	25	**47**	**32**	29	26
Chromium	20	37	72	18	**86**	20	26	61	20	37	53	14	57	34	**105**	**127**	37	73
Mercury	0.2	0.4	0.8	0.4	1.4	<1	0.6	1.2	1.2	**3.1**	1.7	0.6	1.7	0.5	**4.2**	**4.6**	0.8	2.7
Cadmium	1	1	2.1	0.6	1.3	<0.4	0.9	1.3	1.6	**6.9**	1.5	2.8	1.4	1.3	**3.6**	**4**	0.7	2.5
Total Nitrogen	3.9	4.3	4.5	3.4	4.1	1.7	4.5	2.8	7.2	4.1	3.6	4.9	3	2.3	3.9	0.9	3.2	3.8
Total Phosphorus	6.7	3.7	3.6	2.4	2.1	2	2.7	2.2	4.3	4.9	1.9	3.4	1.4	0.9	1.3	0.6	3.9	1.8

a) Data from the Flemish Region
b) data for 2005 as no values available for 2006

2.3 Sludge Treatment and current practice in EU Member States

Directive 86/278/EEC requires that sewage sludge be treated before it is used in agriculture (Member States may authorise the injection or working of untreated sludge in soil in certain conditions, including that human and animal health are not at risk). The Directive specifies that for sludge to be defined as treated it should have undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as to significantly reduce its fermentability and the health hazards associated with its use.

These overall requirements have been interpreted and implemented within individual Member States differently, in part based on specific local conditions and circumstances. Detailed descriptions of sewage sludge management for each Member States can be found in the latest available Commission's implementation report (EC 2006). In general, untreated sludge is no longer applied. In the Czech Republic, Denmark, Spain, Finland, Germany, Hungary, Italy, Luxembourg, the Netherlands, Slovakia, Slovenia, and in the UK it is prohibited to spread any untreated sludge on land (EC 2006).

Where sludge is to be used on land, it is usually stabilised by mesophilic anaerobic digestion, or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting.

In the UK, land spreading of raw, untreated sludge to food crops was banned by the Safe Sludge Matrix from December 1999, and on land used to grow non-food crops from December 2005 (ADAS, 2001).

In the UK, most sludge is stabilised by anaerobic digestion and must meet other management restrictions. A site permit is not required but regulations, notably the Code of Good Practices (CoGP) and Safe Sludge Matrix (SSM), must be followed. Treatment processes for sludge in the UK are managed according to the principles of HACCP (Hazard Analysis and Critical Control Point management) (Water UK, 2004). HACCP applies risk management and control procedures to manage and reduce potential risks to human health and the environment. The approach has been adopted and applied to sludge treatment for agricultural application to provide assurance that the microbiological requirements set out in the Safe Sludge Matrix are met and that risk management and reduction combined with appropriate quality assurance procedures are in place, thus preventing the use on farmland of sludge that does not comply with the microbiological standards.

The periods of prohibition between sludge spreading and grazing or harvesting vary according to the Member State (EC 2006). In Ireland, Spain, Luxembourg, the Netherlands, Portugal and the United Kingdom, the provisions of the Directive apply: i.e. sludge must be spread at least three weeks before grazing or harvesting and on soil in which fruit and vegetable crops are growing, or at least ten months for soils where fruit and vegetable crops that are eaten raw are cultivated in direct contact with soil. In the other Member States the rules are generally stricter than those provided for by the Directive. For more detailed information, please refer to the Commission report (EC 2006).

3 EU Legislation, other EU Acquis and Member State Controls on the Use of Sludge on Land

3.1 EC legislation

The recycling of sewage sludge in agriculture has been regulated by Directive 86/278/EEC since 1986. The Directive both addresses pathogen reduction and the potential for accumulation of persistent pollutants in soils. The Directive sets maximum limit values for Potentially Toxic Elements (PTEs) in sludge (Table 6) or sludge-treated soil (Table 5) and specifies general land use, harvesting, and grazing restrictions, to provide protection against health risks from residual pathogens. The Directive allows untreated sludge to be used on agricultural land if it is injected or worked into the soil. Otherwise sludge shall be treated before being used in agriculture; however, the Directive does not specify treatment processes but rather defines "treated sludge" as "sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use" (Art. 2(b)).

The Commission now plans to undertake a comprehensive review of the provisions contained in the Directive. There have been previous reviews of this Directive, which produced draft proposals that included limit values for Organic Compounds (OCs) (Table 8).

When considering a review of the Directive 86/278/EEC, it is also necessary to consider other (especially more recent) directives and how they might regulate or otherwise affect the production and use of sludge on land as well as restrict other outlets for sludge.

- **Directive 91/271/EEC Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment**

The Urban Waste Water Treatment Directive 91/271/EEC concerns the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors. The Urban Waste Water Treatment Directive 91/271/EEC sets the following targets for secondary treatment of waste waters coming from agglomerations:

- at the latest by 31 December 2000 for agglomerations of more than 15,000 p.e. (population equivalent);
- at the latest by 31 December 2005 for agglomerations between 10,000 and 15,000 p.e.;
- at the latest by 31 December 2005 for agglomerations of between 2,000 and 10,000 p.e. discharging to fresh waters and estuaries.

Since the implementation of these requirements quantities of sewage sludge requiring disposal have increased dramatically in Member States. Foreseeing such issue, the Urban Waste Water Treatment Directive 91/271/EEC encourages the recycling of sludge arising from waste water treatment. It states that sludge arising from waste water treatment shall be re-used whenever appropriate. Under the Directive, Member States authorities must also publish situation reports on the disposal of urban waste water and sludge in their areas.

- **Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources**

This Directive has the objective of reducing water pollution caused or induced by nitrates from agricultural sources and preventing such pollution. To that aim the Directive requires Member States to designate vulnerable zones that contribute to the pollution of water by nitrates. Within these vulnerable zones, a code of good agricultural practice should be applied by farmers. Such a code could for example provide periods when the land application of fertilizer is inappropriate ban the land application of fertilizer to steeply sloping ground or to water-saturated, flooded, frozen or snow-covered ground. Since the Directive considers that sewage sludge falls within the definition of fertilizers, such code of agricultural practice should also apply to the spreading of sewage sludge.

- **Directive 99/31/EC Council Directive 99/31/EC pf 26 April 1999 on the landfill of waste (Landfill Directive)**

EU policy for waste management (CEC 1999) aims to encourage the recovery of value from waste products and to reduce the disposal of biodegradable wastes in landfill. The Landfill Directive (99/31/EC) implements by obliging Member States to reduce the amount of biodegradable waste that they send to landfills to 35% of 1995 levels by 2016. This implies that land filling is not considered a sustainable approach to sludge management in the long-term.

- **Directive 2000/76/EC of the European Parliament and the Council of 4 December 2000 on the incineration of waste**

Dry sewage sludge can be incinerated to produce energy. Sewage sludge falls within the category of waste and thus falls under the scope of Directive 2000/76/EC on the incineration of waste. This Directive sets several standards and technical requirements (air emissions, water discharges contamination, plant designs) that have to be respected by the operators of the plants which incinerate dry sewage sludge.

- **Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive (WFD))**

Cadmium, lead and mercury are designated Priority Hazardous Substances under the Water Framework Directive 2000/60/EC, and thus are subject to further measures leading to the cessation or phasing out of discharges, emissions and losses of these substances to the environment as far as possible. Directive 2008/105/EC implements these provisions in the Water Framework Directive. The Water Framework Directive is discussed further in section 9.

- **Directive 2008/105 on environmental quality standards in the field of water policy**

This Directive lays down environmental quality standards (EQS) for priority substances and certain other pollutants with the aim of achieving good surface water chemical status and in accordance with the provisions and objectives of Article 4 of Directive 2000/60/EC. The environmental quality standards set in Annex I, part A, of Directive 2008/105 are to be applied by Member States for bodies of surface water. Member States have also the option to apply environmental quality standards for sediment and/or biota. Member States might thus apply stricter measures to sewage sludge in order to respect these environmental quality standards.

- **Directive 2006/118/EC on the protection of groundwater against pollution and deterioration**

This directive complements the Water Framework Directive with additional rules to protect groundwater. It establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater. It establishes quality criteria that take into account local characteristics and allows for further improvements to be made based on monitoring data and new scientific knowledge. This Directive might have an impact on the practise of the spreading of sludge since it provides that the protection of groundwater may in some areas require a change in farming or forestry practices. Annex 1 of the Directive sets some groundwater quality standards; the spreading of sewage sludge will need to ensure that contaminants do not contaminate groundwater.

- **Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives**

Directive 2008/98/EC[1] is the new Waste framework Directive that lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing the overall impacts of resource use and improving the efficiency of such use. Directive 2008/98/EC does not mention sewage sludge. However, it provides that waste waters are excluded from its scope to the extent that they are covered by other Community legislation (Article 2(2(a).).

Since Directive 2008/98/EC entered into force recently, the ECJ has not yet ruled whether sewage sludge falls within the scope of this Directive as waste or was excluded from it as waste waters. However, the Directives that refer to "sewage sludge" as well as the commission working papers it is not mentioned that "sewage sludge" is defined as waste waters. For example the report from the commission on the implementation of the "community waste legislation", which dates back to the 19th of July 2006, only provides that waste oils, sewage sludge, and packaging waste are specific waste streams each with different characteristics and management issues.

Furthermore the European Court of Justice in the "Lahti Energia"[2] judgment, defined sewage sludge as a "residue" from the treatment of waste water, thus making a distinction between waste waters and the products that are generated from its treatment.

Finally, in case sewage sludge is considered as waste waters, a preliminary ruling of the ECJ[3] mentioned that waste waters were to be excluded from Directive 75/442/EC (the former waste framework Directive) only if such waste waters were covered by other legislation (national or European) that guarantee at least the same level of environmental protection as Directive 75/442/EC. For example, the Court mentioned that the Urban Waste Water Treatment Directive did not say anything about disposal of waste or decontamination of soils and therefore couldn't guarantee a level of environmental protection as high as Directive 75/442/EC. This interpretation of the ECJ was partially taken into consideration by Directive 2008/98/EC which provides that waste waters are excluded from its scope to the extent that they are covered by other Community legislation.

Thus, it is probable that sewage sludge when discarded or intended to be discarded is waste that falls within the scope of the Directive 2008/98/EC because as the ECJ stressed, it is not waste water but a residue of it. In case sewage sludge is included into the definition of waste waters it might anyway be covered by the new framework Directive if other Community legislation dealing with waste waters do not guarantee at least the same level of environmental protection as this Directive.

Requirements that must be applied to sewage sludge if sewage sludge falls within the scope of Directive 2008/98/EC as waste:

First of all, under Article 6 of Directive 2008/98/EC certain specified waste shall cease to be waste when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions: the substance or object is commonly used for specific purposes; a market or demand exists for such a substance or object; the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and the use of the substance or object will not lead to overall adverse environmental or human health impacts. The criteria shall include limit values for pollutants where necessary and shall take into account any possible adverse environmental effects of the

[1] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance)

[2] http://eur-lex.europa.eu/Result.do?arg0=Lahti+Energia&arg1=&arg2=&titre=titre&chlang=en&RechType=RECH_mot&idRoot=10&refinecode=JUR*T1%3DV100%3BT2%3D%3BT3%3DV1&Submit=Search

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:62005J0252:EN:HTML

substance or object. Thus, sewage sludge that fulfils these criteria might not be considered waste anymore under Directive 2008/98/EC.

Secondly, under articles 10 and 11 Member States shall take the necessary measures as to ensure that waste is recycled or re-used. When it is not possible to do so, under article 12, waste must undergo safe disposal operations, which meet a certain number of conditions regarding human health and the environment (article 13). These disposal operations must occur without risk to water, soil, plants or animals, must not cause noise or odour nuisances, and must not adversely affect the countryside or places of special interest. Their costs lie with the producer of the waste. Under Article 16, disposal of waste must answer to the principles of self-sufficiency and proximity, meaning that MS shall cooperate to set up a network of waste disposal installations. If sewage sludge falls within the scope of this directive, all these measures will have to be taken into account when dealing with its disposal.

Thirdly, article 15 deals with management responsibility. Member States must ensure that any original waste producer or other holder carries out the treatment of waste himself or has the treatment handled by a dealer or an establishment. Member states may specify the conditions of responsibility for the whole treatment chain and decide that it is to be borne partly or wholly by the producer of the product.

Fourthly, Member States must require any establishment intending to carry out waste treatment to obtain a permit from the competent authority, which shall specify the types and quantities of waste that may be treated, the technical requirements relevant to the site concerned, the safety and precautionary measures to be taken, etc. MS may exempt from these requirements establishments intending to carry out recovery of waste. Under article 34, establishments which carry out waste treatment operations, or collect or transport waste on a professional basis or produce hazardous waste, shall be subject to appropriate periodic inspections by the competent authorities. Establishments that treat sewage sludge will have to fulfil these requirements if sewage sludge falls into the scope of the directive.

Finally it is worth mentioning that Directive 2008/98/EC defines 'bio-waste' as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. Thus, sewage sludge cannot fall within the definition of bio-waste. Under Article 22 of Directive 2008/98/EC, member States shall take measures to encourage, the separate collection of bio-waste with a view to the composting and digestion of bio-waste, the treatment of bio-waste in a way that fulfils a high level of environmental protection; the use of environmentally safe materials produced from bio-waste. The Commission shall also carry out an assessment on the management of bio-waste with a view to submitting a proposal if appropriate. The Commission has come up with a Green paper on the management of bio-waste in the European Union[4].

The current measures on bio-waste under Directive 2008/98/EC and the probable future EC legislation on bio-waste will increase the treatment of bio-waste into compost that can be spread on agricultural fields. Compost from bio-waste might conflict with sewage sludge since compost from bio-waste might have a better environmental reputation. Indeed there are fewer probabilities that it contains hazardous substances compared to sewage sludge.

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0811:FIN:EN:PDF

- **EC Regulation 1907/2006, concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**

The purpose of REACH is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of chemical substances, as well as the free circulation of the substances on the internal market while enhancing competitiveness and innovation. The Regulation applies to the manufacture, placing on the market or use of such substances on their own, in preparations or in articles and to the placing on the market of preparations.

Under the REACH Regulation, waste does not fall within the definition of a chemical substance, preparation or article. Thus, sludge sewages producers are not directly affected by the REACH Regulation. However REACH will have an indirect impact on the sewage sludge composition, as it may lead to a reduction in the levels of chemicals contained.

- **Commission Regulation (EC) No 466/2001**

This regulation sets maximum levels for certain contaminants in foodstuffs set limits for Cadmium in foodstuffs ‘as low as reasonably achievable’ following the precautionary principle. The limits are close to background levels which occur naturally in foodstuffs from uncontaminated sources. The spreading of sewage sludge thus needs to respect these requirements (see section 6).

- **Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No2092/91**

Regulation No 834/2007 provides the basis for the sustainable development of organic production while ensuring the effective functioning of the internal market, guaranteeing fair competition, ensuring consumer confidence and protecting consumer interests. It establishes common objectives and principles concerning all stages of production, preparation and distribution of organic products and their control, and the use of indications referring to organic production in labelling and advertising.

This Regulation does not directly refer to sewage sludge. However, on the requirements for soil, article 12 of this Regulation provides that ‘the fertility and biological activity of the soil shall be maintained and increased by multiannual crop rotation including legumes and other green manure crops, and by the application of livestock manure or organic material, both preferably composted, from organic production.’ It is clear from this provision that the application of material coming from non-organic production, including sewage sludge, is not allowed for organic production.

- **Decision 2006/799 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to soil improvers**

Decision 2006/799 defines soil improvers as ‘materials to be added to the soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity.’ In order to be awarded the Community Eco label, soil improvers shall comply with the criteria set in out in the Annex to Decision 2000/799.
1.1 of the Annex mentions that soils improvers containing sewage sludge shall not be awarded an eco-label.

- **Decision 2007/64 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to growing media**

Decision 2007/799 defines growing media as ‘material other than soils in situ, in which plants are grown.’ In order to be awarded the Community Eco label, growing media shall comply with the criteria set in out in the Annex of this Decision. 1.2 of the Annex mentions that growing media containing sewage sludge shall not be awarded an eco-label.

- **Proposal for a Directive establishing a framework for the protection of soil and amending Directive 2004/35/EC** [5]

The Commission adopted a Soil Thematic Strategy (COM(2006) 231) and a proposal for a Soil Framework Directive (COM(2006) 232) on 22 September 2006 with the objective to protect soils across the EU. Sewage sludge contains organic matters which reduce soil degradation but can also contain pollutants that affect the quality of the soil.

Article 3 of the proposed directive provides that in the development of sectoral policies likely to exacerbate or reduce soil degradation processes, Member States shall identify, describe and assess the impacts of such policies on these processes, in particular in the areas of regional and urban spatial planning, transport, energy, agriculture, rural development, forestry, raw material extraction, trade and industry, product policy, tourism, climate change, environment, nature and landscape. Thus, under this proposal Member States would have to identify, describe and assess the impacts of sewage sludge spreading in agricultural fields on the exacerbation or reduction of soil degradation.

- **Proposal for a Directive on the promotion of renewable energy sources.**[6]

Biogas can be produced from sewage sludge treatment, via a process called anaerobic digestion. Article 2 of the proposed directive on the promotion of renewable energy considers that sewage treatment plant gas is energy from renewable energy sources.

The proposed directive sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. Overall, in 2020 there shall be at least a 20% share of energy from renewable sources in the Community's gross final energy consumption. Such targets are likely to create incentives for the use of renewable energy sources of biogas from sewage sludge. An increase in the production of biogas from sewage sludge is expected to contribute to a reduction in greenhouses gas emissions.

3.2 Member State legislation and policy

The development of guidelines, codes of practice and statutory controls has been an ongoing process at national level since the 1986 Directive was implemented. In some Member States (i.e. Sweden and UK), voluntary agreements set more stringent requirements than those in the Directive or in national regulations. Other initiatives have been the development of quality assurance systems, such as in Germany and Sweden. (This section also provides some information from non-EU Members, notably Switzerland and the US.)

A comprehensive review of national regulatory frameworks has been carried out for the European Commission by Sede and Andersen (2002). This study reported that most EU15 had adopted more stringent limits and management practices than were originally specified by the Directive, either through binding rules or via codes or practice and other voluntary agreements (Sede and Andersen, 2002).

For example, the standards for PTEs adopted in different countries vary considerably (Tables 5 and 6). In addition, standards for compounds not included in the Directive (i.e. pathogens and organics) have been set by some national regulations (Tables 7 and 8).

For the limit values of contaminants in soil-treated sludge (Table 5), most national requirements are similar to the ones specified in the Directive, apart from Denmark, Finland and the Netherlands which

[5] http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf

[6] European Parliament legislative resolution of 17 December 2008 on the proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (COM(2008)0019 – C6-0046/2008 – 2008/0016(COD))

have more stringent limits. Some Member States (Spain, Portugal and the UK) have defined limit values for different categories of soil pH, while the regulations set by Latvia and Poland and the new proposed standards in Germany have defined different categories of soil based on their granulometry (Table 5). In addition, several Member States (Finland, France, Hungary, Luxembourg, Netherlands, Sweden, Belgium (Flanders) and three Lander in Austria) have introduce limitations in terms of maximum annual load of heavy metals on a ten year basis.

A comparison of heavy metal concentrations in sewage sludge (Table 6) between Member States shows that most Member States have more stringent limits than the ones in the Directive.

Agricultural application has been effectively prevented in some countries due to prohibitively stringent national limit values for heavy metals (e.g. the Netherlands, Belgium (Flemish region)). Concerns about the potential consequences for human health and the environment of potentially toxic substances and harmful microorganisms in sludge have even led to the banning of the use of sludge in agriculture in some countries, including Switzerland, despite the recognition that there is no conclusive scientific evidence that the practice is harmful. (FOEN, 2003).

Table 5 Maximum permissible concentrations of potentially toxic elements in sludge-treated soils (mg kg^{-1} dry soil) in EC Member States and US, (SEDE and Andersen, 2002)

	Cd	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Directive 86/278/EEC	1-3	100-150(4)	50-140	1-1.5	30-75	50-300	150-300
Austria							
Lower Austria	1.5/1h)	100	60	1	50	100	200
Upper Austria	1	100	100	1	60	100	300/150(9)
Burgenland	2	100	100	1.5	60	100	300
Vorarlberg	2	100	100	1	60	100	300
Steiermark	2	100	100	1	60	100	300
Carinthia if 5<pH<5.5	0.5	50	40	0.2	30	50	100
if 5.5<pH<6.5	1	75	50	0.5	50	70	150
if pH>6.5	1.5	100	100	1	70	100	200
Belgium, Flanders	0.9	46	49	1.3	18	56	170
Belgium, Walloon	2	100	50	1	50	100	200
Bulgaria							
pH=6-7.4	2	200	100	1	60	80	250
pH>7.4	3	200	140	1	75	100	300
Cyprus	1-3	100-150	50-140	1-1.5	30-75	50-300	150-300
Denmark	0.5	30	40	0.5	15	40	100
Finland	0.5	200	100	0.2	60	60	150
France	2	150	100	1	50	100	300
Germany (6)	1.5	100	60	1	50	100	200
Germany (7)							
Clay	1.5	100	60	1	70	100	200
Loam/silt	1	60	40	0.5	50	70	150
Sand	0.4	30	20	0.1	15	40	60
Greece	3	-	140	1.5	75	300	300
Ireland	1	-	50	1	30	50	150
Italy	1.5	-	100	1	75	100	300
Luxembourg	1-3	100-200	50-140	1-1.5	30-75	50-300	150-300
Estonia (10)	3	100	50	1.5	50	100	300
Hungary	1	75/1 (8)	75	0.5	40	100	200
Latvia	0.5-0.9	40-90	15-70	0.1-0.5	15-70	20-40	50-100
Lithuania	1.5	80	80	1	60	80	260
Malta							
pH 5<6	0.5	30	20	0.1	15	70	60
pH 6-7	1	60	50	0.5	50	70	150
pH >7	1.5	100	100	1	70	100	200
Netherland	0.8	10	36	0.3	30	35	140
Portugal							
Soil ph<5.5	1	50	50	1	30	50	150

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
5.5<soil<7	3	200	100	1.5	75	300	300
Soil ph>7	4	300	200	2	110	450	450
Poland							
Light soil	1	50	25	0.8	20	40	80
Medium soil	2	75	50	1.2	35	60	120
Heavy soil	3	100	75	1.5	50	80	180
Romania	3	100	100	1	50	50	300
Slovakia	1	60	50	0.5	50	70	150
Slovenia	1	100	60	0.8	50	85	200
Spain							
Soil ph<7	1	100	50	1	30	50	150
Soil ph>7	3	150	210	1.5	112	300	450
Sweden	0.4	60	40	0.3	30	40	100
UK(1)	3	400 (5)	135	1	75	300 (3)	20
USA (2)	20	1450	775	9	230	190	1500

(1) For soil of pH ≥5.0, except Cu and Ni are for pH range 6.0 – 7.0; above pH 7.0 Zn = 300 mg kg^{-1} ds (DoE, 1996);
(2) Approximate values calculated from the cumulative pollutant loading rates from Final Part 503 Rule (US, EPA 1993);
(3) Reduction to 200 mg kg^{-1} proposed as a precautionary measure;
(4) EC (1990) – proposed but not adopted;
(5) Provisional value (DoE,1989).
(6) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(7) Proposed new German limits (BMU, 2007)
(8) Chromium VI
(9) For ph<6
(10) In soils where 5<ph<6 it is permitted to use lime-sterilised sludge

Other elements only restricted in some countries or regions:

	Arsenic	**Molybdenum**	**Cobalt**
Steiermark		10	50
Belgium (Flanders)	22		
Hungary	15	7	30

Table 6 Maximum level of heavy metals (mg per kg of dry substance) in sewage sludge used for agricultural purposes. (SEDE and Andersen, 2002, Alabaster and LeBlanc, 2008)

	Cd	**Cr**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Directive 86/278/EEC	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Austria							
Lower Austria	2	50	300	2	25	100	1500
Upper Austria	10	500	500	10	100	400	2000
Burgenland	10	500	500	10	100	500	2000
Voralberg	4	300	500	4	100	150	1800
Steiermark	10	500	500	10	100	500	2000
Carinthia	2.5	100	300	2.5	80	150	1800
Belgium (Flanders)	6	250	375	5	100	300	900
Belgium (Walloon)	10	500	600	10	100	500	2000
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Czech republic	5	200	500	4	100	200	2500
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
Finland	3	300	600	2	100	150	1500
France	20	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Germany (2)	2	80	(600)	1.4	60	100	(1500)
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Latvia	20	2000	1000	16	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Malta	5	800	800	5	200	500	2000
Netherlands	1.25	75	75	0.75	30	100	300
Poland	10	500	800	5	100	500	2500
Portugal	20	1000	1000	16	300	750	2500
Romania	10	500	500	5	100	300	2000
Slovakia	10	1000	1000	10	300	750	2500
Slovenia	0.5	40	30	0.2	30	40	100
Spain	20	1000	1000	16	300	750	2500
Spain	40	1750	1750	25	400	1200	4000
Sweden	2	100	600	2.5	50	100	800
United Kingdom	PTE regulated through limits in soil						

(1) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(2) Proposed new limits (BMU, 2007)
(3) Chromium VI

Other elements only restricted in some countries or regions:

	Arsenic	Molybdenum	Cobalt
Lower Austria			10
Steiermark	20	20	100
Belgium (Flanders)	150		
Denmark	25		
Netherlands	15		
Czech republic	30		
Hungary	75	20	50
Slovakia	20		

For organic contaminants (OCs), there is no consistent approach in setting limit values in sludge between different countries (Table 8) (Smith 2008). Some countries, such as the UK, US and Canada, have argued that there is no technical justification for setting limits on OCs in sludge, on the basis that research has shown that the concentrations present are not hazardous to soil quality, human health or the environment (US Environmental Protection Agency, 1992b,c; WEAO, 2001; Blackmore et al., 2006). However, other countries have established limits for different groups of OCs. For example, in Germany, limits are set for the persistent compounds, AOX (total adsorbable organo-halogen), PCBs (polychlorinated biphenyls) and PCDD/Fs (polychlorinated dibenzodioxins and Polychlorinated dibenzofurans), but not PAHs (polycyclic aromatic hydrocarbons). However, Germany's proposed revised regulation (BMU, 2007) includes a limit for one PAH, benzo(a)pyrene, and France regulates PAHs and PCBs, but not PCDD/Fs. Denmark, on the other hand, has established controls for \ bulk volume chemicals including DEHP (Bis(2-ethylhexyl)phthalate), LAS (Linear Alkylbenzene Sulfonate) and NP/NPE (Nonylphenol/Nonylphenol ethoxylate).

Table 7 Standards for maximum concentrations of pathogens in sewage sludge (Sede and Andersen, 2002; Alabaster and LeBlanc, 2008)

	Salmonella	Other pathogens
Denmark a)	No occurrence	Faecal streptococci:< 100/g
France	8 MPN/10 g DM	Enterovirus: 3 MPCN/10 g of DM Helminths eggs: 3/10 g of DM
Finland (539/2006)	Not detected in 25 g	Escherichia coli <1000 cfu
Italy	1000 MPN/g DM	
Luxembourg		Enterobacteria: 100/g no eggs of worm likely to be contagious
Poland	Sludge cannot be used in agriculture if it contains salmonella	

a) applies to advanced treated sludge only
b) tbc – need to be checked

Table 8 Standards for maximum concentrations of organic contaminants in sewage sludge (mg kg-1 DS except PCDD/F: ng TEQ kg-1 DS) (CEC 1986, EC, 2000 and 2003; SEDE and Andersen, 2002; Alabaster and LeBlanc, 2008; and Smith, 2008;)

	Absorbable organic halides (AOX)	Bis(2-ethylhexyl) phthalate (DEHP)	Linear Alkylbenzene Sulfonate (LAS)	Nonylphenol/ Nonylphenol ethoxylate (NP/NPE)	Polycyclic aromatic hydrocarbon (PAH)	Polychlorinated biphenyls (PCB)	Dioxins/Furans (PCDD/F)	others
Directive 86/278/EEC	-	-	-	-	-	-	-	
EC (2000)a)	500	100	2600	50	6b	0.8c	100	
EC (2003)a)			5000	450	6b	0.8c	100	
Austria								
Lower Austria	500	-	-	-	-	0.2 d)	100	
Upper Austria	500					0.2 d)	100	
Vorarlberg	-					0.2 d)	100	
Carinthia	500				6	1	50	
Denmark (2002)		50	1300	10	3b			
France					Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)		
Germany (BMU 2002)	500					0.2 e)	100	
Germany (BMU 2007) f)	400				Benzo(a)pyrene: 1	0.1 e)	30	MBT+OBT:0.6 Tonalid: 15 Glalaxolide:10
Sweden	-	-	-	50	3b)	0.4c)	-	
Czech Republic	500					0.6		

a proposed but withdrawn
b sum of 9 congeners: acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
c sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
d sum of 6 congeners:PCB28,52,101,138,153,180
e Per congener
f Proposed new limits in Germany (BMU 2007)

The remainder of this section reviews the rules and requirements in selected Member States.

In **Sweden** the Swedish Environmental Protection Agency (Naturvårdsverket) (SEPA) by mandate from the Government has implemented the Directive through the *Regulation regarding protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture* (Kungörelse SNFS (1994:2) med föreskrifter om skydd för miljön, särskilt marken, när avloppsslam används i jordbruket). The Regulation is more stringent than the Directive in that it bans the usage of sewage sludge on pastureland and it regulates the necessary analyses for toxins in soil and sludge. Besides the Regulation, Sweden has adopted legislation on several other aspects of sewage sludge such as maximum permissible concentrations of potentially toxic elements in sewage sludge for commercial use, management of fertilizers (including sludge) in agriculture, requirements and permissions for sewage water treatment plants, deposit of sludge etc. In 1994, SEPA, the Federation of Swedish Farmers (LRF) and the Swedish Water and Waste Water Association (VAV) signed a voluntary agreement regarding quality assurance. This has primarily led to additional requirements for organics and the creation of a consultative group. In Sweden a quality assurance system (ReVAQ) has been designed in concert by the concerned parties, water companies, farmers, nature conservation and the food industry. These stakeholders studied the risks and then agreed the standards that they would endorse for using treated sludge on land. Aspects of the DIN ISO certification are included in the system. A pilot implementation has been successful and the next phase is to develop it as a national scheme. Two main drivers have been the need to heighten acceptance of and trust in the use of sludge in agriculture and to aid the achieving of national environmental targets (EWA 2008).

In the **UK**, a voluntary code was agreed in 2001 between the UK Water Industry and British Retail Consortium, known as the Safe Sludge Matrix (ADAS, 2001), that requires more rigorous control over sludge treatment, pathogen removal and use on land than was previously required by the guidelines in the *Code of Practice for Agricultural Use of Sewage Sludge* and the Statutory Instrument (DoE, 1989; UK SI, 1989) implementing the Directive. Importantly, the Matrix also introduced a two tier system of treatment for sludge with regard to the extent of pathogen removal, and strict land use controls that were analogous to the US EPA's Class A and B pathogen reduction requirements in the Part 503 Standards for the Use or Disposal of Sewage Sludge for agricultural use of sludge (US EPA, 1993).

In **France**, agricultural use of sludge is regulated by the Decree No. 1133 of December 8, 1997 and by the Enforcement Order dated January 8, 1998. This recent legislation was implemented in the broader context of the 1992 Water Act, the 1975 and 1992 Waste Acts and the Health Code. In particular, the 1992 Waste Act restricts the landfilling of sewage sludge from 2002 onwards: from this date, landfilling is limited to waste that cannot be recovered at reasonable cost (defined as "ultimate waste").

France's 97/1133 Decree establishes that before any spreading of sludge on land, a preliminary study must be carried out by the sludge producer identifying the sludge treatment and quality as well as the soil quality. In addition, a land spreading forecast must be established each year, specifying the quantities of sludge to be spread on land, the scheduling of each spreading operation as well as the parcels which will receive sludge. A report on the sludge spread on land and on the resulting impacts on soil qualities must be prepared at the end of the year (defined as the end of the "agricultural campaign"). Both the land spreading forecast and annual report must be transmitted to the local authorities by the sludge producer.

The spreading on land of more than 800 tonnes of sludge (DM) per year is subject to authorisation. For industrial sludge a preliminary study is required for such a permit and must include an evaluation of health risks. The French association of land spreading operators have developed a methodology to evaluate health risks of spreading operations (SYPREA 2007). Since March 2004 there are standards of quality regarding composted sludge approved by national authorities. The compost which reaches this quality standard is being considered as a product. Moreover a quality assurance scheme regarding the beneficial reuse of sludge in agriculture has been set out by the SYPREA. Thirty-seven criteria, which are controlled every year by an independent body, guarantee the respect of the best practices of sludge land spreading.

The French legislation on the spreading of sewage sludge is globally more stringent than Directive 86/278/CEE. For example, it provides that minimal distances should be respected between housings, river banks, bathing places, water wells, shellfish zones and the place where sewage sludge is spread. Furthermore, unlike Directive 86/278/CEE, the French legislation bans the spreading of sewage sludge when the soil is covered by snow or frost or during periods of strong rainfall, and it bans application on slopes.

In **Germany** the application of sewage sludge on land is regulated by the *Sewage Sludge regulation of 15 April 1992 (Klärschlammverordnung, AbfKlärV, last amended 20.10.2006) (BMU, 1992)*. This 1992 regulation strengthened an earlier (1982) version, introducing more stringent limit values for heavy metals. The use of untreated sludge is generally forbidden, as is the use of sludge on horticultural, grassland, forestry land, on land in protected areas, on land in water protection areas, and on river banks. Field vegetables may not be grown on land if sludge has been applied that year or the year before. If crops are used as fodder, sludge can only be applied before seeding and has to be incorporated into the soil. Although there are a number of restrictions governing the spreading of sewage sludge in agriculture, there are still concerns in some parts of Germany that the law governing this outlet is not strict enough.

In 2007, a draft for a new ordinance for sewage sludge (BMU, 2007) was issued by the Ministry of Environment (BMU), following an expert seminar held in December 2006 at the BMU in Bonn (www.bmu.de/abfallwirtschaft/fb/klaerschlamm). Delegates from some Federal States wanted to ban the agricultural use of sewage sludge, mainly because of concerns over the accumulation of organic contaminants in the soil (e.g. Baden-Württemberg (Kaimer (2006)), but recognised that this would not be possible under existing EU and German national legislation. Although the Federal Ministry for the Environment (BMU) as well as most Länder do not support a total ban of the use of sludge on land, some of the Länder think that the currently discussed revision of the German sewage sludge regulation does not go far enough and a total ban should be made possible. In June 2008 the Bavarian Minister for the Environment requested an EU wide ban of the use of sewage sludge on land or a provision in the directive for Member States to allow a ban. Bavaria has already reduced the amount of sludge used from 55% in 1997 to 20% in 2008. The Land wants to further reduce this amount by building several incineration plants at waste water treatment plants. Baden –Württemberg also has proposed an end to the use of sludge on agricultural land and has already initiated a “de facto” ban by restricting certain agricultural subsidies to farmers that do not use sewage sludge on their fields.

The main issues of the 2007 draft revision are a significant reduction of existing limit values for heavy metals and new limit values for organic substances (lower limits for dioxins/dibenzofurans, and some PCB congeners, and the introduction of a limit for benzo(a)pyrene). It was envisaged that the process of adopting the revised ordinance would be initiated in autumn 2008.

In the **Netherlands,** Directive 86/278 has been transposed into national legislation mainly through the “Decree on the quality and use of other organic fertilisers” (Besluit kwaliteit en gebruik overige organische meststoffen), abbreviated as “Boom” (BOOM 1991) The decree entered into force on the 1st of January 1993 – after the Commission concluded on the failure of a timely transposition of the directive in 1990. In 1998, the original decree was replaced by a new “Decree on the quality and use of other organic fertilisers” (BOOM 1998).
In sum, the provisions of Chapter II of the Decree concern the quality of organic fertilizers other than of animal origin such as compost, mud and other sediments, compost, etc. Article 8 includes measures for analysing and certifying these substances. The producers of the fertilizing substances are obliged to keep a register in which the information specified in Article 9 is inserted. Chapter III establishes rules with respect to the use of the fertilizing substances concerned. The use of fertilizing substances other than those which are in conformity with requirements laid down in the attachments is prohibited by Article 12. Articles 28 – 36 contain rules respecting the distribution on the land of fertilizing substances concerned. The 1998 Boom Decree sets more stringent limit values for heavy metals in sludge and in soil than the Directive. This has essentially ended the spreading of sewage sludge on agricultural land in the Netherlands. In principle, the use of sewage sludge is not allowed on land that is not used for agricultural purposes (Article 14 of the Decree). The requirements of quality are based on the Fertilisers Law (Meststoffenwet, 1986), whereas the norms of use are based in the Law on soil protection of the (Wet bodembescherming, 1986 and amendments). The 1998 Decree has been amended in 1996, 2001 and 2005 (amending the Decree use of Fertilizers of Animal Origin 1998, the Decree Quality and Use of Remaining Organic Fertilising Substances, and the Decree Discharge Open Cultivation and Livestock Breeding). Strengthening of norms regarding the use of nitrogen in the Netherlands is mainly based on laws transposing both the Nitrates and Water Framework Directive.

4 Economics of Sludge Treatment and Disposal

Agriculture application, incineration or landfilling are the main routes for sludge management across Europe. The amount of sludge that is incinerated significantly increases when agricultural recycling is discouraged or banned. Increasingly, the landfill option is becoming restricted to the disposal of ash from the incineration of sludge. Minor routes include land reclamation and incorporation, usually of ash, into building materials. The incorporation of whole sludge into bricks has also been tried. These minor routes will not be considered further at this point.

Of the developing processes, pyrolysis is probably the most significant. This can be viewed as an alternative to incineration and may prove to be of lower cost. The solid char that is produced may, however, not prove that easy to dispose of. Sometimes the char is incinerated which would appear to remove much of the advantage claimed for pyrolysis. Pyrolysis will not be considered further in this section but new technology options will be considered in the next stage of reporting (Task 3). Dried sludge can be used as a fuel in e.g. power stations. This could be viewed as incineration in stages, though in this case the ultimate disposal route may not be to landfill. In the UK, power stations are not allowed to burn waste material without meeting the stricter flue gas requirements applicable to waste incinerators, which makes this option unattractive to the electricity generators. No costs are given for this route.

Any disposal option/route requires the sludge to be treated in a range of unit processes which contribute to the overall cost. These include:

- Mechanical thickening and dewatering with the aid of polyelectrolytes for sludge conditioning.
- Anaerobic digestion.
- Drying.
- Lime treatment.
- Heating for pasteurisation.
- Incineration.
- Composting.
- Landfilling. Also land reclamation.
- Use in agriculture. A variant is silviculture where sludge is used in a fast rotation coppice.
- Transport.
- Storage.
- Many sludge treatment processes require odour control plant.

As well as the capital costs, there are operating costs which include:

- Labour.
- Energy. Drying in particular is a major user of energy and composting is a moderate user. Anaerobic digestion produces methane which is usually used in combined heat and power engines to produce a significant surplus of electricity, which can be sold. Incineration also generates electricity but less than used within the process.
- Transport fuel.
- Chemicals such as polyelectrolyte and lime. Lime is used for lime treatment and also to treat incinerator flue gas.
- When a sludge product is used in agriculture, the farmer requires less chemical fertiliser. This is a monetary benefit, whether it accrues to the farmer as is usually the case or to the operator responsible for the sludge.

- Even when the use of chemical nitrogen and phosphorus is reduced according to the levels of available nitrogen and phosphorus in sludge, crop yields can be higher. This could be due to a portion of the N or P in the sludge classed as unavailable, actually having some availability, or to other nutrients in the sludge or to the organic matter acting as a beneficial soil conditioner. The extra crop yield can be given a value.
- Instrumentation and analysis associated with regulatory requirements.
- Landfill tax and landfill gate fees.

A costing exercise for the European Commission was reported in 'Disposal and recycling routes for sewage sludge' (Sede and Andersen, 2002). Where costs have been obtained by WRc, these have been in broad agreement.

These costs are shown in Figure 1, in 2002 Euros.

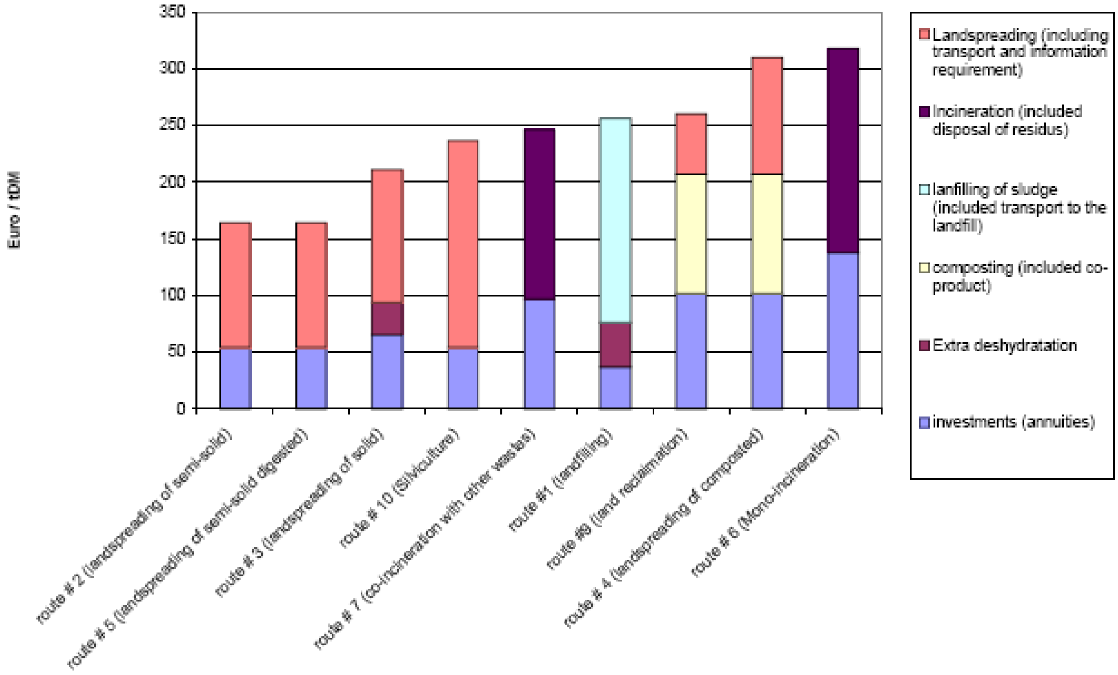

Figure 1 Average internal costs of sludge disposal and recycling in Europe (Euro/ tonne dry matter)

(From SEDE AND ARTHUR ANDERSEN (2002) *Disposal and Recycling Routes for Sewage Sludge*, European Commission, DG Environment – B2, 2002. Available at: http://ec.europa.eu/environment/waste/sludge/sludge_disposal.htm)

The costs in Figure 1 include operating costs and annualised investment costs for capital items. Two of the most commonly employed options are Route #3, the use of sludge cake, usually digested, in agriculture at €210/t DM, and Route #6, incineration in a dedicated incinerator at €320/t DM. Routes that were not costed included lime treatment and any that involved drying. The use of limed raw sludge cake in agriculture in the UK, is cheaper than the use of digested sludge cake (Route #3). Drying is very energy intensive and any route that involves drying would be at least as expensive as dedicated incineration. Despite its expense, drying is used quite frequently since it offers great flexibility to the operator in terms of storage and final destination.

Costs for routes based on use in agriculture assumed that extended storage periods of up to 9 months were required. If these were not required, costs would reduce by €50/t DM. This matches very well with the situation in the UK, where with 3 months storage, the costs for using digested sludge cake in agriculture are around 50% those of dedicated incineration. If additional storage is required this is assumed to be carried out by the farmer at the field-side at no extra cost.

Incinerators require extensive maintenance. If full throughput is required at all times, extra standby capacity is required, increasing costs by 50%.

The costs in Figure 1 include any benefits from energy recovery but not the value of displaced chemical fertiliser, which was costed separately. The value of displaced chemical fertiliser plus additional crop yield for a range of sludge products is shown in Figure 2.

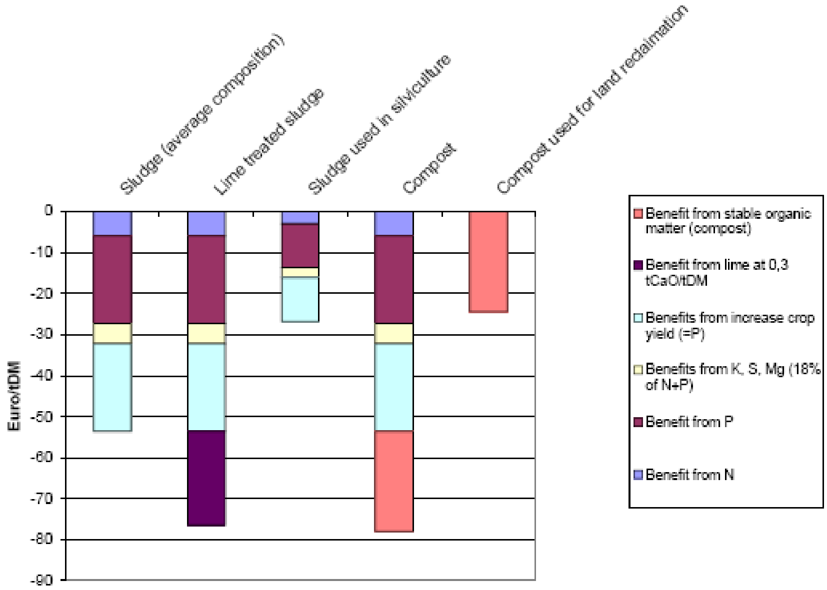

Figure 2 Internal benefits of sludge recycled to land (€/tDM)
(From SEDE AND ARTHUR ANDERSEN (2002) *Disposal and Recycling Routes for Sewage Sludge*, European Commission, DG Environment – B2, 2002. Available at: http://ec.europa.eu/environment/waste/sludge/sludge_disposal.htm)

When comparing routes, the appropriate benefits from Figure 2 should be added to the costs in Figure 1. As an example, to the cost of €210/t DM for the use of sludge cake in agriculture, Route #3, should be added €-53/t DM for the benefit of reduced fertiliser requirement and increased crop yield resulting in just under €160/t DM, which could reduce further given the low storage assumption. This is very much less than the €320/t DM for dedicated incineration.

In the Sede and Andersen (2002) study a range of external impacts was quantified. Some of the impacts from airborne pollutants are quantified in monetary terms but this goes beyond the scope of this section.

Current estimates are that 45% of the EU15 total of 9 million tDM of sewage sludge are used in agriculture (CEC 2006b, Alabaster and LeBlanc, 2008). If this route was lost, to be replaced by incineration, the cost would be of the order of €650 million per year. Andersen suggested a policy of pollution prevention, needed to maintain the agricultural route in the light of the draft revisions to the regulations regarding the use of sewage sludge in agriculture, would cost a similar amount.

5 Agricultural Value of Sewage Sludge

Application of sewage sludge to land recycles nitrogen (N), phosphorus (P), other macronutrients (such as calcium, potassium and sulphur), micronutrients (such as copper and zinc) and organic matter and so confers very positive agricultural benefits. Sewage sludge has also been used successfully in land reclamation, on forest land and in other land applications.

The focus of investigations into the agricultural value of sewage sludge has been on the availability to crops of the N and P it contains and the soil conditioning capability of its organic matter content. The availability factor is the key to determining the fertiliser replacement value of sludge and thereby quantifying its agricultural benefit to farmers.

The availability of sludge N to crops is broadly in the range 15-85% compared with the availability of N in inorganic fertiliser. The availability of N in sludge is largely determined by the treatment process given to the sludge before application to the land. Selection of sludge treatment process is concerned principally with factors such as stabilisation, sanitisation and volume control but it is also important, if the sludge is for agricultural use, to have a sludge product which farmers will want to apply to their land. In general terms the N in anaerobically digested, dewatered sludge cake (20-30% dry solids content) will be at the low end of the scale (15-20% available) whilst liquid digested sludge (3-8% dry solids content), which contains readily plant-available ammonia, will be at the high end of the scale (up to 85% available). Dewatered sludge cake has logistical advantages over liquid sludge and is the sludge product most widely used in agriculture. Sludge cake has the positive attribute that much of its N content is combined with organic matter and will be slowly released to the growing crop roots in the soil as the organic matter decays. Also, the dry solids: N content of sludge cake is comparatively high so an application of sludge cake will add more organic matter to the land before the N limit is reached.

P availability is less influenced by sludge treatment process is likely to be about 50% available in most sludge products. In the case of advanced-treated thermally dried sludge products nutrient availability may be influenced by the physical properties of the dried material. Hard dry sludge pellets of 90%+ dry solids content will break down only gradually in the soil causing very slow release of nutrients.

Thus the agricultural benefit of sludge products has been defined as effectively as is possible for an organic material and many farmers use sludge products, recognising their value and economic benefit. Sludge may be supplied free to the farmer or there may be a charge for a service which would include derivation of rate of application (usually based on the N requirement of the crop and often in the range 5-10 tonne dry solids of sludge per hectare), supply and incorporation of sludge and follow-up monitoring. Demand for sewage sludge in agriculture and for other land uses would undoubtedly be enhanced if it was clearly recognised as a product not a waste, and was accepted as being suitable for use in organic farming and other organic growing practices.

The limiting factor determining the rate of application of sewage sludge to the land is usually the maximum permissible addition of total N which for most purposes is 250 kg N/ha per year as set out in the Nitrates Directive 91/676/EEC. This figure will be reduced in Nitrate Vulnerable Zones to 175 kg N/ha per year. In some circumstances it may be permissible to apply 500 kg N/ha every 2 years if the N availability of the material is low as could be the case for dewatered sludge cake and sludge compost. This would be good for soil conditioning purposes as such an application would supply a beneficial quantity of organic matter to the land. In particular, effective land reclamation operations often require heavy applications of organic matter and nutrients to resuscitate impoverished substrates.

Rate of application of sludge may also be limited or not permissible where the P index of the soil is comparatively high (3-4+) and the P restriction may extend as the requirements of the Water Framework Directive are implemented. Sewage sludge is a P-rich fertiliser product in terms of its P/N content in relation to the P/N requirements of crops. Thus an application of sludge to the land to meet the N requirement of the crop will exceed its requirement for P. Any move to change the permissible rate of application of sludge to land away from the N factor to a baseline determined by the crop requirement for P would have serious implications for the operational viability of the agricultural outlet for sludge because the rate of application would be significantly reduced. Smith (2008) in his review noted that P concentrations in sludge are increasing with the expansion of P removal during waste water treatment and so careful management of nutrient inputs to soil in sludge is necessary to avoid excessive P application. Smith (2008) considered that more information was required on the long-term fate and release of P in sludge-treated agricultural soil in order to assess the agronomic benefit of P and the efficiency of P utilisation by crops. This information is needed as a basis for controlling P accumulation in soil and for minimising risk to the water environment.

Directive 86/278/EEC states that, 'Whereas sludge can have valuable agronomic properties and it is therefore justified to encourage its application in agriculture provided it is used correctly; whereas the use of sewage sludge must not impair the quality of the soil and of agricultural products'. The Directive states also in Article 8 that, 'the sludge shall be used in such a way that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired'. These broad requirements remain sound at the present time and most Member States have available more detailed guidance on how to utilise effectively the nutrient and organic matter content of sludge in agriculture, based on information obtained from field trials carried out on local farms. In view of this, it would seem to be unnecessary to alter 86/278/EEC as regards sludge utilisation and nutrient management with the proviso that a watching brief is kept on P and more information is obtained about the accumulation and fate of P in sludge-treated soils.

6 Contaminants and Pathogens

6.1 Potentially Toxic Elements

The potentially toxic elements (PTEs) include heavy metals and other inorganic elements which may be found in sewage sludge. When sludge is applied to the land the PTEs will tend to accumulate in the cultivated layer of topsoil and following repeated applications of sludge the PTEs could theoretically accumulate to toxic concentrations which might adversely affect for example crop growth and quality, soil fertility and the food chain. Directive 86/278/EEC sets limits for cadmium, copper, nickel, lead, zinc and mercury. Chromium was on the list but was not given a limit. Some Member States have set limits for more PTEs e.g. in the UK there are additional guideline limits for arsenic, fluoride, molybdenum and selenium (see section 3). The way in which Directive 86/278/EEC sets the PTE limits is flexible because they are given as permissible ranges in both soil and sludge and implementation. The Directive states: 'Whereas, moreover, it is necessary to prevent these limit values from being exceeded as a result of the use of sludge; whereas, to this end, it is necessary to limit the amount of heavy metals added to cultivated soil either by setting maximum quantities for the amounts of sludge used per annum and ensuring that the limit values for the concentration of heavy metals in the sludge used are not exceeded or by seeking to ensure that limit values for the quantities of heavy metals that can be added to the soil on the basis of a 10-year average are not exceeded'.

New developments on PTEs in sludge recycled to land include the effect of Zn on soil microorganisms and soil fertility, and the impact of Cd in soil on Cd concentrations in certain foods. Effects of PTEs on soil microorganisms and soil fertility have been the subject of detailed field investigations in the UK (DEFRA 2002, DEFRA 2007). Definitive effects requiring changes to the soil metal limits have yet to be identified but the findings confirm that the precautionary change for Zn from 300 mg/kg to 200 mg/kg for soils of pH value 5.5 – 7.0 was appropriate.

Commission Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs set limits for Cd in foodstuffs 'as low as reasonably achievable' following the precautionary principle. The limits are close to background levels which occur naturally in foodstuffs from uncontaminated sources. The levels for Cd in cereal grains and offal may not be compatible with the existing soil limit of 3 mg Cd/kg where sludge is recycled to land. This needs further evaluation – however, concentrations of Cd (and indeed of other PTEs) in sludge have declined substantially over the years due to tighter controls on discharges from industrial premises and reduction in the use of PTEs in industry. In practice, it is unlikely that applications of sludge to the land, at rates determined as they are by N content, would increase the concentration of Cd in the soil to the extent that the limits for Cd in grain or offal would be exceeded.

A recent risk assessment of sludge in soil conducted by INERIS for EFAR considered the presence of the metals, cadmium, chromium III, copper, mercury, nickel, lead and zinc (together with the organic compounds, mentioned in drafts related to revision of the Sludge Directive in 2003) (EFAR, 2008). They evaluated the potential hazard of each substance to derive a toxicological reference value (TRF), which they compared with an exposure value to give a hazard quotient (Exposure ÷ TRF), a value over 1 being considered concern for human health. The exposure value considered consumers, neighbours and farmers as receptors, and ingestion via soil, water, animals, vegetables and fish for a 70 year lifespan. The results confirmed that the major exposure pathway is the ingestion of plants and animals. The major substances were the heavy metals, zinc, lead, cadmium, copper and nickel. The study concluded that the contribution of sludge spreading to land to the global risk is low compared to the ingestion of food produced on non-spread lands. Nevertheless, the report suggested a reduction in the permissible Pb concentration in sludge for recycling from a maximum of 750 mg/kg ds (in

86/278/EEC) to 500 mg/kg. This would achieve an acceptable level of risk with 70 years of exposure based on very conservative assumptions.

Smith (2008) points out that there remains further scope to reduce the concentrations of problematic contaminants, and PTEs in particular, in sludge. He suggests that this should continue to be a priority and pursued proactively by environmental regulators and the water industry as improving the chemical quality of sludge as far as practicable is central to ensuring the long-term sustainability of recycling sewage sludge in agriculture.

Monitoring and research needs to continue to assess the significance of new developments (including PTEs of new interest e.g. tungsten) as they arise.

6.2 Organic Contaminants

The presence of organic contaminants (OCs) in sludge has been considered to a much greater extent in recent years; the European Commission and JRC has launched their own review in 2001 (EC 2001). The list of potential contaminants that have been detected in sludge is now extensive and includes: products of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dioxins), solvents (e.g. chlorinated paraffins), flame retardants (e.g. polybrominated diphenyl ethers), plasticisers (e.g. phthalates), agricultural chemicals (e.g. pesticides), detergent residues (e.g. linear alkyl sulphonates, nonylphenol ethoxylates), pharmaceuticals and personal care products (e.g. antibiotics, endogenous and synthetic hormones, triclosan) (Smith, 2008).

Some countries such as UK, USA and Canada have not set any limit on OCs in sludge suggesting that research indicates that concentrations present are not hazardous to human health, the environment or soil quality. However, other countries have set limits for some OC groups. For example, Germany has set limits for PCBs and dioxins but not PAHs while France has limits for PAHs and PCBs but not dioxins. Denmark has set limits for a range of OCs including linear alkyl sulphonates, nonylphenol and nonylphenol ethoxylates and the phthalate, di(ethylhexyl)phthalate (DEHP). Therefore, agreement on which OCs should be regulated in sludge could prove to be a major point of discussion when the Sludge Directive is considered for revision.

A considerable amount of information is known on the fate and behaviour of these substances to enable assessment of their potential effects on human health. Ingestion of crop plants and grazing livestock that have taken up OCs from sludge is a potential exposure route for humans. OCs have a number of physicochemical properties which may affect their behaviour in sludge and potential uptake into plants and animals. OCs include volatile compounds which are rapidly lost to the atmosphere from sludge and sludge-treated soil; compounds with little persistence which are mineralised by microorganisms; and persistent compounds which are strongly absorbed to sludge and the soil organic matrix. Compounds with some water solubility have a greater potential for plant uptake but are also more susceptible to rapid degradation or lost through volatilisation or leaching. For example, nonylphenol and nonylphenol ethoxylates have the potential for uptake by crops but are rapidly degraded in soil (half-life of 20-60 days for nonylphenol). The principal concern for livestock grazing on sludge-treated pasture is the potential accumulation of lipophilic OCs in meat fat and milk. Of the main OCs, only the chlorinated hydrocarbons meet this criterion. The review of Smith (2008) suggests that the potential impact of OCs on grazing animals, in terms of subtle physiological responses is very difficult to measure in practice.

The polymer, polyacrylamide, is used extensively as a polyelectrolyte to aid mechanical dewatering of sludge and may constitute up to 1% of the dry sludge. Small amounts of the unchanged monomeric, acrylamide, may be present with the polymer and this has the potential to form *N*-nitrosodimethylamine. While the polymer is inert, both acrylamide and *N*-nitrosodimethylamine are under assessment as potential carcinogens (both classified as 2A, probable human carcinogens, by the

International Agency for Research on Cancer (IARC)). However, rapid degradation in soil and absence of plant uptake and accumulation suggests no transmission to the human foodchain via sludge.

Pharmaceuticals and personal care products have been increasingly detected in waste water. However, although less is known about their behaviour in the environment, it is envisaged that their fate and behaviour will depend on their physicochemical properties as for other OCs described above. There are particular concerns about the presence of antibiotics and the antimicrobial agent, triclosan and their potential indirect effects on human health through effects and resistance in the microbial environment. The present of antibiotic populations of bacteria in soil has been linked to the use of antibiotic in livestock. Although the concentrations of pharmaceuticals in waste water appear to be low, as more knowledge is gained on their presence in sludge, further assessment of their potential effects on human health may need to be made.

There is also concern over the presence of endocrine disrupting chemicals including natural and synthetic hormones and the much less potent industrial agents such as phthalates and their presence in sludge. Endogenous and synthetic oestrogenic compounds do partition to particulates and may be associated with sludge but there is only limited information at present on levels and biodegradation. It appears likely that oestrogenic substances excreted from farm livestock waste will constitute a greater load to the soil than sludge.

Another emerging group of potential contaminants about which nothing is known at present in terms of fate and behaviour in waste water processes are nanoparticles. These are being increasingly used in a range of technologies from personal care products to industrial processes. As more is known about their fate in the environment, assessment will have to be made on their potential presence in sludge spread to land.

There have been a number of risk assessments conducted on the presence of OCs in sludge (reviewed by Smith, 2008). These have concluded that exposure to OCs from the agricultural use of sludge is no greater than background levels. A recent risk assessment of sludge in soil conducted by INERIS(EFAR, 2008) considered the presence of the PTE together with the OCs mentioned in drafts related to revision of the Sludge Directive in 2003, PAHs (with benzo[a]pyrene considered separately), dioxins, PCBs, nonylphenols and nonylphenol ethoxylates and linear alkyl sulphonates, together with DEHP. They evaluated the potential hazard of each substance to derive a toxicological reference value (TRF), which they compared with an exposure value to give a hazard quotient (Exposure ÷ TRF), a value over 1 being considered concern for human health. The exposure value considered consumers, neighbours and farmers as receptors, and ingestion via soil, water, animals, vegetables and fish for a 70 year lifespan. The results confirmed that the major exposure pathway is the ingestion of plants and animals and that heavy metals were the major substances, with PAHs and PCBs being the only major OCs. The study concluded that the contribution of sludge spreading to land to the global risk is low compared to the ingestion of food produced on non-spread lands. OCs such as linear alkyl sulphonates, DEHP and nonylphenols did not contribute significantly to global risk.

Another consideration when assessing the need for OCs to be considered for regulation in any revision of the Sludge Directive is that many of the potential contaminants are already being controlled under other legislation and so the potential levels in sludge are already decreasing. For example, nonylphenols, DEHP, polybrominated diphenyl ethers and other flame retardants, some pesticides and some chlorinated solvents are on the Priority Hazardous Substances or other pollutants lists for the Water Framework Directive. So it appears likely that the majority of the known pollutants will be increasingly controlled at source.

In summary, the reviews of the research on OCs in sludge conducted so far have concluded that they are unlikely to have an adverse effect on human health and will be increasingly controlled by regulation. However, contaminants such as DEHP and chlorinated paraffins, found in sludge at higher levels will need to be further assessed. Further vigilance is also required on emerging contaminants such as pharmaceuticals, where the potential fate and behaviour in waste water, sludge and soil is unclear at present.

6.3 Pathogens, Treatment of Sludge and Land Uses Practices

6.3.1 Current situation

Sludges produced from the treatment of waste water contain a broad range of pathogenic organisms, including viruses, bacteria, parasitic protozoa and helminths. Human, animal and plant populations are exposed to the risk of contact with pathogens in sewage effluents and sewage sludge in the following main ways:

- discharge of sewage into watercourses and bathing waters;
- recycling of sludge onto agricultural land, or renovated land.

Of these only discharge of sewage into bathing waters is subject to specific microbial controls at European level, under the Directive on Bathing Waters (2006/7/EC), whose requirements were developed following extensive human exposure trials.

The risk of pathogen transmission from sewage sludge into human, animal or plant receptors continues to be a major concern to the public, which has been reflected in individual country regulations and codes of practice, and in the significant reduction or complete elimination of agricultural use of sewage sludge in some countries in the EU.

Implementation of the requirements of Directive 86/278/EEC provides effective barriers to the transmission of disease. These have been implemented in different ways in different countries. Although the Directive provided no specification of microbial quality or guidance on appropriate treatment methods the only clear evidence for transfer of disease from sewage sludge has been in a few instances where its requirements have not been properly implemented or where operators may have been using unhygienic practices.

This has not allayed public concerns over the potential for disease transfer. In some countries, for example the UK, regulatory requirements stemming from the Directive, with guidance provided on the types of processes that have been regarded as providing appropriate levels of treatment have been supplemented by “voluntary” agreements that enhance sewage sludge quality requirements. Hence the “Safe Sludge Matrix” in the UK was devised after extensive study of the evidence for pathogen decay in treatment and recycling processes.

The Safe Sludge Matrix provides descriptions of two levels of treatment to achieve specified numbers of *E.coli* and *Salmonella* spp in sludge. The enhanced treated sludge quality standard is only achieved as a result of a degree of treatment that achieves at least some additional pasteurisation, usually involving a thermophilic stage, and potentially also multistage treatment that reduces the likelihood of significant amounts of sludge failing to be retained for a minimum period in the process.

By instituting this and also developing a control and monitoring philosophy for sludge treatment processes that identify critical points in a process stream and ensuring that these are measured and have to meet previously agreed criteria in order for sludge to be regarded as treated or enhanced treated sludge, there appears to be improved acceptance that sludge may be beneficially used on agricultural land without unacceptable hazards to public health.

6.3.2 Pathogen exposure and consequences

Direct exposure is considered an occupational health risk to those producing and applying sludge to land. Epidemiological evidence indicates risks of illness are low from this route when sludge has been treated. There have been some examples of illness resulting from poor hygienic practice (e.g. failure to wash hands, lack of protective equipment).
Various studies have assessed the health risk of workers and other populations in the vicinity of sludge operations as a result of aerosol dispersion of pathogens and residues in the sludge. Some findings (for example Tanner et al, 2008) have suggested that there may be a significantly increased risk of illness in close proximity to loading operations from field site storage of treated sludge to the spreader trucks. Other findings on the health effects on populations residing nearby have not shown any unequivocal evidence for increased risks. These studies are difficult to carry out and many of them suffer from low population numbers and lack of equivalent non-exposed populations, as well as difficulties in assessing measurable illness. It is possible that a combination of endotoxins and pathogens may enhance infectivity.

Various indirect transmission routes exist. The most obvious are sludge applied to land and subsequent use of the land for food production, either for crops or animal husbandry. These routes have been widely studied (Carrington et al, 1998) with attempts to carry out risk assessments using assumptions about ingestion and infection rates. There have been no clearly identified public infections resulting from agricultural use of sewage sludge when it has been used in accordance with the provisions in the Directive, including local additional controls. Gale *et al.* (2003) applied Quantitative Microbial Risk Assessment (QMRA) to assess human exposure to a range of pathogens from sludge applied to land subsequently used to cultivate a range of agricultural crops. Generally, the risks were found to be low although a number of uncertainties were recognised, particularly regarding the lack of reliable data on the long term decay characteristics of pathogens in the environment.

Run-off from land on which sludge has been used is another possible route, with discharges into recreational water, or sources of water used for producing drinking water or longer term contamination of groundwater. This also ties into requirements under the Water Framework Directive. Some workers have reported that faecal indicators and viruses can be detected at a considerable distance in groundwater from possible sources of contamination.

The risk of presence of animal pathogens in sewage sludge cannot be excluded where waste from abattoirs or other animal processing may enter sewer system. Bacteria and parasites may infect humans and animals. Viruses tend to be host specific although there have been recent concerns over zoonotic transmission of certain viruses. Helminths have well defined life-cycles and host specificities but animal to animal transmission may occur where the land is used for grazing.

Plant pathogens may also be present, derived for example, from vegetable washings. Most washing is probably now carried out immediately post harvest, and is likely to be in the vicinity of the producer, so that there may now be a reduced likelihood of transmission of significant levels of pathogens into uninfected areas. Increased use of food waste disposal into sewers may be an additional route for introduction of plant pathogens into sewage and sludge.

6.3.3 Pathogen risk minimisation

The Directive 86/278/EEC includes:

- A requirement for treatment of sludge to reduce its health hazards before using it in agriculture
- A permit, on certain conditions, to use untreated sludge, without risk to human or animal health, if it is injected or worked into the soil;
- Restrictions on applications to sensitive crops and on use of the soil for periods after application.

These conditions provide barriers to the transmission of risks of infection.

In the UK extensive studies (CEC, 1992) on use of sewage sludge on agricultural land were carried out that led to guidance documents and codes of practice to control use and operations, prior to the implementation of the 1986 directive. Risks of animal, plant and human infections were recognised, although there was a lack of clear evidence that for recorded outbreaks of salmonellosis in animals sewage sludge was the route of infection, as most routes for infection were within existing agricultural activities. Other animal infections were also more closely related to agricultural activities than to the water industry.

The EU COST 68 working group studies (CEC, 1992) found some limited evidence for viral hepatitis due to use on vegetables, run-off from fields with incorrect application, and direct contamination of operators using very poor personal hygiene. The 1986 restrictions on planting, grazing and cropping, in conjunction with local additional controls have been considered appropriate to allow time for sufficient viral inactivation.

Time is not necessarily a secure barrier, as some parasites are capable of surviving non-thermophilic sludge treatments and persist in the environment for long periods of time. These include *Cryptosporidium*, and *Ascaris* spp.

Many plant pathogens could be present in sewage sludge. In the UK, before 1989, studies (Carrington et al, 1998) identified the potato cyst nematode as a significant sludge related hazard which resulted in a specific ban on sludge use on land to be used for seed potato growth in the UK Code of Practice. Some other plant diseases may also be transferred into sewage sludge but have not been considered to have sufficient risk to justify exceptional treatment or recycling restrictions.

The Sewage Sludge Directive provides no examples of appropriate treatment processes, but defines treated sludge as sludge that has undergone *"biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use"*.

The appropriateness of sludge treatments for individual applications is derogated to individual countries to regulate, with an exemption to report on the treatments required for treatment works of less than 5000 population equivalent.

The use of untreated sewage sludge is only permitted in the directive under specific conditions of requiring injection or working into the soil and under regulation by each country (Art.6).

Treatment processes used include biological (digestion), chemical (lime treatment), and physical (high temperature drying). All these have different pathogen removal or inactivation characteristics, which vary from the relatively modest capability of mesophilic anaerobic digestion to reduce measurable *E.coli* concentrations by one hundred-fold with significant variation in effectiveness, to the substantially complete inactivation of vegetative cells achieved by thermal drying.

Variants of treatment methods that include thermal stages and multiple barriers to inhibit short-circuiting enable greatly improved reliability and confidence in the expected pathogen content of treated sludge. HACCP is also now used in the UK to manage treatment processes in conjunction with the Safe Sludge Matrix to provide assurance that processes are well managed.

There are areas of uncertainty in pathogen inactivation in treatment processes. For example, inactivation mechanisms in the widely used anaerobic digestion process are poorly understood, with potential for improvements; measurements of *E.coli* after dewatering processes sometimes show unexpected increases in concentration; and thermal inactivation may be linked to development of viable but non-culturable vegetative cells, also leading to difficulty in assessing the true pathogen quality of a treated sludge.

6.3.4 Pathogens of greatest risk

The occurrence of human pathogens is of most concern and has been the subject of a considerable amount of research to assess the health risks associated with the land applications of sludge. Largely, the organisms responsible are those pathogens that infect through the faecal-oral route, although respiratory and blood borne organisms may occur although prevalence generally low.

The nature and extent of human pathogens present largely depends on prevailing levels of infection in the community where the waste water is derived and the treatment used to produce the Sludge. Demographic variation of illness across the EU will influence the pathogen composition in waste water and may place a greater burden on the treatment barriers.

Potential issues include:

- new and emerging organisms, including antibiotic resistance,
- impact of climate change.

There are no widely accepted new risk pathogens in sewage sludge, although from time to time there are new public concerns about individual human pathogens. Since the work carried out for the 1986 Directive there have been developments in understanding quantitative microbial risk assessments and new assessments have been carried out for some pathogens including new variant CJD and *E. coli* O157;H7, in response to particular topical concerns.

6.3.5 Areas of uncertainty

- Since the 1986 directive some animal health issues have been recognised to be due to a range of pathogens potentially present in sludge – rotaviruses, cryptosporidium, and various bacteria;
- Full review of wide range of pathogens was not included during development of the studies associated with the 1986 directive, and whilst information was developed for the UK implementation of the safe sludge matrix this may need to be validated for other EU states;
- Sludge treatment is a crucial barrier to prevent disease transmission and requires better regulation and improved monitoring. The current indicators of process performance, *E. coli* and *Salmonella*, are vegetative bacteria and are not sufficiently robust to act as surrogates for the fate and behaviour of all pathogens of concern. Other organisms have been considered (e.g. enterococci and spore forming bacteria). However, consideration should be given to process verification by monitoring time and temperature requirements and relegate indicator and pathogen monitoring to process validation. This approach fits very much alongside the strategy being adopted in the forthcoming revision to the Drinking Water Directive and the adoption of Water Safety Plans. On this basis, a number of specific issues should be considered, such as;

- Should all EU be regulated in the same way, with the same sludge qualities required;
- What are suitable indicator organisms – see bathing waters enquiries – *E.coli* has been considered to be a good indicator as it is usually present at high concentrations, has similar sensitivities to treatments as a range of pathogens, and inexpensive measurement methods are well established. *Salmonella* is also used in the UK to monitor enhanced treatments. Faecal streptococci, used for bathing water standards, and Clostridia, as an indicator for spore forming pathogens have both been considered as additional or alternative indicators.
- Alternatively, should treatment processes be defined on the basis of process performance and validation;

- Should the impact of regrowth / reinfection potential be taken into account – pseudo stabilised versus stabilised sludges (CEN standard) on process verification if the existing indicator organisms continued to be used ;
- Should all sludges be fully safe for all handling at all stages subsequent to leaving a treatment works, without requiring any knowledge and training of operators or applying a degree of training to reduce occupational exposure ;
- Is the importance of the agricultural outlet sufficiently great for all sludge to be treated to the extent that there is no significant risk of further fermentation and odour generation;
- Are there newly understood exposure pathways; the improved knowledge of quantitative microbial risk assessment methods may be beneficial in improved assessments of a wider range of pathogens than so far carried out.
- Sustainability – long term decay of pathogens; build up of pathogen pool? Has land with long term sludge application greater background of wide range of pathogens
- Aerosol measurements – some have been carried out to assess the extent of distribution of indicator organisms in air during sludge recycling, and have so far indicated that risks of transmission through this route are relatively low, but the extent of the studies has been limited. These studies are difficult to carry out and need to be co-ordinated with other epidemiological studies.
- How will changing compositions of sewage sludge affect pathogen content; for example, co-treatment of food wastes, and other biodegradable materials either as a result of deliberate diversion from less beneficial routes, including household diversion to drains and sewers of materials hitherto treated as domestic solid wastes.

7 Water and Air Pollution

The preamble to Directive 86/278/EEC states that: 'Whereas sludge should be used under conditions which ensure that the soil and surface and ground water are protected, in accordance with Directives 75/440/EEC (OJ No L194,25.7.1975, p.26) and 80/68/EEC (OJ No L 20, 26.1.1980, p.43)'. One of the rules in Article 8 of 86/278/EEC which shall be observed when using sludge states: 'The sludge shall be used in such a way that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired'. If the sludge is applied to meet, as far as possible, the plant nutrient requirements of the crop then the potential for leaching or runoff of excess nutrients will be reduced. In short, the control of water pollution where sludge is recycled to land is managed by adjusting the rate of application to be compatible with crop requirements for nutrients and applying land use practices which restrict or prohibit sludge application where there is a high risk of water pollution.

The principles for water pollution control set out in Directive 86/278/EEC remain sound but a revision could take account of updates in water pollution control legislation and guidelines for land use practices where sludge is used on the land. Domestic guidelines in some Member States already work to these updates which include the Nitrates Directive 91/676/ EEC and The Water Framework Directive 2000/60/EC.

In order to provide a perspective on the potential for water pollution control from landspreading of sewage sludge it can be estimated that in the EU, sludge contributes <5% annually of the total amount of organic manure recycled to land (most of which is of farm animal origin) and is applied to <5% of the available agricultural land bank. Sludge represents a minor input of nutrients to the land compared with farm animal manure and inorganic fertilisers.

The Nitrates Directive 91/676/EEC was designed to protect waters against pollution caused by nitrates from agriculture. It aims to reduce the level of nitrate losses in the catchments of polluted waters, and to prevent further new pollution. The Directive requires Member States to designate areas at risk from nitrate pollution as Nitrate Vulnerable Zones (NVZs) and to establish mandatory "action programme" measures within them. The Action Programmes control both the timing and rate of applications of both inorganic (chemical) nitrogen fertilisers and organic manures (including sewage sludge). For organic manures, farm-based limits of 250 kg N/ha on grassland and 170 kg N/ha on arable land will apply to the overall area of the farm within the NVZ. A field-based limit of 250 kg N/ha will apply to dressings of organic manure to individual fields. Sludge is applied to land in accordance with 91/676/EEC, usually at a rate supplying 250 kg N/ha. In addition, farmers are required to maintain adequate records of their cropping and stocking, together with details, in the form of fertiliser and manure plans, of all applications of in organic nitrogen and organic manures.

The Water Framework Directive 2000/60/EC was designed to provide an integrated approach to managing water bodies in the EU by considering in an holistic manner all the environmental drivers and pressures within river basins. The WFD legislation supersedes and updates existing legislation, and although this will not include the sludge Directive 86/278/EEC, it will potentially have an impact on the application of sludge to land. Nitrogen and phosphorus are under scrutiny because of their potentially significant impact on surface waters in causing eutrophication. The need to reduce diffuse N and P from agricultural routes may result in further limitations being placed on N and P inputs to soils, this will affect landspreading of all fertilising materials. The WFD may result in higher concentrations of P in sludge as concentrations of P in final effluent from waste water treatment works are further restricted (see Section 4 on Agricultural Value of Sewage Sludge).

Apart from nutrients, sewage sludge is organic manure with a significant chemical oxygen demand (COD) and which contains enteric microorganisms which further demonstrate the need to manage sludge recycling operations so that runoff into surface water in particular is avoided. This requires attention to farm and fieldside storage, imposition of buffer zones adjacent to banksides and water sources, and taking account of topography, application rates and prevailing soil and weather conditions. Operational guidance on landspreading of sewage sludge is included in the domestic guidelines for sludge recycling in some Member States and in more general guidance on good agricultural practice.

While the emphasis of control on water pollution where sludge is used on land lies with management of N and P, PTEs, organic micropollutants and pathogens have also been investigated in this context especially as regards leaching into groundwater. A watching brief needs to be kept on leaching of persistent organic micropollutants from sludge-treated soil.

Odour is usually the issue immediately noticed by the general population during distribution of sludge onto agricultural land (see Stakeholder Interests, section 9). Odour is also a very important factor at sewage treatment works and increasingly works have to meet control requirements, including covers on tanks and limiting the storage of raw and treated sludges at the works and appropriate emission controls and treatment processes. Very many chemicals are present in odour plumes, including ammonia, hydrogen sulphide and mercaptans.

8 Greenhouse Gas Emissions and Carbon Footprint

Responsible operators will generally wish to report their emissions of greenhouse gases. This will often include a list of their on-site emissions and certain off-site emissions for which they are particularly responsible such as those associated with the use of electricity and, in the case of sludge, emissions associated with its use in agriculture. Carbon footprints are more likely to be used to assist in the selection of sludge treatment processes or routes. A carbon footprint is based on a life-cycle analysis and draws a wider envelope around a process, such that in addition to the emissions above it will also include emissions embodied in materials of construction and consumables such as chemicals, emissions associated with transport and perhaps a wider range of off-site emissions.

The major greenhouse gases associated with sludge processing and disposal or re-use are carbon dioxide, CO_2, methane, CH_4 and nitrous oxide, N_2O. Sludge solids contain from 30-40% carbon, most of which is converted to carbon dioxide during treatment and disposal or use. This carbon dioxide is considered to be ‘short cycle’. It is returning CO_2 to the atmosphere that was withdrawn by plants in the recent past. This CO_2 does not contribute to global warming. The Intergovernmental Panel on Climate Change, IPCC, does not require countries to report such short cycle CO_2 and it is not considered further in this section. There are still considerable emissions of fossil fuel derived or ‘long cycle’ CO_2 associated with energy use, transport and embodied in materials of construction and consumables and which does contribute to global warming. Emissions of CH_4, while technically containing short-cycle carbon, are considered to be as a result of the anthropogenic conversion of CO_2 to CH_4. Since the latter has a much greater global warming potential this should be reported or included in any assessment of carbon footprint.

CO_2 emissions are associated with:

- The use of energy. Most countries will have produced country specific emissions factors for major sources of energy such as electricity and natural gas. The former, in particular will be based on the particular mix of electricity generation installed in a country.
- Transport. IPCC publish default CO2 emission factors for transport based on vehicle type and miles travelled or on quantities of fuel used.
- CO2 emissions are associated with materials of construction and consumables used. These embodied emissions include that associated with the energy consumed during manufacture, particular process emissions such as the CO_2 produced during the manufacture of cement and the carbon contained within materials such as plastics. Embodied emission factors are obtainable from databases associated with LCA software.

When a process generates useful net energy, this is seen as displacing the requirement for fossil fuel and the CO_2 associated with the generated energy is considered to be a negative emission. The largest generation of electricity is associated with the use of biogas from the anaerobic digestion of sludge in combined heat and power plant, CHP. Significant amounts of energy are generated in steam turbines on sludge incinerators. Frequently, the electricity generated is less than that consumed by the incineration process. The incineration of a well dewatered raw sludge is most likely to lead to a small surplus of energy for export but less than from the digestion of the equivalent amount of sludge. The incineration of dried sludge may produce much larger amounts of electricity but this would be balanced by the energy requirements for drying.

When a product is beneficially used, such as sludge in agriculture, the CO_2 embodied in displaced chemical fertiliser is considered to be a negative emission. If the carbon in sludge was prevented from being converted to CO_2 over a sufficiently long time, this would be considered to be sequestration, and could be ascribed a negative emission. IPCC allows the estimation of sequestration of carbon in soil due to change of use, but not due to the addition of manure or sludge. Some researchers consider that a portion of the carbon in sludge used in agriculture will be sequestered in the soil but it is not believed that any national inventories of greenhouse gas emissions consider sequestered carbon from sludge used in agriculture.

Significant amounts of methane are generated during the processing, storage and disposal or use of sewage sludge. On-site emissions in the UK have been estimated, as shown in Table 9.

Table 9 Methane losses associated with anaerobic digestion and application of cake to land

Source	**Loss as % of total gas produced**	**Loss (kg CH_4/tonne DS)**	**Loss as % of total gas produced**	**Loss (kg CH_4/tonne DS)**
	Existing plant with secondary digestion		New plant with buffer storage	
Losses via annular space of floating roof digesters	2.5%	3.3	0.0%	0.0
Venting due to ignition failure and downtime at flare stacks	0.21%	0.29	0.21%	0.29
Incomplete combustion	1%	1.45	1.0%	1.45
Fugitive emissions	3.8%	5.1	1.0%	1.3
Secondary digestion/buffer storage	5.9%	8	1.5%	2.0
Total	13.4%	18.1	3.7%	5.1

The first two columns are considered applicable to typical existing plant and form the basis for the UK to report emissions of methane from sludge treatment. The second two columns are applicable to new plant which are all of fixed roof type, will have a lower level of fugitive emissions and where 14-day secondary digestion is replaced by a much shorter period of storage prior to dewatering. There are no further emissions of methane if the digested sludge is incinerated and considerable further emissions if the sludge is sent to landfill, a disposal route which has almost ceased in the UK. When sludge is used in agriculture there are further emissions from the emissions of storage of solid cake, which might be from within a sewage treatment works or from field-side storage. Further methane emissions are associated with the spreading of sludge cake on land, which, however, are minimal in a cool climate such as the UK. IPCC Good Practice Guidelines contains emission factors for the storage and spreading of sludge.

When sewage sludge is used in agriculture, there are associated emissions of nitrous oxide as nitrogen mineralises and oxidises. These can be broken down into direct emissions from the soil following application of sludge, and indirect emissions. The indirect emissions come from both nitrogen other than N_2O which is volatilised (mostly ammonia) and which later deposits back onto the land leading to further N_2O emissions and from ammonia in leachate which ends up in rivers where it stimulates further N_2O emissions. The direct emissions of N_2O from the use of sewage sludge in agriculture are equal to 0.01 times the nitrogen content in the sludge.

When sludge is used in agriculture it will replace the use of chemical fertiliser. The nitrous oxide emissions associated with that fertiliser are considered to be a negative emission. If all of the nitrogen in the sludge were available to plants the N_2O emissions from the soil after application would be balanced by the reduced N_2O emissions from the chemical fertiliser. In fact as little as 20% of the nitrogen in digested sludge cake is considered to be readily available to plants so the emissions of N_2O from its spreading are greater than the reduction in N_2O from the displaced fertiliser.

There are also significant emissions of N_2O resulting from the incineration of sewage sludge.

Table 10 compares the estimated greenhouse gas emissions from a UK study between incineration (TD-thermal destruction) and the use of digested sludge cake (MAD-mesophilic anaerobic digestion) in agriculture. The greatest single emission comes from methane lost during anaerobic digestion. As a result the total emissions from the agricultural route appear greater than from incineration. If, however, the reduced methane emissions appropriate to modern digestion plant without secondary digestion had been used, the methane losses from the process would fall by over 300 kg CO_2eq/tonne raw DS, reducing emissions to around zero, significantly better than from incineration.

Table 10 A comparison of greenhouse gas emissions between incineration of raw sludge and the use of digested sludge cake in agriculture

Treatment / Disposal Option	Contributions from different operational sources (all expressed as kgCO_2eq/tRawDS)							
	Natural gas usage	Electrical energy	Consumables	Transport	CH_4 from process & agriculture	N_2O from process & agriculture	Fertiliser displacement	Total
1. TD of raw sludge	0	-156	84	1	0	308	0	236
2. MAD and recycle dewatered digested sludge cake to AL	0	-267	106	11	465	101	-137	279

9 Stakeholder Interests and Public Perception

The principal stakeholders in the sewage sludge recycling to land operation are:

- **Sludge producers**. Recycling of sewage sludge to land is the main outlet for sludge in the EU where suitable land is accessible. The recycling to land option is therefore central to the sludge management strategy of most sludge producers. However, there are differences between Member States in the extent of use of the outlet. For instance, the Netherlands does not recycle sludge to land. The reasons for these differences are discussed in the next phase of reporting on this project.
- **Farmers**. Sludge has proven agricultural value and is usually a cost-effective alternative to other fertilisers so there is a steady demand from farmers in most Member States to recycle sludge on their land.
- **Farmers' advisors**. Advisors are generally supportive of sludge recycling so long as they are reassured that the operation is efficient and properly regulated and does not affect the acceptability of farm products to customers.
- **Landowners**. There may be some concerns about long-term effects of contaminants in sludge on soil fertility where repeated applications of sludge to the land have been made.
- **Regulators**. Sludge recycling to land is established as the BPEO for sludge management and Regulators are generally supportive of sludge recycling provided that operations are carried out in accordance with the appropriate rules and guidelines.
- **Farmers' customers, food processors and retailers**. There should be no problem here so long as regulations and guidelines for sludge recycling have been followed on the farm and the recycling operation is seen to be entirely 'safe'. A problem can arise if the processor/retailer perceives that the acceptance of products may be jeopardised if customers are aware that they have been grown on land treated with sewage sludge.
- **The public**. Studies have shown that the public are generally supportive of sludge recycling when the process of sewage treatment has been explained to them and the options for sludge disposal described (Davis, 2006). However, public nuisance factors (lorries, odour) are of key importance and must be controlled and preferably avoided if the confidence of the public in sludge recycling is to be retained. There is definite public sensitivity to odour nuisance from sewage treatment works and from sludge recycling operations in the field. Every effort must be made to avoid odour nuisance and the negative public response which can escalate to threaten the recycling outlet at least on a local basis.
- **Special interest groups**. In the UK, the pressure group 'Surfers Against Sewage' has carried out a survey of public attitudes to sewage sludge disposal in south West England (Davis, 2004). The report concluded that the 'best' routes for sewage sludge disposal in south west England were spreading on agricultural land for food or non-food crops. Or should either of these two routes become unusable, pyrolysis and gasification was viewed as the main viable large-scale option for sludge disposal in the area. During focus group sessions, when attendees listened to a 25-minute presentation and had the chance to ask questions about sludge disposal, most people agreed that sludge disposal to land was the best option, with 98% of those surveyed happy for sludge to be disposed of in this way and to eat crops grown on sludge-fertilised soil.
- **The media**. Waste water treatment and safe disposal of sludge are central to the protection of public health and should thereby have a very positive public image. However, because of their faecal association sewage treatment and sewage sludge disposal are prone to a negative and sometimes sensational press response often triggered by odour nuisance.

10 Future Trends

Large increases in quantities of sludge produced have taken place since 1995 (30% overall between 1995 and 2005) in the EU15 members, as a result of the UWWTD. The increase was not the same proportion in all countries. Although , much of the development required under the UWWTD has now taken place in the existing 15 Member States, the new 12 Member States, and some of the EU-15 members, have still a long way to go before complying with the UWWT Directive and thus it is likely that a similar rate of increase will continue.

Based on an annual average sludge production rate and population prediction, future sludge quantities produced in the EU-27 can be estimated. In the EU-15, in countries with a high connection rate to sewerage and high level of treatment complying with the UWWT Directive, sludge production rates are about 25 kg per person and per year.

Overall it is predicted that 50 % of sludge is likely to be recycled to land (Alabaster and Leblanc 2008). The situation in the existing 15 member States should not change dramatically over the next 5 years. There are some indications in the new Member States which have no previous experience in this sludge management route, that agriculture recycling may become a more significant outlet in the future.

The concentrations of metals in sewage sludge in Western Europe have significantly been reduced since mid 80's as a combination between increased management of industrial effluents and a reduction of heavy industrial production. The extent of further reductions is unclear, although the range of loadings may be significantly different between different parts of the EU (including new Member states).

Changes in composition as a result of increasingly rigorous nutrient removal requirements may become more significant. This is most likely to increase phosphorus concentration. This may be linked to changes in metal concentration if P-removal is carried out using metal salts (aluminium or iron).

Recovery of energy from biodegradable materials is encouraged by the EU energy policy, in particular to increase the use of biofuels. There is potential to increase sludge production if non-sewage biodegradable materials become incorporated into the sludge treatment route. In contradiction to this, treatment processes are increasing their capability to convert organic solids to transferable fuels with less residual solids. The balance between increase and decrease of mass of residual solids from sewage sludge treatment is therefore unclear.

It is likely that processes that provide enhanced pathogen removal will become more widely used, as they also commonly produce a sludge that is less fermentable and so less odorous and will attract less public concern or criticism. Processes that can reliably and cost-effectively demonstrate substantially reduced pathogen concentrations are likely to be more widely used.

There is a continual desire to reduce sludge volumes during treatment and intensify process operations.

Co-treatment of sewage sludge with a variety of other imported organic materials, particularly with reference to digestion processes, is currently not generally carried out, for reasons that include regulatory constraints. There are potential advantages of co-treatment in terms of asset utilisation (access to energy conversion systems, utilisation of existing infrastructure).

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants. It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertiliser. A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology.

Pyrolysis is still not an established process for sewage, but would offer increased energy recovery with a reduced cost and environmental impact compared to incineration.

Other sources of sludge, food waste, organic fractions of municipal waste, might compete for available land.

Though the carbon in sewage sludge is short cycle, the prevention of its release as CO_2 would be considered ‘sequestration’ (see Section 10). If a reliable route to sequestration could be developed, this might be more valuable than use in agriculture.

The subject of future trends will be considered further in the next stage of reporting for this project (.

11 Monitoring, record keeping and reporting

Information on sludge operations is primarily collated by the sludge producer; however, there may be several sources of the pertinent information:

- The occupier of the land receiving the sludge
- The person that applied the sludge to the land
- The sludge producer which supplied the sludge

The collated results required to be made available to a governing body would ideally relate to:

1. The location of the land receiving sludge
2. Sludge treatment, quantity and quality
3. Soil quality

The frequency of monitoring sludge **quantity** depends on the amounts applied to land units (each location), totalled over each year followed for example by the EPA (Alabaster and LeBlanc, 2008). Thus ideally, records need to be kept of sludge quantity per land unit and per unit time and this is specified in Directive 86/278/EEC. Amounts of sludge need to be recorded in metres cubed per year (total and amount to agriculture) and if possible metres cubed per land unit.

Table 11 Operational sludge data

Record	**Total produced**	**Quantity to agriculture**	**Quantity to land unit**
Units	m^3 per year	m^3 per year	m^3 per land unit per year

Data quality will depend on following standard procedures of measurement, sampling and analysis, and once more, observing the correct frequency of the analyses to be carried out.

11.1 Sludge analysis

Sludge quality will reflect original inputs to sewers and so variability can be assessed taking into account this background. Also subsequent quality will affect efficient treatment process operation. Knowledge of inputs of synthetic organic compounds and other undesirable contaminants can signal seeking specialist advice before use in agriculture (CoGAP, 2009).

Table 12 Sludge quality parameters

Parameter	**Dry matter (DM)**	**Organic matter**	**pH**	**Nitrogen and Phosphorus**	**Heavy Metals (6+)**
Units	% (w/w)	% of DM	'Units'	mg kg^{-1} DM	mg kg^{-1} DM

Parameters currently covered by directive 86/278/EEC are as above, where the heavy metals are; Cd, Cu, Hg, Ni, Pb and Zn. In the UK, further detail on crop nutrient analyses is advisory, for example total nitrogen and total phosphorus and, ammoniacal nitrogen (CoGAP, 2009). Also additional metals are currently included in UK guidelines; Cr, Mo, Se and As, and fluoride. All these additional parameters would be expressed as concentration in the sludge dry matter (mg kg^{-1} DM).

Limit values for the amounts of heavy metals (seven, as above) which may be added annually to agricultural land, based on a 10-year average (kg ha^{-1} yr^{-1}) are given in directive 86/278/EEC in annex 1C. These additions of metal have to be estimated from the sludge quantities and sludge metal analyses.

The frequency of analysis of the parameters in Table 12 above is recommended every six months for the provisions of the directive 86/278/EEC, but more frequently if sludge is found to be particularly variable and, only annually if it is thought consistent over a full year. However, consideration of the size of the waste water treatment plant is also made when deciding on frequency of analysis (CEC, 2006). Because it has been shown that sludge quality varies widely even on a daily basis, it is imperative that the adopted sampling procedure be validated by experimentation and that the sample error be established (Beckett, 1980).

11.2 Soil analysis

For sludge recycled to agricultural land from small sewage treatment plants (< 300 kg BOD/day, equivalent to 5000 population) designed primarily for the treatment of domestic waste water, soil analysis is **not** required according to Directive 86/278/EEC. When sludge is from plants larger than this soil should be analysed prior to the use of sludge and, at a suitable frequency thereafter to prevent soil metal concentrations from being exceeded. Currently only soil metals and pH are included as limit values in soil receiving sludge in the Directive 86/278/EEC. Heavy metals included are; Cd, Cu, Hg, Ni, Pb and Zn, as for sludge analysis. Soil pH is also recorded as this is related to the limit values for concentrations of heavy metal in soil.

Table 13 Soil Quality parameters

Parameter	pH	Cd	Cu	Hg	Ni	Pb	Zn
Units	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM

11.3 Sampling and analysis methods

In the UK both sampling and analytical methods are specifically listed from those by the Standing Committee of Analysts: Methods for the Examination of Waters and Associated Materials, in the code of good agricultural practice (CoGAP 2009). In Directive 86/278/EEC, only brief details of soil and sludge sampling are given, and it is recommended simply that strong acid digestion followed by atomic absorption spectrometry are used for analysis of heavy metals in sludge and soil. Since then the Comité Européen de Normalisation (CEN) have published national standards for sludge characterisation through their technical committee; TC 308 and these would be best to follow for sludges. Relevant examples of the CEN published methods for sludges are given in Table 14 below.

Table 14 CEN/TC 308 - Sludge analyses selected published standards

Standard reference	Title	Citation in OJ	Directive
CR 13097:2001	Characterization of sludges - Good practice for utilisation in agriculture	No	-
EN 12176:1998	Characterization of sludge - Determination of pH-value	No	-
EN 12879:2000	Characterization of sludges - Determination of the loss on ignition of	No	-

	dry mass		
EN 12880:2000	Characterization of sludges - Determination of dry residue and water content	No	-
EN 13342:2000	Characterization of sludges - Determination of Kjeldahl nitrogen	No	-
EN 13346:2000	Characterization of sludges - Determination of trace elements and phosphorus - Aqua regia extraction methods	No	-
EN 14671:2006	Characterization of sludges - Pre-treatment for the determination of extractable ammonia using 2 mol/l potassium chloride	No	-
EN 14672:2005	Characterization of sludges - Determination of total phosphorus	No	86/278/EEC
EN ISO 5667-13:1997	Water quality - Sampling - Part 13: Guidance on sampling of sludges from sewage and water treatment works (ISO 5667-13:1997)	No	

Note: selected from list published on CEN website:
http://www.cen.eu/cenorm/sectors/sectors/environment/tcs/index.asp

In the full list of published standards for sludge characterisation on the CEN website, standards for microbial analyses are also included. Also included in Table 13 is a standard on sampling of sludges from sewage and water treatment works.

Soil analyses methods are under development by CEN but none are yet published covering the relevant parameters. Methods for the standard six heavy metals in soil (total by aqua-regia strong acid) are in practice broadly the same as those for sludges.

Representative soil samples are described in Directive 86/278/EEC as samples made up by mixing together 25 core samples taken over an area not exceeding 5 hectares which is farmed for the same purpose. In UK methods it is also recommended that the 25 samples are taken in a ‘W’ pattern over the field (Standing Committee of Analysts, 1986).

The directive designates soil samples are to be taken to a depth of 25 cm, (or less when the surface soil is below this but not less than 10 cm). In the UK, however, a plough depth of 20 cm is typical for arable land, hence soil sampling to 15 cm is recommended, to avoid edge effects (UN 2008 pp344) and, if land is under permanent or semi-permanent grass soils are sampled to 7.5 cm.

Detailed quality assurance procedures on reporting are now being followed by many of the UK water companies in line with those recommended by Water UK (Water UK, 2004).

12 Summary of areas of uncertainty and knowledge gaps

12.1 Sludge production and management and quality in the EU

Although it is expected that sludge production in the EU27 will continue to increase as population grow and the new Member States continue to implement the UWWT Directive towards 2010, there is no guarantee that all countries will be fully complying by that time. There is also a noticeable trend in some Member States which have high level of connection and treatment of sludge quantities decreasing. The reasons for this will need to be further investigated as this could add uncertainties to our future sludge estimates.

Although overall it is predicted that 50 % of sludge is likely to be recycled to land, there are uncertainties about the future sustainability of this outlet due to public opinion and the competition for land with other organic wastes. The main alternative to landspreading is likely to continue to be incineration with energy recovery for sludge produced at sites where land suitable for recycling is unavailable. Sludge management may continue to vary widely between Member States according to their particular circumstances. A number of other important factors which could influence sludge management in the future need to be evaluated.

Developments in sludge treatment will continue and there may be move towards enhanced treatment for sludge going to land so that the product to be recycled is effectively odour and pathogen free. The subject of future trends will be considered further in the next stage of reporting for this project (Section 3).

The concentrations of metals in sewage sludge in Western Europe have significantly been reduced since mid 80's as a combination between increased management of industrial effluents and a reduction of heavy industrial production. The extent of further reductions is unclear, although the range of loadings may be significantly different between different parts of the EU (including new Member states).

12.2 EU legislation, other EU acquis and Member State controls on the use of sludge on land

Directive 86/278/EEC could be said to have stood the test of time in that sludge recycling has expanded without environmental problems arising since it was adopted. However, several Member States have adopted stricter requirements since. Moreover, EC legislation has evolved in many related fields, such as chemicals regulation. Any revision should aim to retain the flexibility of the original Directive which has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the EU.

12.3 Economics of sludge treatment and disposal.

The baseline and future analysis of sludge management must take account of costs, and information in Section 3 provides the basis to do this.

12.4 Agricultural value of sewage sludge.

Application of sewage sludge to land provides positive agricultural benefit. Demand for sewage sludge in agriculture and for other land uses would undoubtedly be enhanced if it was clearly recognised as a product instead of a waste, and if it were accepted as being suitable for use in organic farming and other organic growing practices. However, a watching brief needs to be kept on P in soils receiving sludge and more information obtained about the accumulation and fate of P in soils.

12.5 Potentially toxic elements

Consideration needs to be given to adjusting the maximum permissible soil metal limits in Directive 86/278/EEC for cadmium and zinc in soil and for lead in sludge.

12.6 Organic contaminants (OCs)

Directive 86/278/EEC does not include specific limits for organic contaminants. Some Member States have set limits for OC groups, while others have not. In summary, the reviews of the research on OCs in sludge conducted so far have concluded that they are unlikely to have an adverse effect on human health and will be increasingly controlled by regulation. However, contaminants such as DEHP and chlorinated paraffins, found in sludge at higher levels will need to be further assessed. Further vigilance is also required on contaminants such as pharmaceuticals, where the potential fate and behaviour in waste water, sludge and soil is unclear at present.

12.7 Pathogens, treatment of sludge and land use practices

There is scope to update the controls set out in 86/278/EEC as regards the use of untreated sludge on the land, through the introduction of microbiological standards related to degree of sludge treatment. Such an update should take into account new developments in quality control of sludge treatment processes (such as HACCP) and in the safe management of sludge on the land.
Alist of 13 areas of uncertainty about pathogens is identified in paragraph 6.3.5

12.8 Water and air pollution

The principles for water pollution control set out in Directive 86/278/EEC remain sound; nonetheless, a revision could take account of the development in EC water pollution control legislation (notably the Nitrates Directive 91/676/ EEC and Water Framework Directive 2000/60/EC). A revision of the Directive might also call for guidelines for land use practices where sludge is used on the land. In both cases, one area for emphasis should be the controls of nitrogen and phosphorus. Apart from nutrients, sewage sludge is an organic manure with a significant chemical oxygen demand (COD) and which contains enteric microorganisms – this further underlines the need to manage sludge recycling operations so that runoff into surface water in particular is avoided. A revision of the Directive could draw on the operational guidance on landspreading of sewage sludge prepared in some Member States as well as more general national guidance on good agricultural practice.

While the emphasis of control on water pollution where sludge is used on land lies with management of N and P, PTEs, organic micropollutants and pathogens have also been investigated in this context especially as regards leaching into groundwater. A watching brief needs to be kept on leaching of persistent organic micropollutants from sludge-treated soil.

Odours – see stakeholder interests below

12.9 Greenhouse gas emissions and carbon footprint

The information presented in this report provides the basis for quantifying these factors for different sludge treatment and disposal options as part of their overall environmental assessment.

12.10 Stakeholder interests and public perception

Ten principal stakeholder groups have been identified and their interests listed.

For the general public, there is a strong sensitivity to odour nuisance from sewage treatment works and from sludge recycling operations in the field. Every effort must be made to avoid odour nuisance and the negative public response which can escalate to threaten the recycling outlet at least on a local basis.

Farmers' customers, food processors and retailers may also be affected by a perception that the use of sewage sludge could lead to environmental and health concerns. There should be no problem here so long as regulations and guidelines for sludge recycling have been followed on the farm and the recycling operation is seen to be entirely 'safe'. A problem can arise if the processor/retailer perceives that the acceptance of products may be jeopardised if customers are aware that they have been grown on land treated with sewage sludge.

12.11 Monitoring, record keeping and reporting

The requirements in this area included in Directive 86/278/EEC need to be updated with particular reference to the Standards prepared by CENT C/308.

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Environmental, economic and social impacts of the use of sewage sludge on land

Summary Report 2

Baseline Scenario, Analysis of Risk and Opportunities

milieu
ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by Milieu Ltd, WRc, and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Bob David. Additional expertise was provided by Anne Gendebien, Rod Palfrey and Judith Middleton

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Executive Summary

Milieu Ltd is, together with partners WRc and Risk & Policy Analysts Ltd (RPA), working on a contract for the European Commission's DG Environment, entitled *Study on the environmental, economic and social impacts of the use of sewage sludge on land* (DG ENV.G.4/ETU/2008/0076r).

Directive 86/278/EEC could be said to have stood the test of time in that sludge recycling has expanded since its adoption without environmental problems. Since its adoption, however, several Member States have put in place stricter national requirements. Moreover, EC legislation has evolved in many related fields, such as chemicals regulation. Any revision should aim to retain the flexibility of the original Directive which has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the expanded EU.

The aim of the study is to provide the Commission with the necessary elements for assessing the environmental, economic and social impacts, including health impacts, of present practices of sewage sludge use on land, provide an overview of prospective risks and opportunities and identify policy options related to the use of sewage sludge on land. This could lay the basis for the possible revision of Community legislation in this field.

This is the second deliverable of the study: the first was a review of literature on the topic, *Assessment of existing knowledge*. The aim of this second report is to develop a baseline scenario to 2020 concerning the spreading of sewage sludge on land and to analyse the relevant risks and opportunities. This report provides information to establish a baseline scenario under which Directive 86/278/EEC remains in place and is not revised.

This study has used existing sources of data as well as forecasts. On this basis, it can be broadly estimated that as compliance with the UWWT Directive is achieved, total sludge generation in the EU15 may increase from 2005 to 2020 by about 20% to 10.4 Mt DS; and for the EU12, by approximately 100% to 2.5 Mt DS. Thus, the total for EU sludge generation in 2020 will be approximately 12.9 Mt DS per annum, compared with 10 Mt DS in 2005, an overall increase of 2.9 Mt DS per annum or about 30%.

From the data on sludge disposal and recycling in the Member States, the proportion of sludge recycled to agriculture has not altered significantly since 1995, remaining at around 40 – 50%. The situation in some Member States has changed; the Netherlands, for example, no longer recycles sludge to land, while the UK and some other Member States have increased the amount of sludge to land. It seems reasonably likely that by 2020 the overall recycling figure for the EU15 will remain at around 40 - 50% and that the EU12 – where overall sludge recycling to land is currently lower – will move towards this value as the UWWT Directive is implemented and the disposal to landfills is phased out. The main alternative to recycling to land will be thermal treatment.

The report considers the expected impacts of current EU legislation, such as the Nitrates Directive, the Water Framework Directive, as well as that of the new renewable energy goals.

The report assesses future trends and future risks and opportunities which are relevant to revision of Directive 86/278/EEC. The areas considered are: sludge production, sludge quality (agricultural value; potentially toxic elements; organic contaminants; pathogenic micro-organisms); sludge treatment, land restrictions; other routes and other factors which have an impact on the outlet such as greenhouse gas emissions and carbon footprint; stakeholder interests and public perception.

This report is presented as a draft for comments on the part of Member States, stakeholders and researchers as part of the first consultation for the study. For this reason, a total of 28 questions are interspersed through the main sections of the report. These request further data as well as opinions and suggestions for individual topic areas.

1 Introduction

Although it could be said that the Sludge Directive 86/278/EEC has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the expanded EU, since its adoption, the situation in the EU has since changed substantially and all these changes must be considered.

Several Member States have adopted stricter requirements than the 86/278 Directive, new research findings in the field have been published, 12 new Member States with specific sludge management practices have joined the EU, technological progress has been made and new EC regulatory orientations (e.g. in wastewater, waste, soil, emission controls and energy policy, etc.) which have various impacts on sludge production and management, have been or are being implemented. Moreover, several Community legislative requests have been made to the Commission to revise this Directive; the Thematic Soil Strategy and the waste prevention and recycling Strategy.

This is the second deliverable of the study on "Environmental, economic and social impacts of the use of sewage sludge on land" for the European Commission (DG Environment). This assessment will build on the existing studies and knowledge (see report 1) and fill any identified knowledge and data gaps in order to provide a full picture of the current situation and the future needs.

The aim of the report is to develop the baseline scenario and the analysis of future risks and opportunities. It aims to prepare a debate on the possible need for future policy action, seeking views on how to improve sludge land recycling management in line with the waste hierarchy, possible economic, social and environmental gains, as well as the most efficient policy instruments to reach this objective.

From the baseline scenario, an assessment will be undertaken of the likely benefits and costs of additional or changed policy measures on the recycling of sewage sludge to agriculture in the EU when compared to the existing and planned policies. The assessment will find if the current policy measures are sufficient to address the issue of proper sewage sludge recycling to agricultural land and whether additional measures on sludge management would deliver significant improvements. The final set of options to be assessed will be based on the results of the baseline scenario and analysis of risks and opportunities as well as those from the consultation.

It is clear that there are data gaps and uncertainties with regards to sewage sludge recycling options, highlighted throughout the report. The Commission would therefore like to invite all Stakeholders to provide any data available to facilitate the subsequent Impact Assessment of different revision options. We have also included directed questions in sections throughout this document. We will invite stakeholders to contribute their knowledge and views on this assessment via a web consultation.

2 Baseline scenario

If no changes are implemented to the current Sewage Sludge Directive, the foreseen changes over the next 10 years due to other Community legislation and policies mentioned below will possibly affect the sewage sludge recycling route in terms of:

- Quantity and quality of sludge generated.
- Sludge treatment requirements.
- Restrictions for application of sewage sludge on soil and
- Monitoring and control requirements.

The baseline or “business as usual” scenario acts as the reference against which the other scenarios are compared. It is therefore the scenario that would emerge if the Directive 86/278/EEC was not revised and was still in force during the considered period of time. Hence, the necessity of considering a baseline scenario that accurately reflects current trends in technical progress, public behaviour, and regulatory policies.

The general objective of the baseline scenario is to provide an appropriate assessment of policies and practices across the EU over the next 10 years (2010 and 2020) and their possible implications on the production and treatment of sewage sludge and recycling to land for each Member State and at EU27 level.

2.1 Sludge quantities

The sludge quantities produced are directly linked to the volume and characteristics of wastewater treated which is dependent on the rate of wastewater collection, type of treatment, size of population connected and type of industries connected.

Sludge production is mainly linked to the following factors:

- size of the population,
- rate of population connected to public sewer system;
- level of wastewater treatment (no treatment, primary, secondary or tertiary treatment),
- type of sludge treatments applied; and
- size and number of industries connected to sewerage system.

2.1.1 Regulatory framework

The 91/271 UWWT Directive has had and will have a direct impact on sludge production in the EU in the next 15 years as it continues to drive the investment in wastewater collection and treatment capacities in the EU. In the EU15, the time schedules for achieving the environmental objectives of the UWWT Directive were phased (1998 – 2000 –2005), depending on the characteristics of the affected waters and the size of the wastewater pollution load (‘agglomeration’). As for the new Member States in Central and Eastern Europe and the Mediterranean, interim targets and staged transition periods were allowed which should not be later than 2015 (2019 for Romania) (Table 1).

Table 8 Transitional periods for the implementation of UWWT Directive in EU 12

Member State	Final deadline
Bulgaria	31 Dec 2014
Cyprus	31 Dec 2012
Czech republic	31 Dec 2010
Estonia	31 Dec 2010
Hungary	31 Dec 2015
Latvia	31 Dec 2015
Lithuania	31 Dec 2009
Malta	31 Dec 2006
Poland	31 Dec 2015
Romania	31 Dec 2018
Slovakia	31 Dec 2015
Slovenia	31 Dec 2015

The latest available information (for 2003) on the implementation of the Urban Waste Water Treatment (UWWT) Directive can be found on http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm (CEC, 2008). Preliminary reports on the latest figures (end of 2005) have recently been made available. Unfortunately there is not a comprehensive picture of the implementation as only 18 Member States have provided information in time (10 out of the EU15 and 8 out of the EU12).

By 1 January 2003, overall, 81.4% of total reported load (470 million pe) for EU15 was treated to the required level of treatment as defined by the UWWT Directive. At the end of 2005, development of collecting systems had made good progress but there were still differences between Member States regarding compliance with secondary treatment. Most of the 18 Member States have reported a rate of collecting systems above 95% of total load. Overall, the pollution load for these 18 Member States amounted to 313 million pe from 13,734 agglomerations above 2000 pe. Collection systems were in place for 93% of the total load. Secondary treatment was in place for 87% of the load. More stringent treatment is used for 72% of the load.

For the previous reporting period, Denmark, Germany and Austria had recorded high levels of compliance of close to 100%, closely followed by the Netherlands (90%) with an only slightly less ambitious record, while the implementation across the other Member States is less successful and still represents a major challenge (Figure 1). In Denmark, Germany, and Sweden the majority of the population is connected to wastewater treatment works with tertiary treatment (EEA 2005).

For the new Member States, the investment programme is on-going and is not expected to be completed before 2015 (2019 for Romania). According to EEA reports (EEA 2005, EEA 2009), in Malta, almost 90% of population has no treatment of their wastewater. More than 65% of the population in the Czech Republic, Estonia, Latvia and Lithuania are connected to wastewater treatment, and roughly half of the wastewater treated undergoes tertiary treatment. For Poland and Hungary around 60% of the population are connected to wastewater treatment systems. In Poland about half of the connected wastewater is given tertiary treatment, whereas in Hungary only 10% gets tertiary treatment. The lowest connection rate is found in Slovenia, where almost 70% of the population are not connected to wastewater treatment systems. For Slovakia there is no detailed information on treatment type available. In Bulgaria and Romania, only around 40% of the population are connected to wastewater treatment, with most of the connected wastewater receiving primary or secondary treatment but with no tertiary treatment.

Although all EU15 countries should have been complying with all the requirements of the Directive by the end of 2005, this was not the case. Although there are uncertainties regarding the delay and level of compliance achieved for the 27 EU Member States over the next 15 years, for the baseline scenario, we have assumed that, by 2020, all Member States of the EU27 should have completed their obligations under the UWWT Directive. We have assumed that by 2010, the EU15 would have achieved full compliance as well as Czech Republic, Estonia, Lithuania and Malta. For the other EU12, the level of compliance would not have changed from 2006.

Table 2 below shows the number of agglomerations in the EU27 and the generated load discharge (CEC 2006). Figure 3 shows the percentage conformity for the EU15 states. Based on our assumptions regarding compliance with the UWWT in the different Member States, by 2020, a total of 671 million pe for EU27 will be discharged and treated in wastewater treatment plants.

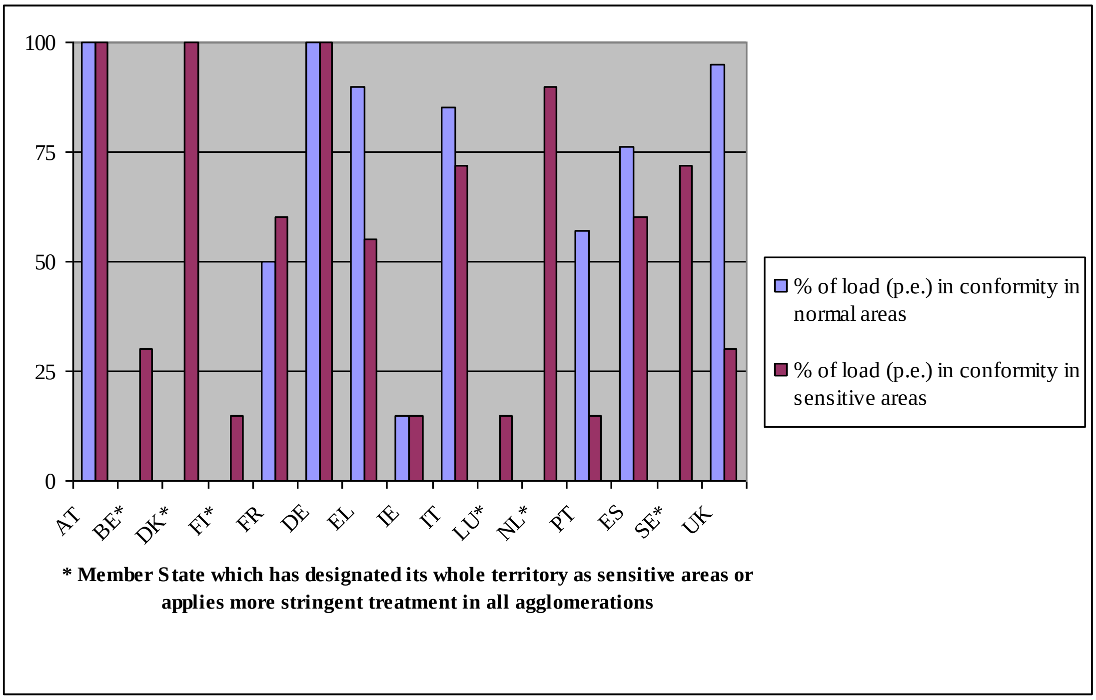

Figure 3 **Compliance with treatment level by EU15 Member States (as reported by 1/01/2003) (CEC 2007)**

	Agglomerations (having the load of more than 2,000pe) to which the Directive applies		Agglomerations >10000 pe discharging to sensitive areas and >15000 pe discharging to normal areas		Agglomerations 2000-10,000 and number of agglomerations >10,000 pe discharging to normal areas		Big cities / big dischargers (having generated pollution load of more than 150,000 pe)	
	Number	**Load (million pe)**	**Number**	**Load (million pe)**	**Number**	**Load (million pe)**	**Number**	**Load (million pe)**
EU15	31374	550	8500	476	22874	74	556	252
EU10	3348	85	1103	73	2254	12	98	39
EU2	2903	36	367	22	2536	14	0	0
Total EU27	**37625**	**671**	**9970**	**571**	**27664**	**100**	**654**	**291**

Table 9 Total number of agglomerations in EU27 and total generated organic pollution load discharged (CEC 2006).

2.1.2 Size of population

A factor to take into account for estimating future sludge quantities is the population growth. The EU population growth is currently 0.4% per year (CEC 2008). For the baseline scenario, we have assumed that there would be no new accession between 2010 and 2020.

The current population growth is positive in some of the old EU15 Member States (Ireland close to 3%, Spain, Cyprus, Luxembourg, over 1%), while in Germany there has been a recent slight decline in population, a pattern that is reported to be common for most of the new Member States like Bulgaria, the Baltic States, Romania, Hungary, Poland and Croatia.

Figures from CEC (2008) show that from around 2010 onwards, the population is expected to decline for the European Union as a whole and that by the year 2050 the population of the European Union is expected to have declined from its current 493 million inhabitants (2007) to 472 millions. The Eurostat projections (Table 3), on the other hand show future population for the EU27 increasing to about 500 millions by 2010 and to 514 million by 2020.

Table 10 Population projection for 2010 and 2020 (Eurostat 2009)

Member State	**2010**	**2020**
Austria	8,404,899	8,723,363
Belgium	10,783,738	11,321,733
Denmark	5,512,296	5,661,099
Finland	5,337,461	5,500,929
France	62,582,650	65,606,558
Germany	82,144,902	81,471,598
Greece	11,306,765	11,555,829
Ireland	4,614,218	5,404,231
Italy	60,017,346	61,420,962
Luxembourg	494,153	551,045
Netherlands	16,503,473	16,895,747
Portugal	10,723,195	11,108,159
Spain	46,673,372	51,108,563
Sweden	9,305,631	9,852,965
United Kingdom	61,983,950	65,683,056
EU15	***396,388,049***	***411,867,857***
Bulgaria	7,564,300	7,187,743
Cyprus	820,709	954,522
Czech Republic	10,394,112	10,543,351
Estonia	1,333,210	1,310,993
Hungary	10,023,453	9,892,967
Latvia	2,247,275	2,151,445
Lithuania	3,337,008	3,219,837
Malta	413,542	427,045
Poland	38,092,173	37,959,838
Romania	21,333,838	20,833,786
Slovakia	5,407,491	5,432,265
Slovenia	2,034,220	2,058,003
EU12	***103,001,331***	***101,971,795***
EU27	**499,389,380**	**513,837,632**

2.1.3 Domestic connection rate

Wastewater pollution load and thus sludge production is directly linked to the proportion of inhabitants connected to wastewater treatment plants. Following the implementation of the UWWT Directive which requires the collection of wastewater from all agglomerations above 2000 pe, the current rate of connection is steadily increasing across the EU.

From the latest available information, at the end of 2005, developments of collecting systems have made good progress but there are still differences between Member States regarding compliance with secondary treatment. Most of the 18 Member States have reported a rate of collecting systems above 95% of total load apart from, in decreasing order: Lithuania (93%), Estonia (89%), Hungary (80%), Slovakia (76%), Slovenia (73%), Cyprus (49%), and Romania (47%). No information was submitted by Bulgaria, Czech Republic, Greece, Ireland, Italy, Latvia, Malta, Poland, Spain, and the UK.

Although some Member States will not reach 100% coverage, for our baseline scenario we have considered that by 2010, EU15 will be fully connected to sewage collection systems and that by 2020, the whole of the EU27 will have achieved full coverage.

2.1.4 Industrial connection rate and level of pre-treatment

Industrial and trade effluents discharging to municipal sewer systems also contribute to pollution load and sludge production at municipal wastewater treatment plants (see below). The ratio between the total pollution load in influent of a treatment plant expressed in population equivalent (pe) and the number of inhabitants ranges from 1 (small communities without industry) to more than 2 (larger cities).

Industries connected to municipal sewers contribute to sewage sludge production in the following ways:

- Untreated industrial effluent permitted under a trade effluent licence;
- Treated effluent which may not be treated to sufficient standard for discharge to a surface water and still contain degradable material or separable suspended solids;
- Treated effluent with waste sludge from the treatment process combined together in a discharge to sewer;
- Combination of liquids and solids transported separately but to be treated as part of the municipal sewage treatment processes.

In Austria (Alabaster and LeBlanc, 2008) the actual BOD5 load to all Austrian treatment plants is, on average, ~2 pe/capita. Figures from other Member States have not been thoroughly investigated and this could be clarified during the consultation period.

We have considered that the contribution of industries to sludge solids production will not change from 2005 till 2020, as a result of opposing effects that include the following factors:.

- Industrial production is expected to grow due to economic growth which will increase liquid and solid effluents.
- Quantities discharged by industry will decrease due to process improvement and pollution prevention;
- The rate of industries with strong wastewaters connected to the sewer may decrease, due to increasing industrial onsite wastewater treatments. Sludge produced from some of these processes may be managed as a separate material.

2.1.5 Level of treatment

The type of wastewater treatment influences sludge production. However it is difficult to predict such changes at Member State level as these will be highly dependant on local situations at each plant. Works that are required to achieve reduced effluent phosphorus concentrations, for example, may see an increase or a decrease in amount of sludge production. Biological P removal may result in slightly lower rates of sludge production rate due to biomass recycle and longer retention times while chemical P removal may result in up to 65% more secondary sludge produced. For N removal, there is a likely reduction in sludge production due to the installation of long sludge age systems, or no change, unless separate denitrification processes are required driven by addition of other chemicals.

Sludge stabilisation processes also have an impact on the ultimate sludge quantities to be disposed of. The most recently constructed sludge treatment processes that involve anaerobic digestion have been designed to achieve increased conversion of volatile solids to biogas. The increase from 45% volatile solids destruction to 55% volatile solids destruction could lead to a reduction in sludge production by 10% to 15% at a single works, or if all works in the country were modified or replaced to achieve the same extent of conversion.

No attempt has been made at this time to closely model the forms of sludge treatment used in each country as the combinations of sewage and sludge treatment processes lead to a very wide variety of possible scenarios.

2.1.6 Sludge production trends

Sludge production rate per capita is considered to be a good indicator for future sludge estimates at Member State level. However, current sludge production per capita shown in Table 4 varies greatly across countries. Countries that have the most comprehensive infrastructure and treatment technologies (e.g. secondary and tertiary treatments) produce the largest mass of sewage sludge per person. Countries which have less developed wastewater treatment infrastructure and collect and treat wastewater from lower percentages of their populations produce less sewage sludge per person on a national level. The proportion of industrial discharges to municipal sewer influence the sludge production rate by increasing the relative sludge production per capita.

For our baseline scenario, we have considered that sludge production will increase and be stabilised once the UWWT Directive is fully implemented. We have considered that full implementation of UWWT across all of the 27 Member States will be achieved by 2020.

The sludge production per capita in the complying countries (i.e. Austria, Denmark and Germany) should be a good indicator of the maximum sludge quantities that can be expected when a Member State will be in compliance with the UWWT Directive. Per capita, sludge production in these countries ranges from 23 to 29 kg/person per year. Thus an average 25 kg per capita per year is a good estimate for maximum sludge production rate.

Thus for our baseline scenario we have considered that, by 2020, sludge production per capita across the 27 EU Member States will reach at least 25 kg per capita per year. This value has been used for estimating future sludge production in Member States which currently have lower sludge production rates. For countries with higher rates, future sludge production rates have been estimated using these higher values.

Table 11 Current annual sludge production (period 2004-2006) and production rate per capita in the EU27

Member State	**Year data recorded**	**Sludge production (t DS / year)**	**Population [a] ($x10^6$)**	**Sludge production (kg DS /capita)**
Austria	2005	238,100/ 420,000 [b]	8.3	29/ 50 [b]
Belgium				
• Wallonia	2003	23,520	3.4	7
• Flemish	2005	76,254	6.1	13
Denmark	2002	140,021	5.5	25
Finland	2005	147,000	5.2	28
France	2002	910,255	64.4	14
Germany	2006	2,059,351	82.2	25
Greece	2006	125,977	11.1	11
Ireland	2003	42,147	4.5	9
Italy	2006	1,070,080	59.6	18
Luxembourg	2003	7,750	0.48	16
Netherlands	2003	550,000	16.5	33
Portugal	2002	408,710	10.6	38
Spain	2006	1,064,972	46	23
Sweden	2006	210,000	9.2	23
United Kingdom	2006	1,544,919	61	25
Sub-total EU15		***8,786,569***	***394***	***22***
Bulgaria	2006	29,987	7.6	4
Cyprus	2006	7,586	0.77	10
Czech republic	2006	220,700	10.3	21
Estonia	2006	nd	1.3	?
Hungary	2006	128,380	10	13
Latvia	2006	23,942	2.3	10
Lithuania	2006	71,252	3.4	21
Malta		nd	0.4	
Poland	2006	523,674	38.1	14
Romania	2006	137,145	21.5	6
Slovakia	2006	54,780	5.4	10
Slovenia	2006	19,434	2	10
Sub-total for EU12		***1,216,880***	***103***	***12***
Total		**10,003,449**	**497**	**20**

Notes:

a) Based on data from national Statistical offices. Depending on Member States, reference year is mainly 2007 or 2008 with a few figures for 2006

b) without/with industrial discharges especially from cellulose and paper industry

Questions for the consultation

If you disagree with our assumptions on per capita sludge production rate for your country please provide corrections and if possible explain the reasons using the following supporting questions.

Q1 – What are the special reasons in your country that result in a reported sludge production rate of less than 23kg/pe/year or greater than 28 kg/pe/year?

Q2 - What change in the rate of sludge production do you expect will take place up to 2020?

Q3 - Why would any change in the reported rates of sludge production per person take place?

Q4 – What proportion of total sewage sludge reported here is due to industrial sources in your country? Is this expected to change, and to what proportion?

Although, it may not be the case, for our baseline scenario, by 2010, we have considered that compliance with the UWWT Directive should have been achieved in all EU15 and in 4 of the EU12, i.e. Czech Republic, Estonia, Lithuania and Malta. For the remaining EU12, sludge production in the baseline year of 2010 will remain the same as reported for 2006 and that by 2020, full compliance with the UWWT Directive will be achieved across the EU27. Unless recent figures (calculated after 2005) on future sludge production have been found in the literature, future sludge production quantities have been calculated using the 25 kg/capita per year figure or greater if reported in Table 4 and population projection in Table 3.

Table 12 Future forecasted (2010 and 2020) sludge quantities arising in the EU27

Member State	2010 ($x10^3$ tds pa)	2020 ($x10^3$tds pa)
Austria	270	280
Belgium	170	170
Denmark	140	140
Finland	155	155
France	1,600	1,600
Germany	2,000	2,000
Greece	260	260
Ireland	135	135
Italy	1,500	1,500
Luxembourg	10	10
Netherlands	560	560
Portugal	420	420
Spain	1,280	1,280
Sweden	250	250
United Kingdom	1640	1,640
EU15	***10,393***	***10,400***
Bulgaria	47	180
Cyprus	8	16
Czech Republic	264	264
Estonia	33	33
Hungary	175	200
Latvia	25	50
Lithuania	80	80
Malta	10	10
Poland	520	950
Romania	165	520
Slovakia	55	135
Slovenia	40	50
EU12	***1,418***	***2,484***
EU27	**11,811**	**12,884**
Note: As working estimates 2010 production rates have been taken to be the same as 2020 production for states expected to be in full compliance in 2010. For non-compliant states a rounded 2006 production rates have been used – see text in Annex 2 for detail		

Future sludge production has been estimated to increase by approximately:

- For the EU15 - 20% to 10.4 Mt DS by 2020, and
- For the EU12 - 100% to 2.5 Mt DS by 2020.

This gives a grand total for EU27 sludge production by 2020 of approximately 13 Mt DS per annum, compared with 12.0 Mt DS in 2010, an overall increase of about 30% compared with 2006 (Table 5 above). Figure 2 (below) presents the past and future trends for sludge production in the EU15 and EU12.

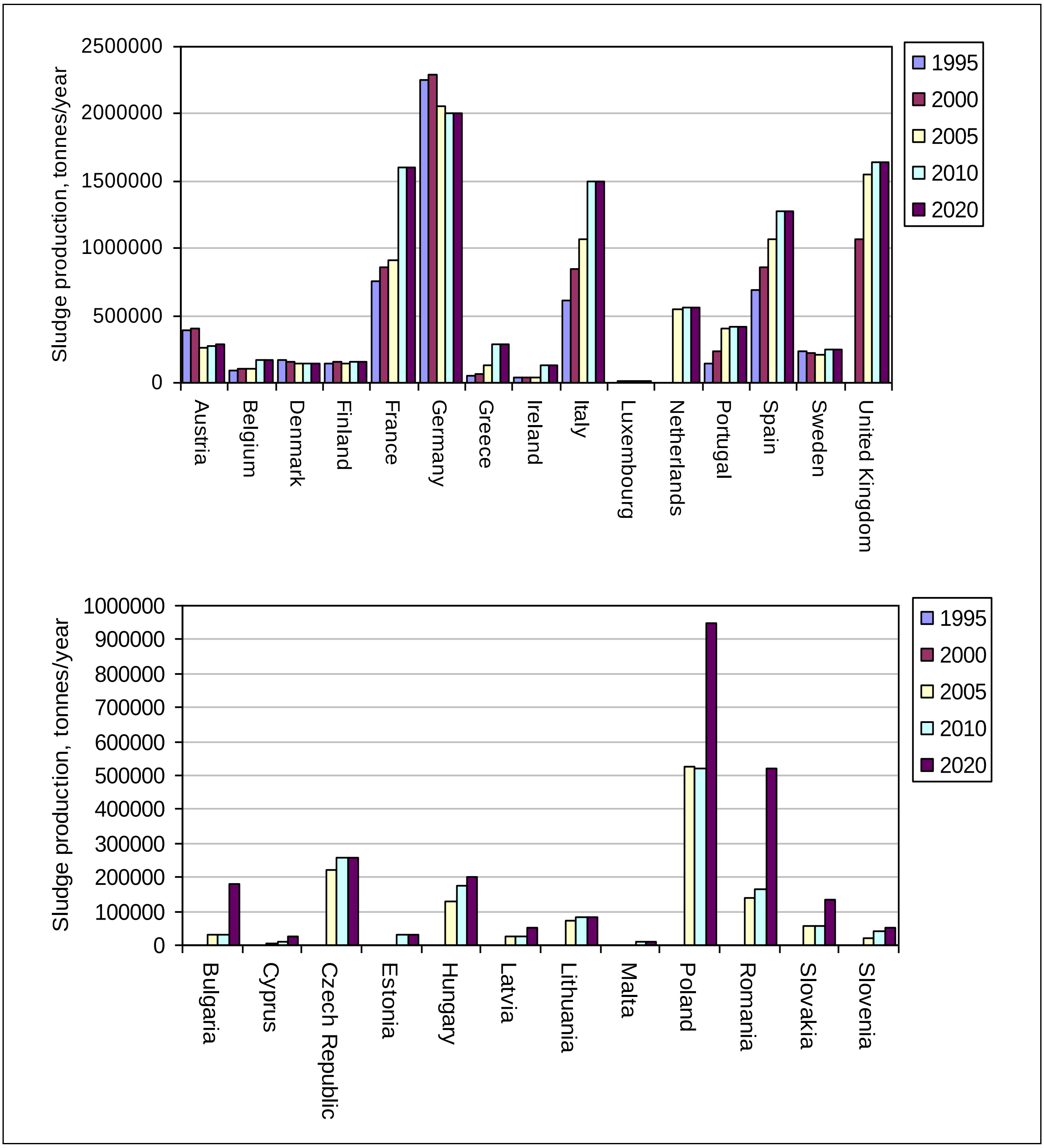

Figure 4 Past and future trends in sludge production in the EU15 and EU12 sludge production case studies

Sludge estimates in Austria and Slovenia

Austria (Doujak, 2007) is already in line with the UWWT Directive requirements with about 1,500 municipal sewage treatment plants collecting wastewater from about 90% of a population of 8.2 million for a territory of 84,000 km^2. Municipal sludge production amounts to 266,000 tds pa; 47% are thermally treated; 18% recycled to agriculture; 1% sent to landfill and 34% to other outlets including composting (77%), landscaping (12%) and unknown (data for 2005). The connection rate to sewer and treatment plant is forecast to be 92% of population by 2010 and sludge production to amount to 273,000 t DM and to stabilise to a maximum of 94% by 2015/2020 with a total municipal sludge production of 280,000 tds – 100% coverage is not foreseen. In 2015/2020, the outlets for municipal sewage sludge are forecast to be: 5% going to agriculture, 10% to be treated by bio-mechanical treatment and 85% to be treated thermally.

Slovenia is reported to struggle to implement EU environmental legislation on wastewater treatment (Slokar, 2006). Slovenia's two million people live in 6,000 settlements, scattered over 20,000 km^2. About 53% of population is connected to about 200 municipal WWTPs while 42% of the population rely on septic tanks. Nevertheless, it is reported that when work on wastewater treatment plants for the country's three largest cities are completed, 60% of the nation's settlements will be compliant with the UWWTD. Sludge production amounts to 30,000 tds (2005 data). Although sludge was recycled in the past in agriculture; after 2002, the quantities decreased down to 1% due to the quality of the sludge and most sludge is landfilled. By 2010, with the construction of 50 new WWTPs, sludge production is forecast to amount to 40,000 tds. Thermal treatment will be the preferred option.

The values in Table 5 forecast that each country will produce sludge at a rate at least equal to 25kg/pe/year even if not currently doing so as treatment works develop to meet current frequently applied requirements. These include a small proportion of works with sewage effluent quality requirements that include restrictions on phosphorus and nitrogen concentrations. No adjustment has been made to these data to apply more detailed analysis of the likely increase in works that are required to achieve reduced effluent phosphorus concentrations and do so by using chemical treatments. These works would significantly increase the amount of sludge production from the combination of the chemical treatment and the associated requirement for low effluent suspended solids concentrations.

The sludge production values are the reported values of treated sludge, but before any conversion to ash through incineration or sludge powered generators. No attempt has been made at this time to closely model the forms of sludge treatment used in each country as the combinations of sewage and sludge treatment processes lead to a very wide variety of possible scenarios.

Two case studies from Austria and from Slovenia illustrate the disparity in meeting the EC requirements and thus the uncertainties in future forecasted sludge production (see box above).

Questions for the consultation

In assessing the likely amount of sludge production in 2020 the effect of the WFD and the UWWTD must be considered with respect to nutrient removal processes used in sewage treatment. Biological nutrient removal (N and P) which can meet requirements for total N<10mg/l and P < 2mg/l may have little impact on sludge production dependant on requirements for imported additional substrates, but use of chemical P removal to enable reliable enhanced P removal may increase whole works sludge production by 30% or more. This assumes current common technologies, and does not take into account any future off-line sludge processing to extract nutrients.

Q5 – What proportion of your country is likely to have sewage effluent consents for:

- Total Nitrogen
- Phosphorus.

Q6 – What are the likely consent values?

- Total Nitrogen < 15mg/l – for what population
- Total N < 10 mg/l, P < 2mg/l – for what population
- Total N < 10mg/l, P < 1mg/l – for what population
- Total N < 10 mg/l, P < 0.2mg/l – for what population

Q7 – What other combinations of consents may have significant impact on treatment processes?

Q8 – How will these consents be achieved?

- Biological nitrogen removal
- Tertiary nitrogen removal using chemical addition (methanol)
- Biological nitrogen and phosphorus removal
- Chemical phosphorus removal
- Combination of chemical and biological removal
- Other likely common process combination

2.2 Sludge disposal routes

The main factors in decision-making for selecting a disposal route for sewage sludge are transportation cost, PTEs concentration in sludge, and landfill capacity. Furthermore, the efficiency and cost of dewatering and drying are important for each disposal option. In addition to the factors mentioned above, EU and national regulation is an important factor as it can impose stricter limits values precluding its use in agriculture. Another important factor is public confidence.

Other factors which can also affect the decision in this field are concerns about global warming and the focus on energy efficiency and sustainability at wastewater treatment and wastewater sludge management facilities driven by energy prices.

Which approach prevails in any given region seems to be best predicted by the following factors:

1. population density;
2. availability of agricultural land; and
3. local social, political – and thus regulatory requirements.

2.2.1 Regulatory framework

Although, the Sludge Directive only concerns sewage sludge used in agriculture, this cannot be looked at in isolation of the other routes. For example, existing legal requirements on landfilling, thermal treatment as well as alternative energy production, by restricting or encouraging one outlet can have an indirect impact on sewage sludge recycled to land. In addition, other sources of sludge, food waste, organic fractions of municipal waste, might compete for available land and thus restrict the amount of sewage sludge which is recycled to land in the future.

If the Directive 86/278/EEC is not revised, some Member States may change their national legislation in the future – several have indicated that they would like to do so and some have already published draft proposals (for example, Germany) and/or introduced their own national voluntary guidelines to supplement the Directive (for example, The UK Sludge Safe Matrix).

It seems unlikely that if sewage sludge use is banned already, and consequently alternate routes have been found, that there would be a reversal unless sludge could be beneficially mixed with other organic wastes (to improve for example the conditioning properties) and processed using a high quality treatment (negligible pathogens, no smell) then the zero use could be reversed to a limited extent.

We have considered the baseline scenario as the current regulatory situation in each Member State regarding sludge recycled to agriculture/land. No other safe prediction can be made regarding possible developments of national legislation in the coming years.

The Community regulatory framework on waste management and energy is impacting on sludge management. Community waste policy applies a five-step waste management hierarchy as a priority order. The highest priority is given to waste prevention, followed by preparation for reuse, recycling, other recovery and disposal. Recycling to land of sewage sludge fits within the highest priority and is thus supported by the EC waste regulatory framework.

EC controls on landfills are reducing and restricting the proportion biodegradable waste (including sewage sludge) disposed into landfills. This potentially creates a desire to recycle more sludge to land and/or to improve or change treatment of sludge. Treatment and disposal methods that stabilise and reduce solids mass and volume will be encouraged, especially with energy recovery; these include thermal decomposition processes.

Recovery of energy from biodegradable materials is encouraged by the EU energy policy, in particular to increase the use of biofuels. There is potential to increase sludge production if non-sewage biodegradable materials become incorporated into the sludge treatment route. In contradiction to this, treatment processes are increasing their capability to convert organic solids to transferable fuels with less residual solids. The balance between increase and decrease of mass of residual solids from sewage sludge treatment is therefore unclear.

Facilities in which biological treatment takes place will have to comply with higher standards through the upcoming review of the IPPC Directive.

The Thematic Strategy on Soil addresses the wider subject of carbon depletion in soil and how to avoid and remedy it. This will take into account the potential of using compost as a means to increase the carbon content of soil.

A summary of drivers that may affect the disposal of sludge is shown below with a judgement of the importance of each driver in either promoting use or restricting the use of sewage sludge on land.

Technical issues will continue to require research, and best management practices for sludge management will continue to evolve. For example, the potential for excessive phosphorus to be applied to soils through sludge and animal manures may require application of developing technologies for removal of phosphorus. Likewise, current issues about trace chemical contaminants in sludge used on soils will continue to require support for research and analysis of risks.

Driver	**Expected consequences**	**Potential influence on use of sludge on land**	**Overall Importance**
EC Landfill Directive	• Reduction of biodegradable fraction in landfill • Increased treatment of sludge (i.e. composting) • Increase diversion of sludge to land • Increased diversion of sludge to incineration	Uncertain (Both positive and negative)	High
Incineration Directive	• Regulates emission limit values for selected potential contaminants (e.g. NOx, SOx, HCl, particulates, heavy metals and dioxins), • indirect improvement of sludge quality	Positive	Low
IPPC Directive	• Permits for biological treatment of organic waste (if pre-treatment before disposal) (i.e. composting capacity and of anaerobic digestion)	Negative	Medium
Renewable energy Directive	• By 2020, 20% share of energy from renewable sources • Incentives for the use of renewable energy sources such as biogas from sewage sludge.	Positive	Medium
Waste Directive	• Recycling has priority over energy • End of waste status for compost	Positive	Medium
Decision 2006/799/EC – eco-label requirements for soil improvers – sewage sludge not eligible	• Increased competition with alternate improvers that meet eco-label criteria • Sludge users not currently demanding additional quality standard • Reduces prospect of promoting sewage sludge as a beneficial product	Negative	Low – no significant demand for eco-label sludge
Decision 2007/64/EC – revised eco-label requirements for growing media – sewage sludge not eligible	• Sewage sludge not used currently to any significant extent as a growing media • Eliminates opportunity of promoting co-digested or co-composted materials	Negative	Low
Environmental Liability Directive 2004/35/EC	• In countries that adopt a strict liability regime for the use of sewage sludge on land, this might a) somewhat encourage the use of sewage sludge; and b) where used, encourage a preference for sludge treated to higher standards.	Negative	Low

Questions for the consultation

If you disagree with our judgements on regulatory influences on agricultural recycling please provide us with corrections and if possible explain the reasons using the following questions.

Q9 – In your country, what are the special conditions that encourage or discourage the amount of agricultural recycling?

Q10 – What change do you expect to take place in the rate of agricultural recycling by 2020?

Q11 – How will the existing regulations noted above affect your recycling and other disposal routes?

Q12 – Will the Nitrate Directive and the WFD have a significant effect on restricting or reducing the availability of land for agricultural recycling of sewage sludge? How much of an effect?

2.2.2 Population density and land availability

Population density and the availability of agricultural lands for sludge recycling to land will continue to be an important factor influencing policy decisions on sludge management. Indeed, these factors interact with social and political factors.

Even though most Member States hypothetically would only need to utilize less than 5% of their agricultural area to apply all of sludge produced, there still needs to be a relatively high level of acceptance by farmers and public for this outlet to be sustainable.

A simple view of the opportunity for using agricultural land for recycling sewage sludge is shown in Figure 3. The amounts of sludge produced and the amounts that are recycled to agriculture have been normalised to the total 'utilisable' agricultural land. This shows distinct differences between Member States, with the Netherlands having the smallest 'utilisable' area compared to the amount of sludge production. In general the EU12 have greater opportunities for recycling to agriculture.

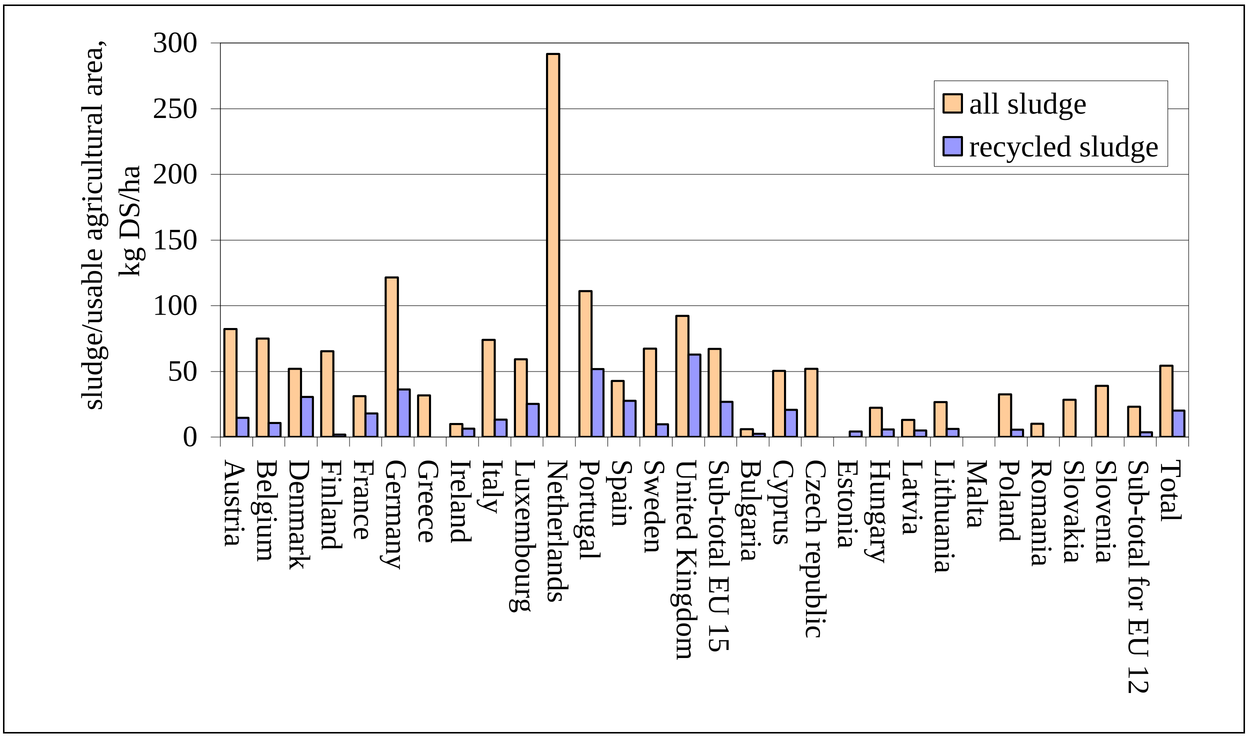

Figure 5 Comparing sludge arisings and extent of agricultural land: Total arisings and sewage sludge recycling to land per hectare of available agricultural land[7]

This approach does not take account of other recycling that may be taking place, such as the use of animal manure, which represents an alternative to sewage sludge and reduces the amount of available land for the latter. Nor does it take account of the different nature of farming across different countries: sewage sludge may be less suitable for some uses than for others.

In northern Europe, some of the most densely populated countries as well as regions (notably Netherlands; as well as Vienna and many cities in Germany) rely almost entirely on incineration as they have limited available agricultural land for the spreading of sludge.

2.2.3 Incineration as an alternative

Concerns have also been expressed about contaminants in sludge applied to soils. While scientific studies have not indicated major concerns, the future development of public opinion in this area is uncertain. These issues are addressed further in section 2.7.

A further influence will be the potential attraction of incineration of sewage sludge as an alternative, in particular as a potential source of renewable energy.

It can be noted that in general sewage sludge incineration occurs in large cities, but large cities do not always rely on incineration and some prefer recycling to land. However, as technology advances and population densities increase, a country may move toward more incineration for sludge management. This shift is advancing more quickly now, because of the higher costs of fossil fuel energy as well as European policy goals calling for the increased use of renewable energy.

Whether this trend toward incineration will continue is uncertain. Some studies have found incineration of sewage sludge to be much more costly in terms of total life cycle analysis,

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[7] Data for utilisable agricultural land from: www.ec.europa.eu/agriculture/agrista/2008/table_en/2012.pdf

economically and environmentally – including impacts on greenhouse gas emissions. In contrast, the most sustainable option has been assessed to be treatment by anaerobic digestion followed by some form of use on soils that offsets fertilizer use, such as composting. It is very important that these decisions take full account at each individual location of all factors including land availability, transport requirements, energy recovery and greenhouse gas emissions.

Some policy makers consider incineration to be a second choice to the recycling of sludge to land. However, negative public perceptions of sludge use on land may direct the political decision in favour of incineration.

2.2.4 Past, current and future trends in sludge treatment and disposal options

In 2008, sludge recycling to agriculture appears to be the dominant management option across the EU27 and is growing in the some of the new Member States (for example, Bulgaria). Many are developing sludge recycling programmes, and this option is expected to substantially replace landfill in the coming years. Figure 6 presents overall trends in management routes for the EU15, EU12 and overall EU members. Figure 7 presents past and future trends in terms of member country sludge recycling to agriculture in the EU15 and EU12.

The two most common treatments prior to sludge applications to agriculture seem to be anaerobic digestion and lime stabilization. In some of the old Member States (EU15), land application of raw and/or limited treated sludge is diminishing and composting and other treated products are increasingly used. There is also an increase of advanced treated sludge to be used in non-agricultural applications.

In many countries, corn is the crop most likely to receive sludge, but vineyards, orchards, grains, and other crops are also fertilized with sludge. Most countries discourage or prohibit the use of sludge on food crops destined for direct human consumption, and, if allowed, there are prescribed waiting periods between applications of sludge and harvesting of crops.

Most of the sludge used in domestic, horticultural, and green space (landscaping, parks, sports fields) is composted; some is heat-dried (for example, heat-dried pellet fertilizer).

Sludge is also used as a soil improver on degraded soils at mine sites, construction sites, and other disturbed areas such as in Portugal (Duarte) where sludge has been used for stabilising soils after forest fires. However, use of sludge in forests is relatively uncommon or even prohibited in some Member States.

Most Member States are, in general, moving away from landfilling to recycling sludge to land and/or – to a lesser extent – incineration with some recovery of energy.

Some (for example, Germany) have diversified outlets, with growing reliance on incineration with energy recovery (sludge powered generators) while some countries are committed to single options (for example, Netherlands relies almost entirely on incineration or Romania on landfilling). Norway implements the Sewage Sludge Directive as an EEA country, and it has followed a path that combines extensive use of sewage sludge on land, high environmental standards and public acceptance (see box)

Sewage sludge recycling in Norway

Norway recycles the majority of sludge to land. The reasons for successfully achieving this high level of recycling with public acceptance are many but include:

- stringent standards for the content of heavy metals (stricter than the EU standards) and pathogens, and
- high priority given to control of the odour nuisance.

This requires sanitation systems that keep significant levels of toxic elements (heavy metals) and chemicals (POPs, PPCPs, etc.) out of wastewater and thus sludge. It requires industrial and commercial pre-treatment programmes, stringent regulatory controls that encourage the recycling to soils of high-quality sludge and other organic residuals in integrated, nutrient management systems.

The level of public understanding and support is a major determinant in whether or not a country recycles significant portions of its wastewater sludge to soils. Therefore, public consultations, local demonstration projects, with the involvement of diverse stakeholders, to show the benefits of sludge recycling to land, and information to political leaders, regulators, and the public are important.

Finally, the development of products (other than soil amendments) from sewage sludge continues to be explored. Incinerator ash and melted slag are being used more in construction materials (mostly cement) and there are some examples of extracting phosphorus (P) from wastewater sludge and distributing it as fertilizer. But the complex technologies and operational costs required to extract or produce products from sewage sludge continue to be less cost efficient in comparison to the traditional, proven options such as recycling to land, incineration, and landfilling.

In comparison, there are relatively few EU15 countries – notably Austria, the Flemish region of Belgium and Germany – that are currently moving away from sludge recycling to land. Together with the Netherlands, they are moving toward more incineration with a focus on energy recovery. On the other hand, some cities are focusing on increasing methane gas production from anaerobic digestion, because of the energy benefits and climate change focus.

Although the proportion of sludge recycled to agriculture has not altered overall since 1995, at around 40 – 50%, the situation in some Member States has dramatically changed. Thus the overall recycling average of 40% of sewage sludge obscures substantial differences between Member States (see Annex 2). These trends have been used to predict future trends in sludge recycling to land in the different Member States. Table 13 summarises past trends regarding sludge recycled to land in the EU based on figures reported to the Commission between 1995-2006. Some of the main changes include:

- In Italy, in the mid 1990's, experts were predicting that incineration was going to increase; this did not happen and today, composting is on the increase.
- In the Netherlands, in 1996, 11% of wastewater sludge was recycled in agriculture and 82% was disposed in landfills while currently, most of the sewage sludge is sent to incinerators inside the country or in Germany, some of it after composting or heat drying.
- In Bulgaria, in 1996, all the sewage sludge was sent to landfill. New national regulations should lead to a high level of land application and a reduction in landfilling.

Table 13 Past trends (1995-2006) in sludge recycling to agriculture and current (2006) level of recycling in the EU27

Increasing (current %)	Status quo [1)] (current %)	Diminishing[2)] (current %)	Already very little use[3)]
United Kingdom (70%)	Sweden (10%)	Italy (18%)	Netherlands
Spain (65%)	France (60%)	Finland (3%)	Flemish Region [4)] (Belgium) (3%)
Ireland (63%)	Norway (~95%)	Austria (10%)	
Latvia (37%)	Denmark (50%)	Germany (30%)	Greece
Portugal (46%)	Walloon Region (50%)	Czech Republic (12%)	Slovenia
Bulgaria (40%)	Lithuania (25%)	Slovakia (0% but 61 % being composted)	Romania
Estonia	Poland (17%)	Cyprus (40%)	Malta
	Luxembourg	Hungary (26%)	

Note:

1) Although the quantities recycled to land have decreased over the years, the level seems to have stabilised in the last 3 years.
2) Although quantities recycled to agriculture are reported to have decreased over the years, for some of these Member States this masks the fact that sludge is still used on land but there has been a shift towards composting followed by recycling to agriculture and/or to other land uses
3) Although for some of these Member States (i.e. Netherlands and Flemish Region) recycling to land is definitely no longer an option while for some it may well become a sustainable outlet (i.e. Romania).
4) Although for the latest reported year (2006) 3% was still recycled to land, there was indication that no more sludge would be recycled to land in the following years.

The future trends in sludge management for most of the Member States are detailed in Annex 2, together with Table 15 and Table 16 that summarise sludge management routes for each country and the EU15, EU12 and EU27 groups. The trends for the EU15, EU12 and EU27 groups for the agriculture, incineration (or thermal treatments), landfill, and other routes (including land recovery, compost production) are shown in Figure 6 with additional details for the agricultural route for individual countries shown in Figure 7.

The overall trends for the EU27 are summarised below:

- Continued increased level of sewer connection and wastewater treatment across the EU27 which means more sewage sludge being produced which will need proper management.
- Increased treatment of sludge before recycling to land through anaerobic digestion and other biological treatments, like composting. The use of raw sludge will no longer be acceptable.
- Potential increased restrictions on types of crops being allowed to receive treated sludge.
- Enhanced production and utilisation of biogas. For example, trials with anaerobic co-digestion of wastewater sludge and MSW have proved to produce increased volumes of methane and to improve the quality of the wastewater sludge in Italy, Norway and Slovenia. Another technique is lysis and thermophilic anaerobic digestion as tested in the Czech Republic.
- Production of alcohols and other fuels directly from sewage sludge using pyrolysis and gasification.
- Similar proportion of treated sludge recycled to agriculture at around 40-50% by 2020. The situation in the existing 15 Member States should not change dramatically over the next 5 years. There are some indications in the new Member States which have no previous experience in this sludge management route that agriculture recycling may become a more significant outlet in the future.
- Phasing out sludge being sent to landfill due to EC restrictions on organic waste going to landfill and increased dislike by the public of use of landfill disposal. The most likely change will be for Member States which currently rely heavily on landfill as sludge disposal options –

these quantities will be diminishing over the next 15 years. By 2010, in these Member States, the proportion of sludge going to landfill will be lower than currently reported, and we have assumed that by 2020 there will be no significant amounts of sludge regularly going to landfill in the EU27.

- The main alternative to landspreading is likely to continue to be incineration with energy recovery for sludge produced at sites where land suitable for recycling is unavailable.
- Co-treatment of sewage sludge with a variety of other imported organic materials, particularly with reference to digestion processes, is currently not generally carried out, for reasons that include regulatory constraints. There are potential advantages of co-treatment in terms of asset utilisation (access to energy conversion systems, utilisation of existing infrastructure).
- Where population densities make it more difficult to recycle to land and/or where animal manures are over-abundant, increased treatment of sludge with energy recovery through anaerobic digestion, incineration or other thermal treatment, with recycling of the ash.
- Increased application of sludge to fuel crops such as miscanthus, hybrid poplars and other non-food energy crops.
- Increased industrial water pre-treatment and pollution prevention, reducing or eliminating discharge of toxic substances (heavy metals, chemicals) and improving sludge quality.
- Introduction of semi-voluntary and voluntary quality management programs such as the ones in place in England and Sweden to increase the safety of sludge use on food chain crops.
- Increased attention to climate change and mitigation of greenhouse gas emissions and thus recognised additional benefits of sludge applications to soils.
- Increased attention to recovery of organic nutrients, including those in sludge.

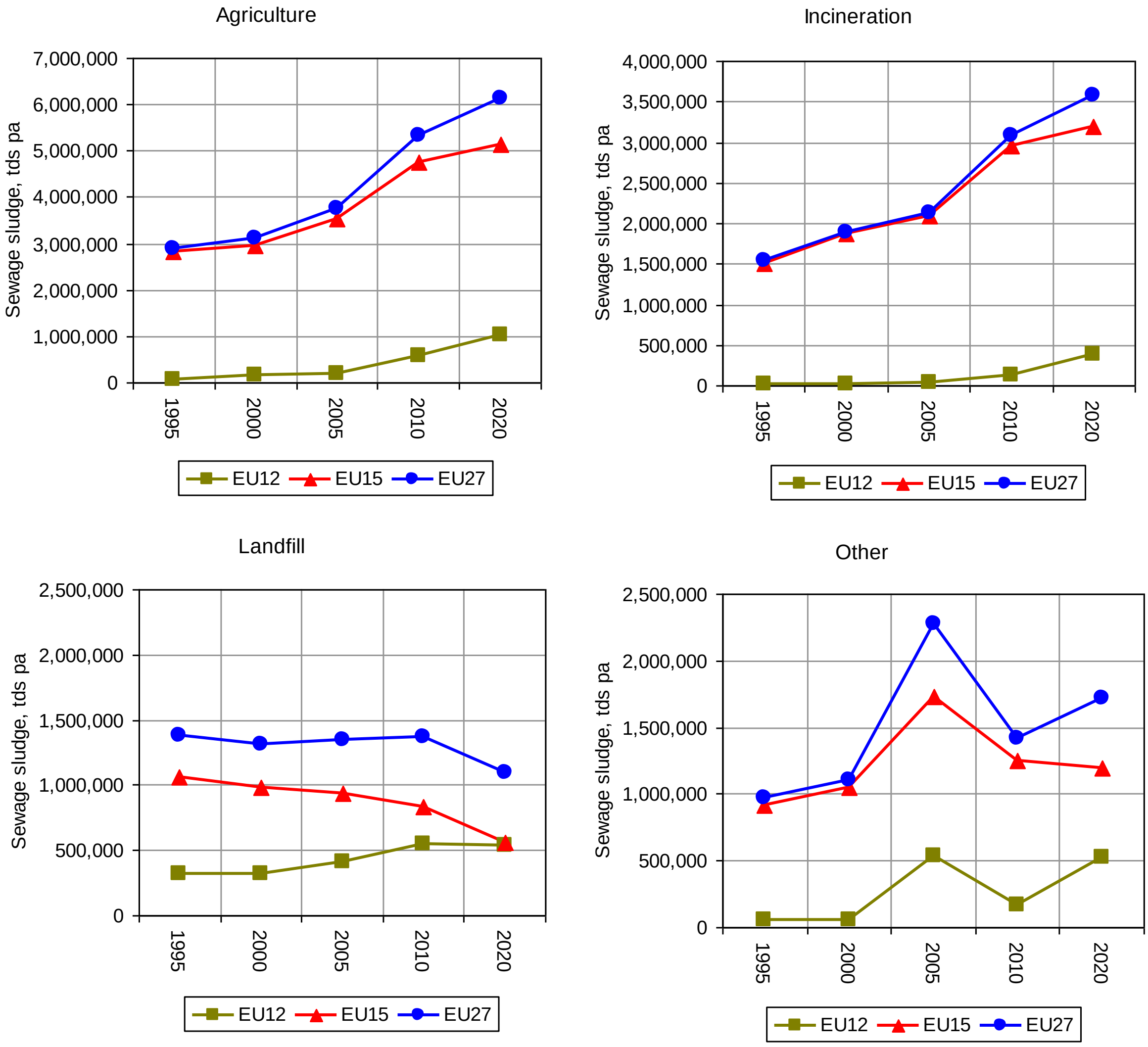

Figure 6 Main routes for sewage sludge recycling and disposal in the EU

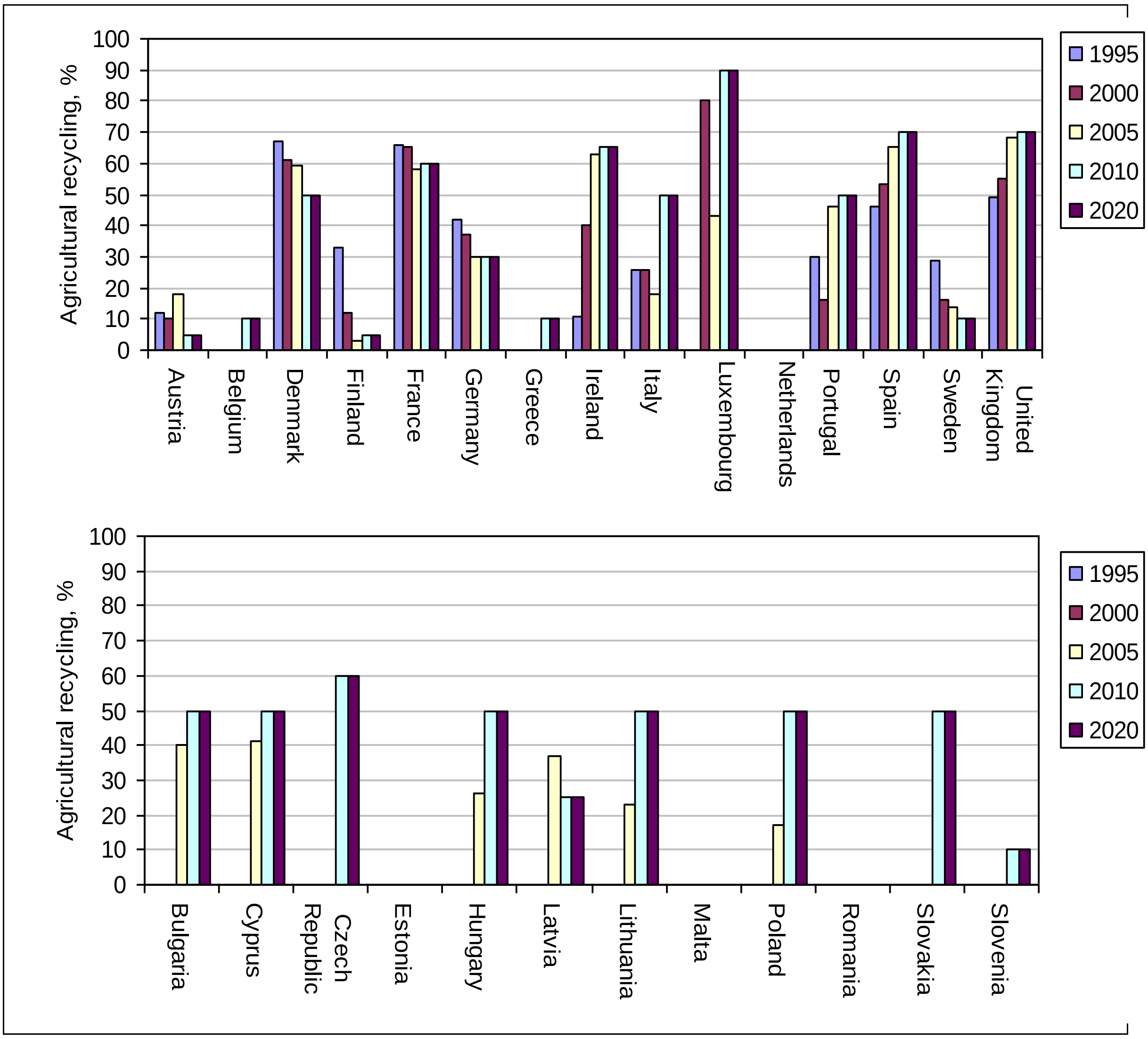

Figure 7 **Past and Future trends for sludge recycling to agriculture in the EU15 and EU12**

2.3 Sludge quality

The concentrations of metals in sewage sludge in Western Europe have been significantly reduced since the mid 80's as a combination between regulatory industrial effluent controls and a reduction of heavy industrial production. The extent of further reductions is unclear, although the range of loadings may be significantly different between different parts of the EU (including new Member states).

As new and existing environmental legislation at Community level is implemented (for example, REACH), it should also have a positive impact on the quality of sludge as better understanding and reduced use of hazardous substances is encouraged and better controls on environmental emissions are implemented.

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants.

It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertilizer. A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology. This has however not been covered in detail country by country but will be further researched during the consultation. It can be noted that in general sewage sludge incineration occurs in large cities, but large cities do not always rely on incineration and some prefer recycling to land. However, as technology advances and population densities increase, a country may move toward more incineration for sludge management. This shift is advancing more quickly now, because of the current increases in costs of fossil fuel energy.

2.3.1 Regulatory framework

A summary of drivers that may affect the quality of sewage sludge is shown below with a judgement of the importance of each driver.

Driver	Consequence	Potential influence on use of sludge on land	Importance
EC Regulation 1907/2006 – REACH regulations	• Reduction in poorly degradable chemicals in sludge • Increased confidence in sludge composition; improved acceptability	Positive	Medium
EC Regulation 466/2001 – foodstuff contaminants limits, including cadmium to be as low as reasonably achievable	• Sludges that contain measurable trace metals may be increasingly difficult to use on agricultural land • Increased landbank required to manage metal rich sludges • Diversion of metal rich sludges to thermal processes or investment in metal removal processes	Negative – EU15 mostly low Cadmium contents; some high contents in individual EU12 countries	Low
Decision 2006/799/EC – eco-label requirements for soil improvers – sewage sludge not eligible	• Increased competition with alternate improvers that meet eco-label criteria • Sludge users not currently demanding additional quality standard • Reduces prospect of promoting sewage sludge as a beneficial product	Negative	Low – no significant demand for eco-label sludge
Decision 2007/64/EC – revised eco-label requirements for growing media – sewage sludge not eligible	• Sewage sludge not used currently to any significant extent as a growing media • Eliminates opportunity of promoting co-digested or co-composted materials	Negative	Low
Monitoring of organic contaminants in sewage and sewage sludges	• Public perception that sludges may contain substances with adverse effects on health drives unacceptability of agricultural use	Negative	Medium
Water Framework Directive 2000/60/EC – enhanced nutrient removal requirements	• Increased phosphorus concentrations, may be linked to increased metals • Increased production	Negative	Low

Local controls on pathogen content	• Improved public acceptability defends and increases available landbank • Enhanced treatment reduces nuisance and so defends available landbank • Enhanced treatment can improve energy efficiency • Operating costs to customers increase	Positive – apart from operating cost negative	High
Compost standards – PAS 100	• Need to improve definition and quality standards of sewage sludges to compete with alternate materials	Negative	Low

2.3.2 Potentially toxic elements, PTEs

It has been confirmed by several studies (Sede and Andersen 2002, Smith 2008) that since the mid 1980's concentrations of heavy metals in sewage sludge have steadily declined in the EU15 (illustrated by figures for France, Austria, Germany and the UK) due to regulatory controls on the use and discharge of dangerous substances, voluntary agreements and improved industrial practices; all measures that lead to the cessation or phasing out of discharges, emissions and losses of these PTEs into wastewater and the wider environment.

The extent of further reductions is unclear. There is probably a minimum for PTE concentrations in sludge determined by diffuse inputs of PTEs to the sewer, which are less easily controlled. The range of loadings may be significantly different between different areas of the EU (including the new Member States). Indeed, Smith (2008) has pointed out that there remains further scope to reduce the concentrations of problematic contaminants, and PTEs in particular, in sludge. He suggests that this should continue to be a priority and pursued proactively by environmental regulators and the water industry as improving the chemical quality of sludge as far as practicable is central to ensuring the long-term sustainability of recycling sewage sludge in agriculture.

Monitoring and research needs to continue to assess the significance of new developments (including PTEs of new interest, for example, tungsten) as they arise.

2.3.3 Organic contaminants

The presence of organic contaminants (OCs) in sludge has been increasingly considered and the list of potential contaminants that have been detected in sludge is now extensive and includes: products of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dioxins), solvents (e.g. chlorinated paraffins), flame retardants (e.g. polybrominated diphenyl ethers), plasticisers (e.g. phthalates), agricultural chemicals (e.g. pesticides), detergent residues (e.g. linear alkyl sulphonates, nonylphenol ethoxylates), pharmaceuticals and personal care products (e.g. antibiotics, endogenous and synthetic hormones, triclosan).

However, at present, only a few countries, such as France, Germany and Denmark, have set limits for some individual OCs in sludge, while others, such as UK, USA and Canada have not, citing that research suggests that concentration present in sludge are not hazardous to human health, the environment or soil quality. Agreement on which, if any, OCs should be regulated in Europe could be important when the Sludge Directive is considered for revision.

OCs are being increasingly monitored in both sewage treatment waters and sludge and environmental waters. Improving analytical methods mean that OCs can be detected at very low concentrations. This fact and new toxicological information on effects at low levels and possible synergistic effects of mixtures mean that the presence of OCs in sludge will be increasingly under scrutiny, although present research does not indicate a concern for human health.

Pharmaceuticals are one group of OCs being extensively monitored in the sewage treatment process. While they are normally present at extremely low levels, it is possible that rapidly increasing use of a drug in, for example, a pandemic flu epidemic, may lead to a high concentration at the sewage treatment works and its potential presence in sludge. This potential problem will need to be considered, preferably in advance of the problem occurring.

Other OCs which are continuing to cause concern as they are detected in environmental waters are endocrine disrupting chemicals, including natural and synthetic oestrogenic hormones, such as 17β-oestradiol and ethinyl oestradiol and much less potent industrial chemicals such as nonyl and octyl phenols and their ethoxylates, and phthalates. Oestrogenic substances do partition to particulates and may be associated with sludge. Better known OCs such as PAHS, dioxins, flame retardants and perfluorinated compounds (and their new alternatives as they are phased out) will continue to be studied while novel technology may lead to the emergence of new OCs or substances such as nanoparticles, which will require new methodology for the detection of their potential presence in sludge and assessment of their risk to human health, the environment and soil quality.

While concern over OCs in sludge will continue and probably increase as our ability to detect low levels and their effect also increases, it should be remembered that many potential contaminants are already controlled by legislation, such as the Water Framework Directive. Therefore, levels in sludge of these chemicals should already be decreasing. The new REACH regulations although not specifically concerning waste, will add to our knowledge of toxicity, use, exposure and disposal of a wide range of chemicals which can be of use in predicting potential presence in sludge. As this knowledge increases, emerging hazardous pollutants will also be controlled where necessary, although persistence in the environment may mean that it takes some time before concentrations in the environment are undetectable.

2.3.4 Nutrient value

The concentrations of nitrogen (N) and phosphorus (P) are the factors which determine the rate of application of sludge to the soil in most landspreading operations. This results from the need to comply with the Nitrates and Water Framework Directives (91/676/EEC and 2000/60/EC respectively). Changes in the N and P composition of sludge as a result of increasingly rigorous nutrient removal requirements from wastewater may become more significant. They are most likely to increase the P concentration of sludge. This may be linked to changes in the metal concentration of sludge if P-removal is carried out using metal salts (aluminium or iron).

2.3.5 Pathogens

The Sludge Directive provides no specific controls on pathogen content apart from the general requirement for treatment before use in agriculture. It permits implementation of local rules or codes of practice suitable for local conditions and circumstances. Treatment under the sludge directive requires biological, chemical or heat-treatment, long term storage and any other appropriate process to reduce fermentability and health hazards associated with its use.

Local controls which specify indicator pathogen limits in the sludge have been implemented in several of the EU15 countries. These have been driven by stakeholder demands (farmers, food retailers, public requirements). Associated with these developments have been demands to reduce nuisance, in particular, odour, and perceptions that aerosols may contain pathogens. To meet these requirements sludge producers have been installing new treatment processes that achieve more reliable and greater levels of pathogen destruction during treatment.

The installation of processes that recover greater fractions of the energy present in the sewage sludge is also a factor in the greater reduction of pathogens initially present in the sewage sludge.

There are no widely accepted newly present pathogens in sewage sludges. However, concerns are frequently raised regarding one or more pathogens that may be normally present, or present as a result of unusual levels of population infections.

It is likely that a combination of:

- Replacement and new sludge treatment equipment;
- Economic and environmental drivers that enhance energy recovery and efficient treatment;
- Public and agricultural products users pressure on producers;

will combine to continue to enhance the microbial quality of treated sludges, both in countries in which there are existing pathogen content controls and extend these to countries that have hitherto not had specific additional pathogen content controls.

Other materials are in competition with sewage sludge as beneficial fertilizers for agricultural use, including a variety of composted organic wastes. Increasingly these are also being made to standards, such as the UK PAS100 standard, that includes specifications for pathogens content in the compost.

Questions for consultation

If you disagree with our estimations and assumptions concerning your country please provide us with corrections and if possible explain the reasons, using the following supporting questions if they are applicable.

Q13 – In your country what are the most significant local restrictions on sewage sludge quality that affect the availability of land for sewage sludge recycling?

Q14 – What changes to local statutory or practice requirements do you expect up to 2020 (in terms of limits on quality, etc.)?

Q15 – To what extent do the current requirements in the EU sludge directive affect the availability of land for sludge recycling? To what extent are the requirements believed to be unsuited to current farming and public needs?

Q16 – In your country what changes to the concentrations of metals in sludges do you expect up to 2020?

Q17 – What changes to concentrations of the nutrients nitrogen and phosphorus do you expect up to 2020? Will changes to sewage effluent phosphorus concentration requirements affect the balance of nutrients in sewage sludge?

2.4 Sludge treatment requirements

There is a continual desire to reduce sludge volumes during treatment and intensify process operations balanced by cost implications.

2.4.1 Regulatory framework

Directive 86/278/EEC requires that sewage sludge be treated before it is used in agriculture (Member States may authorise the injection or working of untreated sludge in soil in certain conditions, including that human and animal health are not at risk). The Directive specifies that for sludge to be defined as treated it should have undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as to significantly reduce its fermentability and the health hazards associated with its use.

These overall requirements have been interpreted and implemented within individual Member States differently, in part based on specific local conditions and circumstances. In general, untreated sludge is no longer applied and where it is to be used on land, it is usually stabilised by mesophilic anaerobic digestion or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting.

A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology. For example, The Safe Sludge Matrix, agreed between the British Retail Consortium and the UK Water Companies, requires either conventionally treated or enhanced (or 'advanced') treated sludge be used on agricultural land. Conventional treatment requires that at least 99% of pathogens have been destroyed and enhanced treated sludge requires that it is free from *Salmonella* spp. and that there has been a 99.9999% reduction in *E.coli* as a surrogate for a range of other pathogens. Enhanced treatment processes produce residual sludges for recycling to land which are low in odour and sanitised. These advanced treatment sludges have the advantages that they cause much less odour nuisance during landspreading, and do introduce fewer pathogens into the agricultural environment – so public perception and acceptability problems are likely to be avoided.

A summary of drivers that may affect the quality of sewage sludge is shown below with a judgement of the importance of each driver.

Driver	**Consequence**	**Potential influence on use of sludge on land**	**Importance**
Directive 86/278/EEC – Sludge use on agriculture – requires treatment	• Sludge treatment methods must be installed and used	Positive; most sludge is already treated in most countries	Low
Proposed directive on promotion of renewable energy sources	• Would promote use of more efficient and complete energy recovery biogas production processes • May promote other sludge powered generation systems (thermal processes) •	Positive – treats sludge as a resource with value	Medium
Directive 2000/76/EC on incineration of waste	• Allows use of thermal processes when appropriate to meet publicly acceptable standards so maintaining range of treatment options	Positive	Low
Local use of HACCP procedures	• Enables claims of treatment quality standards to be defended • Identifies treatment critical points for efficient monitoring	Positive	Medium
Local rules on renewable energy obligations and uses	• Promotes treatment efficiency	Positive	Medium

2.2.4 Future treatment of sludge

It is likely that processes that provide enhanced pathogen removal will become more widely used, as they also commonly produce a sludge that is less fermentable and so less odorous and will attract less public concern or criticism. Processes that can reliably and cost-effectively demonstrate substantially reduced pathogen concentrations are likely to be more widely used.

Co-treatment of sewage sludge with a variety of other imported organic materials, particularly with reference to digestion processes, is currently not generally carried out, for reasons that include regulatory constraints. There are potential advantages of co-treatment in terms of asset utilisation (access to energy conversion systems, utilisation of existing infrastructure).

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants. It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertilizer.

When updating plants operators have the following factors foremost:

- Reducing sludge solids quantity;
- Increasing energy recovery;
- Meeting current standards (current regulation AND any additional code of practices);
- Minimising operating costs;
- Capital cost minimisation is required by operators or financial regulators.

Treatment processes are listed below and described in more detailed in Annex 1.

Current	**Proven new processes or variants being used to replace or supplement existing processes**	**Novel**
MAD – Mesophilic anaerobic digestion TD – Thermal destruction (normally now with energy recovery) Lime addition for stabilisation or pasteurisation Compost Aerobic or Thermophilic aerobic digestion Landfill Drying	THP – Thermal Hydrolysis Process APD – Acid phase digestion processes Co-digestion or co-composting with non-sludge organic materials Wet oxidation (after digestion)	Pyrolysis Gasification (Both of the above already exist but few installations)

Questions for consultation

We have made estimations of current and future sludge management routes in individual countries, shown in Table 15 and Table 16 in Annex 2. If you disagree with our estimates, or our judgment of influences of treatment and management processes in your country, please correct them, and if possible explain the reasons, using the following supporting questions.

Q18 – What are the proportions of your sludges that are treated with the following main processes:

- Anaerobic digestion
- Advanced anaerobic digestion
- Drying
- Lime treatment

Q19 – What are the proportions of sludge converted or disposed of using:

- Incineration
- Landfill
- Other thermal processes (gasification, pyrolysis, wet oxidation)

2.5 Restrictions for application of sewage sludge on soil

2.5.1 Regulatory framework

A summary of drivers that may affect the use of sludge for agricultural and soil improvement purposes is shown below with a judgement of the importance of each driver in either promoting use or restricting use of sewage sludge.

The Nitrates Directive could be a significant restricting factor locally for the application of sewage sludge to land in regions where nitrates vulnerable zones have been identified and intensive animal production zones. The rules for organic farming could also have a negative impact on the proportion of sludge recycled to land as in most Member States – organic farming labels implicitly or specifically mean that no sewage sludge is allowed to be recycled to land.

The other drivers may have an impact but it has been estimated that it would be low negative.

We have, however, not carried out a detailed analysis of the effect of this impact at this stage. This aspect will need to be discussed during the consultation period.

According to the latest implementation report (CEC 2007), during the period 2000-2003, progress has been made in nitrate vulnerable zone designation. Seven out of fifteen Member States took the option in the Nitrates Directive not to identify specific nitrate vulnerable zones, but to establish and apply an action programme through the whole territory. In addition to Austria, Denmark, Finland, Germany, Luxemburg and the Netherlands, Ireland established a whole territory approach in March 2003. Other Member States increased, in several cases substantially, the nitrate vulnerable zones since 1999: United Kingdom (from 2,4% to 32,8% of the territory), Spain (from 5% to 11%), Italy (from 2% to 6%), Sweden (from 9% to 15%), Belgium (from 5,8% to 24%). Motivation for increased designation was not always provided.

Overall, in EU15, designation of nitrate vulnerable zones increased from 35.5% of the territory at the end of 1999 to 44% at the end of 2003. From 2003 onwards further designations were made, in Italy, Spain, Portugal and United Kingdom, Northern Ireland. Belgium has established the procedure to increase its designation to include 42% of Wallonia territory and all Flanders

Driver	**Consequence**	**Potential influence on use of sludge on land**	**Importance**
Directive 91/676/EEC – Nitrates Directive	• Nitrate vulnerable zones limiting fertilizer application • Good agricultural practice required with particular care in the zones • Sludge cake may be more beneficial as nitrogen in slow release form	Negative	Medium
Council Regulation (EC) No 834/2007 on organic production and labelling of organic products	• No clear ban on organic labelling of sewage sludge • Member state practices generally do not accept sewage sludge as organic	Negative	Medium
EC Decisions 2006/799 and 2007/64 on criteria for the award of a Community eco-label to growing media	• Growing media containing sludge shall not be awarded an eco-label	Negative	Low
Soil protection – proposal for amending Directive 2004/35/EC	• Impacts of sludge recycling to land to be evaluated	Negative	Low
Directive 2003/87/EC on greenhouse gas emissions	• Impact on ammonia production	Positive	Low
The effort sharing Decision	• Recovery of biogas from sludge treatment	Positive	Low
Directive 2006/118/EC – groundwater protection against pollution and groundwater quality standards	• Spreading of sludge requires local rules • In some areas may require change in farming or forestry practice	Negative	Low
Directive 2008/105/EC – EQS for pollutants to achieve good surface water quality	• Local rules may be required either to control pollutants in the sludge or to control sludge distribution and incorporation in soil • Undefined sludge composition in competition with defined inorganic fertilizers	Negative	Low

2.5.2 Future land use restrictions

As Member States increase their designation of vulnerable zones, land application of sewage sludge will be more restricted in terms of loading rate and land available for application.

Questions for consultation

If you disagree with our judgements on the effects of regulatory requirements on sewage sludge agricultural recycling in your country please correct them, and provide explanations using the following questions if they are applicable.

Q20 – What are the likely impacts of the Nitrates Directives on the current sludge recycling proportion in your country? By how much?

Q 21 – What local codes of practice or other restrictions related to land use have the greatest impact on sludge recycling to agricultural land in your country?

Q22 – What changes in land use are likely to affect sewage sludge recycling?

Q23 – Will the lack of eco-label qualities (including organic farming) affect the use of sewage sludge in your country? By how much? Would other standards improve desirability?

2.6 Monitoring and control requirements

2.6.1 Regulatory framework

The existing Directive imposes periods of prohibition between sludge spreading and grazing or harvesting. These vary according to the Member State (EC 2006). In Ireland, Spain, Luxembourg, the Netherlands, Portugal and the United Kingdom, the provisions of the Directive apply: that is, sludge must be spread at least three weeks before grazing or harvesting and on soil in which fruit and vegetable crops are growing, or at least ten months for soils where fruit and vegetable crops that are eaten raw are cultivated in direct contact with soil. In the other Member States the rules are generally stricter than those provided for by the Directive. Some Member States ban the application of sludge on forestry or land recreation areas.

Some Member States have published specific Code of Good Agricultural practices for land application of sludge and have also introduced quality assurance systems (for example, HACCP, Hazard Analysis and Critical Control Point management). HACCP applies risk management and control procedures to manage and reduce potential risks to human health and the environment from agricultural application of sludge. It is designed to provide assurance that specified microbiological requirements are met and that risk management and reduction combined with appropriate quality assurance procedures are in place, thus preventing the use on farmland of sludge that does not comply with the microbiological standards.

2.6.2 Future monitoring and controls

Although there is no regulatory requirements, the use of quality assurance systems will be generalised on a voluntary basis mainly though the pressure from the food industry.

Questions for consultation

Q24 – Are further restrictions needed on types of crops and or specific land areas (i.e. forest) or longer harvesting intervals?

Q25 - Should formal risk management methods be consistent throughout the EU?

2.7 Other factors which could influence sludge recycling to land

A number of other factors which could influence sludge management in the future need to be further evaluated including their risks and opportunities for the recycling outlet. This will require further discussion with the Stakeholders during the consultation period. Some areas of uncertainties are listed below:

- Treatment technologies - Developments in sludge treatment will continue and there may be a move towards enhanced treatment for sludge going to land so that the product to be recycled is effectively odour and pathogen free.
- Another possible change is the opportunity to co- treat sludge with other materials such as municipal solid waste
- Public perceptions - Although overall it is predicted that 50 % of sludge is likely to be recycled to land, there are uncertainties about the future sustainability of this outlet due to public opinion and the competition for land with other organic wastes.
- Mineral fertilizers – sewage sludge represents only a very small amount of total nutrients spread on land, of which mineral fertilizers provide the largest share. The future demand and supply of mineral fertilizers could thus influence the use of sewage sludge..

Factor	Potential risk	Potential opportunity	Degree of uncertainty	Influence on future changes on spreading sewage sludge on land
Public opinion	Widespread rejection of sewage sludge use	Wider acceptance of land spreading as effective recycling	No major changes expected; but future opinion is uncertain	National level: stricter requirements or bans possible NGO and public opposition Farmers acceptance of sludge
Scientific research	Could identify new health risks. Ambiguous results could be interpreted as health risks	Could provide stronger evidence for a lack of health risks	No major changes expected	National level: stricter requirements or bans possible NGO and public opposition
Sludge treatment technology	Could be expensive compared with other outlets for sludge. Lower level of nutrients	Greatly reduced levels of odour and pathogens	Level of developments Proportion of sludge being treated	On the one hand, improve public acceptance; on the other, lower nutrient value
Mineral fertilizer	A fall in fertilizer prices could lead to lower demand for sludge.	Possible shortage of natural resources and higher prices could increase demand for sludge. Added conditioning value with sludge	Future availability	On a local basis only not nationally

2.7.1 Competition with inorganic fertilizers

In coming decades, global fertilizer consumption is predicted to increase steadily (see Figure 8). In industrialised countries such as the EU15, FAO forecasts that consumption will rise by about 20% from the late 1990s to 2030. Elsewhere, consumption will increase even higher. World fertilizer demand has been increasing to meet global plant nutrient requirements driven by a combination of population changes, increased crop production, and development of biofuel crops (Heffer and Prudhomme, 2008). The increased consumption has also been reported with forecast increases in consumption by the EEA and shown in Figure 8.

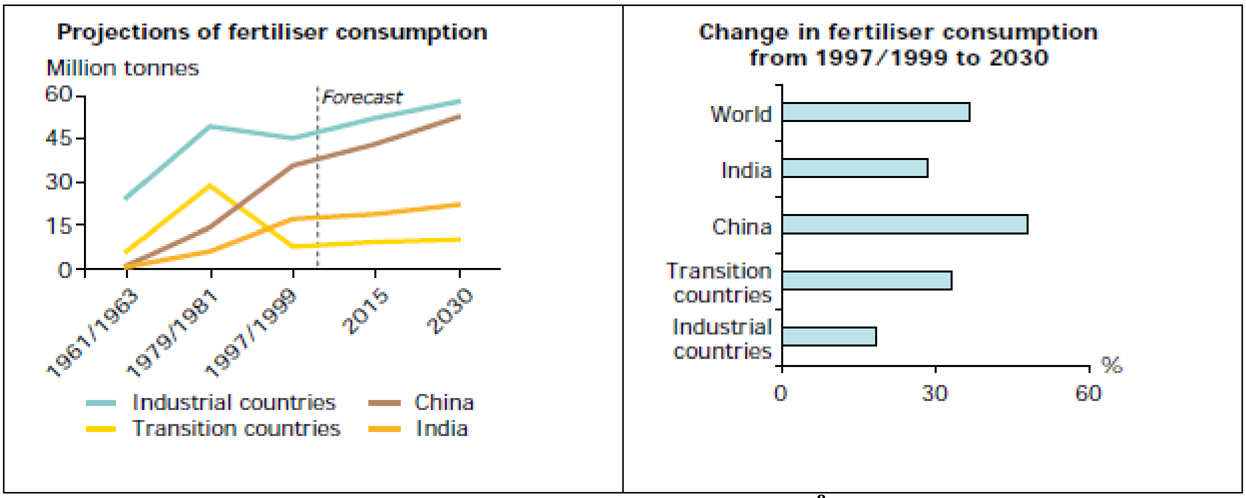

Figure 8 Forecast of world fertilizer requirements to 2030[8]

The increase in demand in the current decade has led to higher prices of the raw materials used in mineral fertilizers, as shown in Table 14. A possible shortage phosphate for use in fertilizer has been forecast for many years, and this could be a concern in the coming decade. Nonetheless, current forecasts of known extractable sources of phosphate rock indicate that at current rates of use reserves are available for almost three centuries.

More generally, the increased demand for fertilizer is now being matched by newly available supply, with further increases in supply of all components including phosphate expected from current extraction developments (Heffer & Prud'homme, 2008).

Table 14 Fertilizer component costs at source

	$/tonne	$/tonne
	2004	Jul 2007
Sulphur	60	110
MOP (Potassium brine)	110	200
NH_3 (ammonia)	250	240
Urea	150	270
DAP (Di ammonium Phosphate)	310	420

While sewage sludge – due to the much smaller volumes – cannot be regarded as a significant alternative source of fertilizer components, a shortage of fertilizer would likely lead to higher demand

[8] http://www.eea.europa.eu/publications/technical_report_2008_8

for alternatives, including sewage sludge. Moreover, sludge may be a valuable alternative or supplemental source with its particular properties of soil conditioning and long release fertilizer components which may be particularly valuable in areas sensitive to high nitrate or phosphate loading. Whilst inorganic fertilizers remain available increases in transport and energy costs may make locally available sewage sludge a more desirable source of fertility.

Questions for consultation

If you disagree with our judgements of influences or effects of factors that include public opinion, financial pressures or materials availability, please correct them and provide explanations where possible using the following questions.

Q26 – Is sewage sludge likely to be used as a replacement for inorganic fertilizers? To what degree is the use of sewage sludge influenced by the market for inorganic fertilizers? Are the qualities of sewage sludge as a replacement for inorganic fertilizers sufficiently well understood to increase the demand for sewage sludge recycling onto agricultural land?

Q27 – How will public opinion in Member States that currently send high levels of sludge to landfills (e.g. EU12) react to greater use of sewage sludge on land?

Q28 – Will the co-treatment of sludge with municipal solid waste become an important path for the future?

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Annex 1 Sludge Treatment processes

Mesophilic Anaerobic Digestion (MAD) is a well established process for treating sewage sludge that operates in the mesophilic temperature range (30 – 38°C). The organic matter that can be converted to biogas within the sludge, referred to as volatile solids, is metabolised microbially, typically over a period of 12-15 days. The volatile solids are first broken down by acid-producing (acidogenic) bacteria and produce smaller, volatile fatty acids (VFA) compounds, which can then be used by methane-producing (methanogenic) bacteria to produce biogas.

In conventional MAD approximately 40-45% of the volatile solids can be converted to biogas. Biogas is approximately 65% methane (CH_4) and 35% carbon dioxide (CO_2) and will typically be burnt in a CHP engine to generate electricity and heat, a portion of which will be used to maintain the optimum temperature in the MAD. Conventional MAD may not always destroy pathogens to the required level and therefore a pasteurisation step is sometimes incorporated.

Acid Phase Digestion (APD) is a variation of the MAD process. Instead of the one reactor in a conventional MAD plant, APD uses two or more reactors, whereby the acidogenic phase and the methanogenic phase are separated. In the first reactor a large amount of volatile solids are added and the pH drops over 3-4 days as VFAs are produced. This material is then fed to the main digester where the methanogenic process occurs, producing biogas. In APD it has been estimated that 53% of the volatile solids is converted to biogas. Therefore, more biogas is produced in APD compared to a conventional MAD. The low pH of the acid stage leads to an increased destruction of pathogenic organisms.

The Thermal Hydrolysis Process (THP) is also a two stage process. In the first stage the sludge is treated in a reactor by injecting steam at high temperature (150°C – 170°C) and pressure (5 - 7 bar) for approximately 30 minutes. This essentially 'pressure cooks' the sludge, solubilising more of the organic material and making it easier to digest. It will also destroy pathogens. In the second stage, this residue is fed to an anaerobic digester where approximately 60% of the volatile solids can be converted to biogas. Therefore, more biogas is produced by THP than by either conventional MAD or APD. An additional benefit of THP is that higher concentrations of volatile solids can be added to a digester, meaning that a higher throughput of sludge is possible for a given volume of digester. Retrospectively fitting THP to a MAD plant can therefore increase the capacity of the plant.

The Wet Oxidation Process for sewage sludge involves the injection of air, or oxygen, into sewage sludge at high temperature and pressure. It was first used for sludge in the 1960's but has not been widely installed for sludge treatment. It has some similarity to incineration in terms of the completeness of the conversion, but with a reduced risk of production of substances such as dioxins, furans, nitrogen oxides and dusts that could or are present in incinerator off-gases. The process has chiefly been used previously for strong and poorly degradable industrial effluents, with a reputation for being highly corrosive to equipment. The Athos® process (Veolia) uses conditions of 250°C temperature and 50 Bar pressure, injects pure oxygen and uses a copper sulphate catalyst, to achieve 85% COD removal, a residual solid that dewaters readily to 55% dry solids, and a liquid effluent rich in acetic acid that can be used to drive a biological phosphorus removal plant. Recently installed processes in France, Belgium and Italy treat sludge after anaerobic digestion to reduce the oxygen and energy demands,

Brief description of pyrolysis and gasification

Pyrolysis is the heating of a substrate such as coal, wood or sewage sludge at around 500°C. This drives off hydrocarbon vapours which on cooling produce a mixture of tar, oil and permanent gases. The residue left after pyrolysis is termed a char – coke and charcoal being examples. The char contains the ash that would be produced by incineration, together with non-volatile carbon compounds. It should be assumed that the environmental impact from char is greater than that of incinerator ash.

Gasification involves heating the substrate to 800°C or higher, sometimes with added steam. This enables the water gas or syngas reaction to take place, which produces a mixture of carbon monoxide and hydrogen. In principle this reaction can proceed to completion, leaving behind a mineral ash essentially the same as incinerator ash, though in practice it may retain some of the characteristics of a char.

The high temperatures are often obtained by introducing a limited supply of air, allowing combustion of part of the substrate. This will introduce CO_2 into the gas, reducing its calorific value. As sludge is heated up to gasification temperatures, a certain amount of pyrolysis will always take place. In practice there are a large number of process configurations which can be geared towards producing oil, hydrocarbon gas or syngas and which may produce char or ash as a solid residue. Sometimes the char is incinerated. In general, these processes have not been developed at any significant scale for sewage sludge, except for one large scale oil from sludge plant in Perth, Western Australia. Pyrolysis/gasification cannot yet be considered to be a developed process for sewage sludge.

Incineration or complete gasification with combustion of the gas both liberate essentially the same amounts of energy. Fluidised bed incinerators, however, require substantial amounts of electricity to run. While sludge gasifiers are at a much earlier stage of development, it is believed they will require much less energy to operate than an incinerator. As a result, the net electricity production from gasification should be considerably greater than from incineration.

Annex 2 – Country files

Reviews of individual EU countries are presented, with summary tables of annual sludge production and percentages to different disposal routes shown as Table 15 (1995 – 2005) and Table 16 (2010 – 2020).

Austria

The following description is based on information provided by Kroiss for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and a presentation given by Doujak in 2007.

In 2005, there were about 1500 municipal treatment plants in Austria with a treatment capacity of 18.6 million capita. Approximately 90% of the population was connected to a municipal treatment plant while 10% had in-house treatment plants (for example, septic tanks, cesspits).

The annual sludge generating rate is reported to vary between 11 to 32 kg DS per capita per year. In 2005, municipal sewage sludge production in Austria amounted to 266,100 tds including 28,000 tds of imported sludge; 47% was incinerated; 18% was recycled to agriculture, 1% sent to landfill and 34% disposed by other routes such as composting (77%); landscaping (12.3%), intermediate storage (2.4%) and unspecified.

It is expected that, by 2010, the connection rate will increase to 92% and annual sludge production will rise to 273,000 tds and that, by 2015, the connection rate will rise to 94% and sludge production is expected to have reached 280,000 tds pa. By 2020 the sludge production will stay at this level as 100% connection is not expected.

Region	Sludge production (tds/y)	Agriculture	Incineration	Landfill	Other (inc. composting, landscaping, intermediate storage and unknown)
Burgenland	10,700	5650	110		4910
Kärnten	11,800	830	2560		8410
Niederösterreich	41,000	13410	5690		21900
Oberöstereich	44,200	17550	23810		2810
Salsburg	12,800	1950	8320		2560
Steiermak	25,900	5430	4930	2850	12710
Tyrol	16,400	170	2460	990	12810
Voralberg	10,400	2200			8180
Vienna	64,900		62780		2160
Imports	28,000		12800		15200
Total	**266,100**	**47,190 (18%)**	**123,460 (47%)**	**3,840 (1%)**	**91,650 (34%)**

In addition, there was also 155,000 tds of sewage sludge from industries (mainly cellulose and paper industry) being produced in 2005, which was mainly incinerated (83%) or sent to landfill (13%), with 3% recycled to agriculture and 1% to other outlets.

Based on predictions presented by Doujak, for our baseline scenario, we have assumed that by 2020 in Austria, the proportion of municipal sewage sludge recycled to agriculture will decrease to 5% and that about 10% will be treated in MBT plants (mainly composted) to be recycled to land reclamation projects and that about 85% will be thermally treated (by either incineration and/or co-incineration). In addition, sludge from industries will be entirely thermally treated (100%).

The development of sludge disposal routes in Austria is strongly influenced by the regional regulatory framework for sludge and waste management.

There are stringent restrictions on the application of sewage sludge and compost on agricultural land specified in the regulations. These requirements vary according to the federal state: two of the 9 federal states have, for example, banned sewage sludge application in agriculture. Where it is allowed, sludge has to be treated and at least dewatered. At the treatment works, up to a half-year storage capacity is necessary to fulfil the requirement that sludge must not be applied during late autumn and winter. Direct application of sewage sludge on grass land has little relevance today in Austria. The use of sludge on forestry in Austria is forbidden by law.

There are additional restrictions imposed on the use of sewage sludge and compost in agriculture due to product quality requirements for different markets (for example, organic farming, eco-labelling, and retailer requirements).

As the legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are much less stringent; an increasing part of sewage sludge, mainly after composting, is used for this purpose especially where the agricultural reuse is no longer accepted.

In recent years, there has been an increase of sludge-drying facilities with different processes (drum dryers, solar drying) to reduce storage volume and transport load. On a national scale this method still has low relevance. There is also an increase of adding other organic wastes into anaerobic sludge digestion to increase biogas production. Mechanical Biological Treatment plants (MBT) have been proposed as a suitable option for sewage sludge composting in combination with other organic materials.

While in the past 11% of sewage sludge was sent to landfill for disposal, since 2004, only material meeting the following criteria is permitted in landfill disposal:

- Less than 5 % TOC related to total dry solids
- Less than 6000 MJ/kg dry solids.

These criteria cannot be met by conventional sludge treatment and stabilization processes; only the ashes after incineration meet the requirements which means that sludge disposal on landfill sites is effectively banned and has no major role in Austria.

During the last 10 years, waste incineration capacity in Austria has increased. The overall capacity is still dominated by fluidized bed incineration plant on the site of the Vienna Main Treatment Plant where about 25% of the total sewage sludge production in Austria is incinerated. For the remaining, sludge is mainly co-incinerated with other wastes in coal-fired power plants and cement kilns.

The current debate in Austria on sludge disposal is dominated by soil and food protection from potentially hazardous organic micro-pollutants and sustainable phosphorus management.

In Austria there is general requirement for treatment plants > 1000 pe for P-removal which results in a ~80 to 85% transfer of P from waste water to sewage sludge. It has been estimated that the P-load in sewage sludge could replace up to ~40% of P-market fertilizer imports to Austria.

There are two clear options in the debate on sludge disposal. The first favours incineration as organic pollutants are destroyed. The second favours sludge application in agriculture as this is the least-cost solution for recycling phosphorus and favours mono-incineration of sewage sludge with P-recovery from the ashes. It does not favour co-incineration with cement coal and wastes as it interferes with P-recovery.

Under waste legislation, energy recovery from sewage sludge has a lower priority compared to nutrient and organic material recycling. But as the political discussion on sludge treatment and disposal is increasingly focussing on possible risks for soil and food due to application of sewage sludge that may contain organic micro-pollutants, public acceptance of incineration is increasing.

Belgium

The situation in Belgium has to be described separately for the 3 regions. The description below is based on information provided by DGRNE 2005, IRGT 2005 and from a presentation given by Leonard in 2008.

Wallonia

Since 2000, a public water management company (SPGE) has been coordinating and financing wastewater treatment in Wallonia. While in 1999, only 38% of wastewater could be treated in Wallonia, at the end of 2004, 137 UWWT plants with capacity of 2,000 p.e. or more were in service with a total treatment capacity of 2,500,000 pe or about 60% of the 2005 UWWT target (i.e. 4,215,775 pe). An additional (700,000 pe + 483,000 pe.) treatment capacity was constructed and had been commissioned, respectively, thus leaving about 11 % short of the target to be met. By 2007, treatment capacity had increased to 88 % of population, compared with 60% in 2005 and 38% in 1999. Treatment capacity is reported to be over scaled by 20% to allow for population and industrial growth. From 3,413,978 inhabitants in 2006, population is expected to grow up to 3,450,555 by 2011 and to 3,551,351 inhabitants by 2020.

About 80% of the population are located in agglomerations above 2,000 pe, about 9% are in agglomerations less than 2,000 pe with both connected to sewer while about 12% of the population (400,000 inhabitants) live in areas without municipal sewer and need to install an individual wastewater treatment system.

The whole territory has been designated as sensitive area which means that all the plants with a capacity of more than 10,000 pe have to have been equipped with tertiary treatment by 2008 at the latest. Ninety percent of the 137 plants in 2004 were small or medium-sized (less than 10,000 pe). Most treatment plants had secondary treatment and only 33 plants with a capacity above 10,000 pe had tertiary treatment.

From the latest figures submitted to the Commission, sludge production amounted to 18, 514 tds in 2001, 20,300 tds in 2002 and 23,520 tds in 2003. By 2005, sludge production was estimated to 30,000 tds and it is expected that by 2010, when Wallonia will have completed investment for the UWWT Directive, IRGT (2005) and Leonard (2008) estimated that sludge production will rise to 45,000 tds which is lower than our estimate of 80,000 tds based on 25kg per capita, 3.5 M inhabitants and 88% connection. For our baseline scenario, we have assumed that it will stay at that level until 2020 as population growth and industry expansion is expected to be limited.

In Wallonia, recycling to agriculture has traditionally been the preferred option although the proportions have decreased over the last 10 years from more than 70% in 1995, 88% in 1998, 65% in 2000 to about 50% in 2002 and 2003. It was reported by Leonard that, in 2006, about 32% was still recycled to agriculture. Quantities sent to landfill have first increased from 18% in 1998 to 45% in 1999, 34% in 2000 and 37% in 2001 but would only be around 5% in 2006. Proportions of sludge sent to MSW incinerators have dramatically increased since 1999 from 2% to more than 60% in 2006. The agriculture outlet should continue to play an important role in sludge management despite some fear and opposition from the population.

For our baseline scenario we have assumed that the proportion of sludge recycled to land will remain at the current level for the next 15 years, i.e. 30-35%.

Leonard reported the growing interest in drying facilities and methods to improve dewatering of sludge.

Flemish region

In the Flemish Region, in 1990, approximately 78 % of the wastewater from households was collected in sewer systems, but only 30 % was treated in a wastewater treatment plant. In 2002 the collection and treatment rates increased respectively up to 86% and 60%. By the end of 2005, treatment levels amounted to 64.4% (VMM, 2006) and by 2007 this figure was expected to have reached 80%.

From the figures submitted to the Commission, sludge production amounted to 81,351 tds in 2001, 82,871 tds in 2002 and 76,072 tds in 2003 (CEC 2006). From the latest reports (CEC 2009, personal communication), sludge production was reported to amount to 87,382 tds in 2004, 76,254 tds in 2005 with no figure available for 2006. According to IRGT (2005), it is expected that by 2010, when Flanders should have completed investment for the UWWT Directive, sludge quantities will increase by 43% compared with the 2002 figure amounting to about 118.000 tds which is lower than our estimates of 135,000 tds based on 25kg per capita, 6.1 M inhabitants and 88% connection.

Due to more stringent restrictions on PTEs, quantities of sludge recycled to agriculture have decreased sharply since 1998 from 22% down to 7% in 1999, 0% in 2000/2001, 2 % in 2002 and 3% in 2006. Quantities sent to landfill have also decreased steadily since 1998 from 35% down to 3 % in 2002 while quantities sent to incineration have risen steadily since 1998 from 43% to 95 % in 2002. For our baseline scenario we have assumed that there will be no longer any sludge recycled to agriculture in 2010 and in 2020 and that all sludge will be thermally treated.

Brussel region

In the Brussels region, it is currently estimated that 90% of inhabitants are connected to the sewage system. It is expected that, by the year 2015, 100% of inhabitants will be connected. The first (and only) wastewater treatment plant with a capacity of 360,000 pe started operation in 2000. The second UWWT plant with a capacity of 1.1 M pe started operating in 2008. Since 2009, sewage sludge is treated by thermal hydrolysis/anaerobic digestion followed by wet oxidation reducing sludge quantities by 99% and the final product will sent to landfill or used in construction materials.

Following the implementation of the UWWT Directive, sludge quantities are expected to increase by 300% by 2010 compared with 2002 figure of 2,792 tds. However with the wet oxidation treatment applied, the final quantities should not increase dramatically. In 2002, sludge produced at the first works was recycled to land (32%), sent to landfill (66%) and incinerated (2%). For our baseline scenario we have assumed that there will be no longer any sludge recycled to agriculture by 2010 but sludge will be treated by wet oxidation and disposed of for other uses and that the situation will not change by 2020.

Bulgaria

The following description is based on information provided by Paskalev for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and various other reports including MoEW 2003 and UNDP/GEF Danube Project 2004.

Bulgaria joined the EU only recently (January 2007) and has been granted an extended deadline until December 2014 to comply with the UWWT Directive.

The population in Bulgaria was around 8.1 M in 2000 and decreased to 7.8 M in 2002. The forecast is for continued decline: from 7,785,091 inhabitants in 2003 to 7,323,708 inhabitants in 2014 that is a 6% decrease of population (MoEW, 2003).

The transition period for implementing the Directive 91/271/EC in Bulgaria is as follows:

- By 1 January 2011 - construction of sewerage systems and WWTPs for settlements with more than 10000 pe;
- By 1 January 2015 - construction of sewerage systems and WWTPs for settlements with 2000-10000 pe.

In 2002, the proportion of population served by public sewer network and wastewater treatment was 68.4% and 38.6%, respectively. The number of WWTPs was 55, of which 43 plants had biological treatment while the remaining had only mechanical treatment. The total length of the network is around 9,000 km and is in poor condition and needs to be upgraded. The Government plans to build an additional 16,000 km of sewers to connect 2.4 million people as part of the plan to meet the EU directives. The plans of the Government are to treat wastewater generated by 85% of the population.

In 2002, about 500Mm^3 of urban wastewater was discharged annually into sewer; 21.7% is untreated, 2.5% is treated by primary treatment and 75.8% is treated by secondary biological treatment. In addition, 64Mm^3 is not collected. The existing WWTPs with biological treatment were under utilised by 44%.

About 1,000 new urban wastewater treatment plants are planned between 2003 and 2015 in Bulgaria for agglomerations with populations over 2,000 pe (MoEW 2003 reported by UNDP/GEF 2004).

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
New WWTPs >10,000 pe:	1	2	7	22	43	53	48	33	0	0	0	0	209
New WWTPs for 2,000-10,000 pe;	0	0	0	0	0	19	87	129	177	196	154	87	849
WWTP for completion	6	8	7	9	8	5	2	2	0	0	0	0	47
WWTPs for reconstruction and modernisation	6	16	18	29	30	32	20	23	4	2	0	0	180

Sludge production was reported to amount to 31,300 tds in 2004, 33,700 tds in 2005 and 30,000 tds in 2006 for a population of 7.5 million (CEC 2009, personal communication). Based on the above table, by the end of 2010, Bulgaria is expected to have completed 50% of construction of new WWT plants (mainly above 10,000 pe) and to have upgraded existing plants; and thus sludge production is expected to increase by 50% compared with 2004, amounting to around 47,000 tds. By 2020, compliance should be achieved and sludge production has been estimated to reach 151,000 tds (85% of 7.1 M * 25 kg/capita and per year).

In Bulgaria, there is a National Plan for sewage sludge. The Plan recommends development of a programme for recycling of sewage sludge in agriculture and forestry, as well as in land reclamation projects. The Plan requires that sludge be, at least, mechanically dewatered for WWTPs with more than 10,000 pe; and treated by anaerobic digestion for WWTPs with more than 150,000 pe. It is also planned to incinerate sludge in fluidized bed furnace units for WWTPs with more than 500,000 pe.

In Bulgaria, the majority of sludge is currently sent to landfill after stabilization. The most common method of stabilization of sludge from a treatment plant of this size (100,000 pe) is mesophilic anaerobic digestion, while aerobic digestion is rarely used. Recent practice for landfilling is to partition special cells for sludge at the landfills.

There is currently no incineration plant for municipal sewage sludge in Bulgaria. A project for incineration of waste produced in Sofia is under development. This could potentially also handle sewage sludge.

Although there was no experience of recycling sludge on land in Bulgaria in 2006, 40% of sludge was reported to be used in agriculture. There have been only a few cases of sludge recycling in land reclamation and it is considered in Sludge Management Plans. There are no special regulations for the use of sludge in land reclamation and there are other possibilities of reuse on non-agricultural land.

For our baseline scenario, we have assumed that in Bulgaria, by 2010, the current outlets for sludge will be the same as in 2006 but that recycling to agriculture will increase together with recycling to land reclamation; with the combination reaching around 80 % by the year 2020. Disposal of sludge to landfill will decrease to below 10% by 2020 and incineration and co-incineration will increase to about 10% by 2020.

Cyprus

The following description is mainly based on information provided from different presentations by Mesimeris in 2004 and Pantelis in 2005 both from the Ministry of Agriculture, National Resources and Environment (MANRE).

Cyprus joined the EU in May 2004 and has been granted an extended period until 2012 for full implementation of the requirements of the UWWT Directive. In 2005, the total load for rural and urban agglomerations was estimated at 675,000 pe (545,000 pe+130,000 pe, respectively). In 2005, overall 73% of urban agglomerations and only 9% of rural agglomerations were in compliance. However, it is expected that by 2012 Cyprus would have completed its implementation programme for wastewater connection and treatment. In 2007, wastewater treatment plants were in operation for the 4 largest agglomerations on the coast of Cyprus. Treated effluent is almost entirely reused for irrigation. There is no discharge of untreated wastewater (municipal or industrial) to the sea. Two of these treatment plants, e.g. the Limassol/ Amathousa STP and the Larnaca STP, periodically discharge tertiary treated effluent to the sea during the winter months. Two sensitive areas have been designated.

It was reported that previous to 2004, no data were available on sludge production and disposal routes but that only limited quantities were recycled to agriculture. The quantities produced and recycled to land reported to the Commission for 2004-2006 (CEC 2006) are presented below:

Year	**Total production Tds/annum**	**Agriculture Tds/annum**	**%**
2004	4,735	3,134	66%
2005	6,542	3,427	52%
2006	7,586	3,116	41%

The future sludge production estimated by Pantelis (2005) in Cyprus is presented in table below and will amount to about 9,000 tds. This gives a sludge production rate per pe of 24 kg pe per annum. For our baseline scenario, we have assumed that by 2010, the future sludge production will be similar to the figure reported in table below and that by 2020, sludge production will have increased to 16,000 tds when all effluent will be treated (24 kg/pe* 675,000 pe).

WWTP	**Design capacity (pe)**	**Future sludge production (tds/y)**
Vathia Gonia (1)	56,000	1,200
Limassol	76,000	1,600
Nicosia	150,000	3,000
Larnaca	32,000	700
Agia Napa/ Paralimni	54,000	1,100
Paphos	63,000	1,300
Total	377,000	8,900

Notes:

1) include imported sludge from smaller works

Some studies have considered alternative disposal outlets for sewage sludge such as an alternative fuel at cement kilns. Trials have started in Vassiliko Cement Plant (Cyprus) (Zabaniotou and Theofilou, 2008). Also reclamation of disturbed mine land with sewage sludge has been investigated (Kathijotes, 2004).

Czech Republic

The following description is based on information provided by Michalova, 2004 and Jenicek for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

The Czech Republic joined European Union in 2002. Sludge production has increased by about 50% from 146,000 tds in 1995 to 220,000 tds in 2006 (see table below based on data from Michalova, 2004, CEC 2006, CEC 2009, personal communication). Compliance with the UWWT Directive is expected to be achieved by 2010, and future sludge production is estimated to increase by about 20% by 2010 and to stabilise to that level (263,600 tds per annum) for the next 10 years as population growth is reported to be limited over that period.

Year	**Annual sludge production (x10^3 tds)**	**Quantities recycled to agriculture (x10^3 tds)**	**Quantities sent to landfill (x10^3tds)**
1995	150	35	60
1996	140	Ni	30
1997	180	Ni	40
1998	180	Ni	20
1999	190	Ni	40
2000	210	Ni	45
2001	146	70	40
2002	206	0.2	45
2003	211	0.3	25
2004	206	33	Ni
2005	211	35	Ni
2006	221	25	Ni
Ni – no information			

Historically, sludge was typically recycled to agriculture. Untreated sludge application to land has decreased in recent years due to stricter rules concerning sludge quality in terms of heavy metal and pathogens content. At the same time, application of composted sludge has increased. While in 2001, 42-48% of sewage sludge produced was reported to be recycled to agriculture, there was nearly no recycling in 2002 and 2003. From the latest report to the Commission (CEC 2009, personal communication), quantities recycled to agriculture have risen again to around 12% in 2006. However, it is reported that 66% of sewage sludge is ultimately recycled to agriculture, probably after composting.

The amount of sludge landfilled in the Czech Republic has steadily decreased over the last decade from 50% down to about 10-15 % of annual production.

A negligible amount of sludge is incinerated in the Czech Republic. At present, only one municipal wastewater treatment plant has such technology. The incineration of sludge in cement plants is also practiced. A slow increase in the market share of more expensive technologies, such as incineration or other thermal treatment methods can be expected. However, this increase will probably be lower than in Western Europe.

For our baseline scenario, we have considered that recycling of sludge to agriculture will remain high at about 75% mainly after composting and that by 2020, landfilling will only cover 5 to 10 % and thermal treatment will rise to 15-20 % of annual production.

Denmark

Denmark has achieved high level of compliance with the UWWT directive. By 2010, based on a sludge production of 25kg/capita, the increase in annual sludge production should be limited to 141,500 tds. As population growth is limited, sludge quantities should not change between 2010 and 2020.

No recent figures on sludge quantities have been submitted to the Commission for Denmark, but past records showed that sludge production has decreased significantly since 1995 from 167,000 tds down to around 140,000 tds in 2002. According to Eureau survey, sludge production amounts to 77,530 tds.

There is a target for 2008 for 50% recycling through agriculture, 45% incineration corresponding to 25% incineration with recycling of ashes in industrial processes and 20% “normal” incineration.

For our baseline scenario, these proportions have been estimated to be valid for 2010 and 2020.

Finland

The following description is based on information provided by Rantanen for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and data provided to the Commission.

In Finland, in 2005, around 4.4 M inhabitants lived in cities or smaller towns (Santala et al. 2006). Finland has achieved high level of compliance with the UWWT directive. The total amount of municipal sewage sludge produced in Finland was about 150,00 tds in 2004 and 2005 (see table below). Quantities seem to have decreased since 2002.

Although in 2003, 17% of sludge was recycled to agriculture, only 3 % of the sludge was used in agriculture by 2006. The rest was used in landscaping (Syke, 2007). Although the concentrations of heavy metals and nitrogen and phosphorus were well below the levels described in the Sludge Directive and also below the more stringent Finnish requirements, the proportion of sludge recycled to agriculture has diminished and has shifted to landscaping operations.

Future sludge production by 2010 is estimated to have a limited increase to 154,000 tds and proportions for the two main outlets to stay the same; that is less than 10% recycled to agriculture and 90% recycled to other land after composting.

	Total amount of municipal sewage sludge (tds per annum)	**Sewage sludge used in agriculture**	
		(tds per annum)	**%**
1995	141 000	47 000	33
1996	130 000	49 000	38
1997	136 000	53 000	39
1998	158 000	23 000	14
1999	160 000	23 000	14
2000	160 000	23 000	14
2001	159 900	25 000	16
2002	161 500	22 000	14
2003	150 000	26 000	17
2004	149 900	11 600	8
2005	147 700	4 200	3

In 2006, Finland passed a new legislation, Government Decree (539/2006), concerning the use of organic fertilizers including sludge. The Decree regulates potentially harmful elements, pathogens and pathogen indicators as limit values in products as well as rates of application. The amounts of nutrients are also regulated. The Decree also stipulates which treatment methods are suitable for producing products of high hygienic quality. The listed methods for sludge treatment are thermophilic anaerobic digestion, thermal drying, composting, lime stabilization, chemical treatment. Other methods can also be validated, that is, each new method has to demonstrate a product with a consistently good hygienic quality.

The old legislation, which is the national implementation of Sludge Directive, is still enforced. More can be found in *http://www.finlex.fi/fi/viranomaiset/normi/400001/28518* in Finnish and Swedish.

The most typical sludge treatment process in Finland is composting, which is done in windrows, reactors or both. According to a survey, 73 % of the wastewater treatment plants compost their sludges (Sänkiaho and Toivikko, 2005). Mesophilic anaerobic digestion is also common in the largest cities. Other methods that include lime stabilization, thermal drying, incineration, thermophilic digestion and chemical treatment are marginal.

France

In France, results from a national survey by the Agences de l'Eau in 2004, show that there were about 16,400 WWT plants with a treatment capacity of 90 M pe. There are regional differences (see table below) but overall the quantities of sludge produced amounted to 807,000 tds per annum; 62% recycled to agriculture, 20% disposed of to landfill, 16% to incineration and 3% to others. According to 2008 Eureau survey, 963,800 tds of sludge were produced.; 55% were recycled to agriculture; 24% sent to landfill; 17% tds were incinerated; and 3% to other outlets.

For our baseline scenario, we have considered that future sludge production will continue to increase and should amount to 1.6 million tds by 2010 and that quantities produced should stabilise to that level until 2020. The proportion of sludge recycling to agriculture will stabilise at around 60-65% over the next 15 years.

Region	Sludge production ($x10^3$ tds)	Agriculture (%)	Landfill (%)	Incineration (%)	Other (%)
Artois picardie	57	90	10	0	0
Rhin Meuse	82	46	23	24	7
Loire Bretagne	160	68	19	13	0
Seine Normandie	192	81	4	9	6
Adour Garonne	70	63	22	8	7
Rhone Mediterranee Corse	246	36	34	28	2
Total	**807**	**62**	**20**	**16**	**3**

Germany

The following description is based on information provided by Schulte for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

In 2008, about 10,000 municipal wastewater treatment plants were in operation in Germany; 250 of the biggest plants (with design capacities of more than 100,000 pe treat about 50% of the wastewater volume, while a further 7,000 small sewage works (with design capacities less than 5,000 pe) contribute less than 10 % of treatment capacity. About 94% of the wastewater volume is treated according to a high standard that comprises biological treatment with nutrient removal.

In 2003, about 2 million tonnes of sewage sludge (dry matter) were produced in Germany. A substantial increase in sewage production in the future is not expected due to the existing high connection rate to sewer and thus to wastewater treatment. Our baseline estimate for 2010 and 2020 is a sludge production of 2 million tds.

Over the past few years, thermal processes have gained greater importance for sludge management, at the expense of landfilling and recycling to land (agriculture and landscaping). This was primarily due to the following developments:

1. Since 2005, disposal of sludge to landfill is no longer possible in Germany, as materials with a total organic content (TOC) of more then 3% are banned from landfill; and

2. The political debate about sludge recycling to land which went on during the past few years in Germany caused a lot of uncertainty. These discussions proposed not only the possible introduction of higher requirements, but also the possibility of a complete ban on sludge recycling. In consequence, some operators of sewage treatment plants felt that sludge recycling to agriculture might not be a reliable disposal option in Germany and therefore viewed thermal treatment as more sustainable choice.

Even though the use of sewage sludge has been strictly regulated by the 1992 Federal Ordinance in terms of limit values for heavy metals and some organic compounds, many experts considered the maximum permissible values as too high, and in November 2007, the Federal Environment Ministry published a draft for a new sludge ordinance. The draft proposes a significant reduction of existing limit values for heavy metals and limit values for additional organic substances.

The proportions of sludge going to the different disposal outlets for sewage sludge in Germany in 2003 are presented in the table below.

Year	**Agriculture**	**Landscaping**	**Mono-incineration**	**Thermal treatment - Co-incineration**	**Thermal treatment - special process**	**Landfill**	**Intermediae storage**
2003	32	25	20	14	3	3	3

For our baseline scenario, for 2010 and 2020, the proportion of sludge recycled to agriculture may decrease slightly to around 25 to 30% and proportion being used for landscaping remains stable at around 25% and the proportion treated thermally increases to about 50%.

Greece

The following description is based on information provided in a presentation from Karamanos et al (2004) and information on implementation of UWWT Directive.

In 2004, it was estimated that about 95% of households were connected to a sewerage system and that about 60% of the permanent population was served by around 350 municipal wastewater treatment plants. The remaining population is in small villages and remote areas for which individual sanitation technologies should be used. According to the Commission, there are around 100 agglomerations above 2,000 pe in Greece with a total generated load of about 10 M pe; 600,000 pe in sensitive areas; 3.7 M pe. in normal areas and 5.5 M pe from large agglomerations.

Following the implementation of the UWWT Directive, large-scale sewage treatment plants have been constructed in recent years. However, by 2009, Greece has not yet fully complied with the UWWT Directive requirements. About 56% of generated load from agglomerations discharging into sensitive areas was in compliance while about 90% of generated load from agglomerations discharging into normal areas was in compliance

In Greece, sludge production is reported to have dramatically increased from 52,000 tds in 1995, 83,400 tds in 2004, 116,800 tds in 2005 to about 126,000 tds in 2006 (CEC 2006 and CEC 2009, personal communication). There are currently only small trials of recycling of sludge to agriculture (less than 100 tds per annum), the majority of sludge produced is sent to landfill. This is in agreement with figures provided from a recent Eureau survey (2008), which reported that sludge production amounted to about 126,000 tds; the majority being disposed of to landfill with only minor trials of sludge recycling to agriculture (100 tds).

For our baseline scenario, we have assumed that, by 2010, Greece will be complying with the UWWT Directive and thus that sludge production will have more than doubled to amount to 260,000 tds (25 kg * 95% of 11.1 M inhabitants). By 2010, recycling to agriculture will remain low to inexistent (5%) and landfilling will remain the main outlet at 95%. By 2020, sludge production will remain at around 260,000 tds but landfilling will have decreased to 55-60 % and be replaced by thermal treatment (35-40%) while agriculture will remain low at about 5%.

Hungary

The following description is based on information provided by Garai for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and from a presentation by Toth (2008).

Hungary joined the EU in May 2004. It has a population of around 10 million people and a total area of 93,000 km^2. Budapest has a population of 1.85 million with 96% connected to sewer but only 49% are served by one of the 2 existing wastewater treatment plants and thus untreated sewage is discharged into the Danube. A new plant (Central) has been commissioned and should be operational in 2010. In the rest of the country the situation is worse with only an estimated 68% of population connected to sewer and less than 1/3 of 3000 settlements having adequate wastewater treatment.

The priority is to tackle sewerage problems from industry and 10 large cities. There are smaller investments for settlements below 15,000 people and by 2015, it is planned that all agglomerations of more than 2,000 pe will have a modern sewage treatment system.

In Hungary, the most commonly applied wastewater treatment technology is activated sludge. Sewage sludge is usually dewatered by filter belt press or centrifuge to a typical dry solids content of 18-20%. At the largest treatment plant in Hungary (North-Budapest Wastewater Treatment Plant), membrane presses are operated and sludge dry content is between 36-38%. A small proportion is dried.

At the larger plants, sludge is usually treated by mesophilic anaerobic digestion. At some plants, electricity is produced by biogas engines.

According to a 2008 Eureau survey, the total sludge production in Hungary was about 119,000 tds per year. Sewage sludge was predominantly sent to landfill (72,000 tds, 69%) or recycled to agriculture (47,000 tds, 39%). The quantities produced in the latest Commission survey for 2004-2006 are reported to be slightly higher (128,400 tds in 2006) while a smaller proportion was recycled to agriculture (24%). Figures reported by Toth (2008) for 2005 also differ significantly from the ones reported in the Eureau and Commission surveys; quantities produced amounted to 105,000 tds; quantities recycled to land including recycling to agriculture and land reclamation directly and after composting amounted to 70,000 tds (67%) while quantities sent to landfill were only about 25,000 tds (24%) and about 10,000 tds to other/unknown outlets (9%).

According to Toth (2008), total sludge production will rise to 175,000 tds by 2010 and reach a plateau of 200,00 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 135,000 tds (77%) and then decrease to about 115,000 tds (58%) by 2020. Quantities sent to landfill will steadily decrease down to 20,000 tds in 2010 and 10,000 tds by 2020 while quantities sent for incineration will increase from 2010 until 2020 to reach about 60,000 tds per annum. The quantities sent to other/unknown will not change.

According to Garai (2008), the goal of the government is to decrease landfilling and increase the proportion of sludge being recycled to agricultural. By 2015, the proportion of landfilling is expected decrease to 33%.

Year	**Sludge production (tds per annum)**	**Agriculture (tds)**	**Forestry (tds)**	**Incineration (tds)**	**Landfill (tds)**	**Other (tds)**	**Ref**
2004	120,741	36,105					a)
2005	125,143	42,329					a)
2005	105,000	70,000			25,000	10,000	c)
2006	128,379	32,813					a)
2007	120,000	47,000	0	1,000	72,000	0	b)

References:

a) CEC 2009, personnel communication
b) Eureau survey 2008

c) Toth 2008

Agricultural recycling is controlled under two regulations: the first covers compost product and the second one is for use of sewage sludge in agriculture. Sewage sludge is allowed to be disposed in municipal waste landfill if it is treated, not contagious, and the dry content is at least 25% and complies with leaching tests**.**

There are no incinerators for sewage sludge in Hungary as the capacity of hazardous waste incinerators is not sufficient to receive significant amount of sewage sludge, and the price of processing is too high. Some cement factories are authorised for sludge incineration and trials have been performed, but it is not used on a regular basis (Garai 2008).

For our baseline scenario, we have used figures presented by Toth (2008). We have assumed that by 2010 sludge production would amount to 175,000 tds reaching 200,000 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 135,000 tds (77%) and then decrease to about 115,000 tds (58%) by 2020. This will include a certain proportion of composted sludge. Quantities sent to landfill will steadily decrease down to 20,000 tds in 2010 and 10,000 tds by 2020 while quantities sent for incineration will dramatically increase from 5,000 tds in 2010 until 60,000 tds by 2020. The quantities sent to other/unknown will not change over that period and remain at 10,000 tds.

Ireland

Information has been extracted from an EPA report on urban wastewater discharges in Ireland for 2004/2005 (EPA 2005).

In Ireland, there are 478 agglomerations with populations greater than 500 pe, which collectively represent a total of 5.6 M pe. It is reported that in 2004/2005, 11% of wastewater received no treatment; 7% of wastewater received preliminary or primary treatment; 70% of wastewater received secondary treatment; and 12% of wastewater received nutrient reduction in addition to secondary treatment.

By the 31st of December, 2005, secondary treatment was required for all agglomerations discharging to freshwaters and estuaries with a population equivalent of 2,000 or greater and for agglomerations with a population equivalent of 10,000 or greater discharging to coastal waters. There have been delays in providing the required treatment plants at a number of locations throughout the country. Of the 158 agglomerations requiring secondary treatment or better by 31st December 2005, the required level of treatment was not in place at 30 of these agglomerations. The level of compliance with discharge limits was 86% for agglomerations above 10,000 pe discharging into sensitive areas and 67% for agglomerations above 15,000 pe and 38% of plants between 2000 and 15,000 pe.

Sludge quantities produced and recycled to land have sharply increased over the last 10 years from 38,000 tds in 1997 to 42,000 tds in 2003. The proportion of sludge recycled to land has also increased dramatically over the same period from 11% to 63%. (CEC 2006). About 62,000 tds in 2004 and 60,000 tds in 2005 respectively were reported to have been produced nationally; 76% (45,5000 tds) was used in agriculture and 17% (10,300 tds) went to landfill and a small proportion (4,000 tds, 7%) was either recycled to forestry or composted (EPA 2005).

We have estimated that, by 2010, sludge quantities will continue to increase and reach up to twice the current amount with full implementation of the UWWT directive, and reach 135,000 tds and remain at that level until 2020. By 2010, we have assumed that proportions recycled to agriculture and disposed of to landfills and other outlets would be at the similar level as in 2005 – i.e. 75%, 15 % and 10%, respectively and that by 2020, while agriculture would still be the major outlet at about 65-70%, incineration would steadily increase to replace landfilling.

Italy

The following description is based on information provided by Spinoza and Canzian for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Sludge management in Italy varies widely as far as local disposal or reuse options are concerned due to different geographical, geological, technical, economic and social contexts. Some Italian Regions have undertaken the revision of the regional legislation on sludge utilisation in agriculture. For example, the Region Emilia-Romagna, in Northern Italy, published a new Regional Decree 2773 of December 30, 2004, modified and completed by Decree 285 of February 14, 2005.

In addition, as monitoring of sludge recycled in agriculture in Region Emilia-Romagna showed an almost constant occurrence of toluene and hydrocarbons, a research programme to define limits values for the above components was started in April 2007. Preliminary theoretical evaluations indicated possible safety limits of 500 mg/kg-ds for toluene and 10,000 mg/kg-ds for hydrocarbons.

In 2004, it was estimated that annual production of sewage sludge was about 4.3 Mt, corresponding to about 1 Mt of dry solids at a solids concentration of 25%, with an increase of about 10% with respect to years 2001-2003 (ONR, 2006). This is in line with the figures reported to the Commission for the period 2004-2006 which are presented in table below.

Year	Sludge production (t DS per annum)	Agriculture	
		(t DS per annum)	%
2004	970,235	195,161	20
2005	1,074644	215,742	20
2006	1,070,080	189,555	18

According to ONR (2006), disposal of sludge to landfill now accounts for only 24% of total quantities of sludge produced, and agricultural recycling, including co-composting and land reclamation, has increased to 69%. About 2% of sewage sludge is incinerated and 5% kept in temporary storage basins.

Sewage sludge is usually thickened and digested before being recycled to agriculture or sent to landfill. Sludge post-treatments, such as pasteurisation and thermal drying, are seldom practiced. Increasingly combined composting is performed by treating sewage sludge with other organic fractions, for example municipal solid wastes, food wastes, wood chips from broken pallets, cuttings from gardening and forest maintenance, and other similar materials.

When the quality of the compost is not good, mainly because of heavy metals exceeding the limits for unrestricted use, the resulting material can be used in land reclamation or as landfill cover. In 2005, wastes treated in composting plants amounted to about 3 million tons, with an increase of 125% with respect to 1999. Plant inflow consisted of 70 % of organic fraction deriving from separate collection and green wastes, 16% of sludge (+7% with respect to 2004) and 15% of other organic wastes, mainly from the food industry.

In some cases, sewage sludge is added in small amounts (up to 5%) to lime and clay in thermal processes to produce inert materials, such as expanded clay for construction.

Adoption of sludge thermal treatment in Italy is low, and accounts as already stated for a mere 6% at most. Incineration or co-incineration with municipal solid wastes is the most common thermal sludge disposal route in Italy. Sludge pyrolysis with gasification is currently under evaluation by a few water service companies.

In all cases, current management practices are influenced by both sludge characteristics and plant size.

In Italy, small WWTPs (those not exceeding 2,000 pe) usually treat domestic wastewater only, no primary sedimentation is usually provided and excess sludge is often already stabilized as deriving from extended aeration activated sludge processes. Alternatively, excess sludge is stabilized by separate aerobic digestion. Sludge is seldom treated on site, but is hauled to centralized plants for dewatering and final disposal or reuse.

In small to medium size plants (up to approx. 100,000 pe), anaerobic digesters are commonly used, and normally built to treat mixed primary and putrescible biological excess sludge However, in areas where eutrophication must be controlled, strict standards on nutrients require biological processes for nutrient removal, with long sludge retention times. Often, in these cases, primary settling is not present or it is by-passed to save internal organic carbon for denitrification. As a result, in these plants anaerobic digesters are no longer used and the sludge is stabilized aerobically. A typical example is the Milan Nosedo WWTP, serving over 1 million pe, that has been built without anaerobic digestion.

Thermal driers have seldom been used in medium-size WWTPs, as 100,000 pe is usually considered the minimum threshold for economic viability. However, recent regulatory restrictions on disposal to agriculture are favouring this technology, as dried sludge can be used as alternative fuel in cement kilns or for energy recovery in waste-to-energy plants. Especially for large size WWTPs, thermal treatment of sludge (drying, pyrolysis with gasification, incineration with energy recovery), is currently considered a feasible solution, as agriculture and landfilling will be no longer be viable disposal routes within few years.

Sludge composition is reported to be highly variable in Italy because almost all WWTPs serve urban areas where industrial activities contribute to the organic pollution load. Further, many medium and large size plants are located in industrial districts, such as (i) the wool district (Biella, Piedmont), (ii) the silk district (Como, Lombardy), (iii) other textile finishing district (Prato, Tuscany), (iv) tannery districts in Veneto and Tuscany, (v) metal surface finishing districts in Piedmont and Lombardy, and other minor districts.

In such cases, obviously, sludge characteristics strongly depend on the influent industrial wastewater, as, for example, it carries many organic recalcitrant compounds that are absorbed by the sludge (such as hydrocarbons and LAS) and contain heavy metals, which usually precipitate as metal hydroxides during treatment and accumulate in the sludge.

It is also worth noting that sludge deriving from textile finishing districts has often poor dewatering characteristics: it is very hard to reach values higher than 22% solids concentration by centrifugation, while belt-presses hardly reach 17-18%.

According to the Italian National Institute of Statistics (ISTAT, 2006), the total population equivalent (urban + industrial) in Italy is estimated to be around 175 million pe, of which the urban fraction is as much as 102 million pe (55.9% resident population, 14.9% tourists, 16.6% commercial sites, 12.6% crafts and small enterprises).

Based on an average annual production of dry solids per capita (after aerobic or anaerobic digestion) of 30 kg ds/annum/pe, the potential total sludge production in Italy can be estimated at around 5.25 million tds/annum, of which about 3 million tds/annum is linked to the urban population only. This is a three-fold potential increase compared with the current sludge production when all the population would be served by sewerage and subsequent appropriate treatment.

It is expected that, at least in Northern Italy, where co-management with municipal solid wastes due to the integration of public services (energy, waste and water), could become a real possibility for the future, anaerobic co-digestion of sludge and wet fraction deriving from separate collection of municipal solid wastes would increase. This is still a marginal practice in Italy but some examples of this type are listed below:

- Treviso: 3,500 t/annum of solid waste wet fraction and 30,000 t/annum of sewage sludge are co-digested.
- Cagliari: 40,000 t/annum of solid waste wet fraction and 15,000 t/annum of sewage sludge,
- Camposampiero: 12,000 t/annum and 12,000 t/annum, plus 25,000 t/annum from zootechnical wastewaters,
- Bassano: 16,000 t/annum of MSW and 3,000 t/annum of SS,
- Viareggio: 5,000 t/annum of MSW and 50,000 t/annum of SS.

The co-incineration of sewage sludge and solid wastes in incineration plants appears feasible if a drying step for sludge is introduced. Some trials are being carried out in Sesto San Giovanni, near Milan, involving the cooperation with two public companies and results are encouraging.

To meet requirements of the UWWT directive, Italy has had to put systems in place for adequately collecting and treating wastewater of agglomerations of more than 15,000 pe before 31 December 2000. Some 299 towns and cities have been listed as not yet being in compliance with EU standard. Discharges of untreated urban wastewater are the most significant source of pollution in coastal and inland waters and Italy faces the prospect of being brought before the European Court of Justice (ECJ).

For our baseline scenario, we have assumed that, by 2010, Italy will have complied with the UWWT Directive and that sludge production will have reached its maximum at about 1.5 M tds and remain at that level for the next 10 years. Sludge recycling to agriculture will increased to about 50% and a large proportion will also be recycled to land reclamation projects both totalising 70% of sludge produced. Most of the sludge recycled to land will be first co-composted.

Latvia

Information is mainly extracted from a report produced by GHK (2006).

Latvia is a small Baltic state with an area of 65,000 km^2 and 2.5M inhabitants. Agricultural land occupies 39% and forestry 44% of Latvia's territory. In the last decade, with the dismantling of collective farms, the area devoted to farming decreased dramatically - now farms are predominantly small. Latvia joined the Union in January 2007 but Latvia started a programme of improving wastewater treatment in 1995. The whole territory of Latvia has been classified as sensitive area under the UWWTD. In 2005, it was reported that overall 71 % of the population was connected to the sewer system (almost all connected to a WWTP). The availability of a centralised wastewater infrastructure varies from town to town. In towns with a population above 10,000 it typically reaches 70-85% of the population while in towns with a population below 10,000 it can be as low as 30% of the population.

Out of 71 agglomerations that have a wastewater treatment plant, only 7 are complying with the UWWTD standards while 64 have a WWT plant which is not fully compliant. All together, in the wastewater sector, numerous projects have been planned to be implemented during the time period from 2006 – 2015. By the end of 2008, Latvia should have finished improvements to the wastewater collection in the largest cities above 100,000 pe and investment will continue until 2015 to construct about 60 new WWT plants with a total capacity of 1.9 M pe and upgrade existing non-compliant WWT plants with a capacity of 1.17 M pe.

Most of wastewater treatment plants do not have adequate sludge treatment. The most common final disposal routes for sewage sludge are agriculture and compost.

Wastewater volumes have decreased by 2.2 times between 1990 and 2000 and thus the quantities of sewage sludge. It was estimated that about 20,000 tds were produced in 2000 and about 29% was recycled to agriculture, 38% stored (landfilled?), 26% for other uses and 7% was composted. No incineration was reported (EIL, 2002). Sludge production seems to have continued to decrease between 2004 and 2006 from 36,000 tds, 28,900 tds down to 24,000 tds (CEC, 2009, personal communication) and quantities recycled to agriculture have fluctuated from 7,700 tds (31%) in 2004, 6,500 tds (22%) in 2005 and nearly 9,000 tds (39%) in 2006. It was mentioned that the high level of heavy metals sometimes restrict the recycling of sludge to agriculture.

For our baseline scenario, we have assumed that by 2010, Latvia will not have finished installing new WWT capacity and thus that sludge quantities will not have increased substantially compared with 2006 figure while, by 2020, compliance with the UWWT directive will have been achieved and sludge quantities will have more than doubled to 55,000 tds. In 2010, we have considered that recycling to agriculture will remain at around 30 %, landfilling at 40% and 30% to other unspecified outlets and that, by 2020, while agriculture remains at around 30%, landfilling will have decreased to 20% and incineration will have increased at about 5 to 10% .

Lithuania

The following description is based on information provided from a presentation by Ciudariene in 2007 and Cepelè in 2008.

Lithuania has a population of 3.4 million inhabitants – its territory is divided in 10 counties and 61 municipalities with regional differences in economic development and treatment connection rates. It has joined the Union in May 2004. Lithuania has designed the whole territory as sensitive area under the UWWT Directive. It was granted until 31 December 2007 to provide collection of wastewater and more stringent treatment for agglomerations of more 10,000 pe (i.e. 38 agglomerations) and until 31 December 2009 to fully comply with the requirements of the UWWT Directive (collection and more stringent treatment for all agglomerations of more than 2,000 pe, i.e. 57 agglomerations). It is reported that there are about 95 agglomerations with more than 2,000 pe generating a total load of 3.34 M pe.

In 2006, 60% of the population was connected to a centralised wastewater treatment plant and at least 32% of wastewater received at least secondary treatment. Sewerage and wastewater treatment plants are reported to be in great need of upgrade and further investments have been identified for the period 2007 - 2013. From the latest Commission report on implementation of UWWT Directive (UBA 2009), in 2005/06, 93% of generated load of all agglomerations >2,000 pe were reported to be collected with 82% of the total generated load treated by secondary treatment and 61% with more stringent treatment.

Between 2004 and 2006, sludge production increased from 60,500 tds to about 71,000 tds per annum (see table below). Due to lack of digestion capacity, most sludge is only dewatered before being recycled to land (25%) or sent to landfill (75%).

Year	Total sludge production (tds/y)	Quantities recycled to agriculture	
		(tds)	**%**
2004	60,579	14,315	24
2005	65,680	16,240	25
2006	71,252	16,376	23

There is a national plan for strategic waste management which prioritises management of bio-waste with energy recovery (biogas production) and preservation of nutrients (composting). This is encouraging separate collection or MBT treatment.

The plan includes establishing 10 regional sludge treatment centres between 2007 and 2013, to include digestion, drying and composting plants. There are 2 existing centralised plants for anaerobic digestion of sewage sludge; 3 private composting plants including one for sewage sludge and 13 public regional waste composting plants. 76 additional composting plants are to be built between 2007 and 2013 using EU funding. There are currently no municipal waste incineration plants.

For our baseline scenario, we have assumed that Lithuania would have reached compliance with UWWTD by 2010 and that sludge production would reach its maximum by then and amount to 80,000 tds with no further change to 2020. In 2010, recycling to land may increase up to 30% as landfilling is increasingly restricted down to 70% of produced sludge and incineration capacity will not yet be available. By 2020, landfilling will have decreased further down to 30%, agricultural recycling up to 50-60 % and incineration and other thermal treatment up to 10-20% of produced sludge solids.

Luxembourg

According to the latest figures from the Commission (UBA 2009), the collection rate for wastewater in Luxembourg has reached 98% with 93% of generated load treated by secondary treatment and up to 80% to a more stringent level. Luxembourg has wastewater treatment capacities of for approximately 950,000 pe; 80% of the treatment is provided by 10 biological wastewater treatment plants with capacities > 10,000 pe. 5 out of these 10 WWTP's do not comply with the EU standards with regard to organic discharges and 6 out of 10 do not comply with the emission limits for nutrients.

Sludge quantities produced are reported to amount to 9,300 tds (2008 Eureau survey) and to be mainly recycled to agriculture 8,736 tds (95%). The remaining sludge is sent to incineration.

For our baseline, by 2010, we have assumed that there will be no change in the collection rate but that compliance with UWWT will have been reached for all the sewage and that sludge quantities would have risen by 7% to their maximum of 10,000 tds. The majority (95%) will still be recycled to agriculture including after composting and 5% thermally treated. In 2020, the proportion of composted sludge recycled to land will have increased. The proportion of sludge thermally treated either by incineration or co-incineration in cement plants will increase to at least 20% after a study found it to be the best environmentally option (CRTE).

Malta

No information is available, but it is believed that until 2004 there was only a very small amount of sludge produced as there was limited wastewater treatment (17% of generated load). Under the UWWT Directive, by 31 March 2007, all untreated wastewater (25 M m^3 per year) should have been collected and treated to relevant standards. Since 2006, 3 new wastewater treatment plants have been built or are under construction with the construction for the final one having started in January 2009.

For our baseline, by 2010, we have assumed that all urban wastewater will be collected and treated to the relevant standards and that sludge production will have risen to 10,000 tds (25 kg * 400,000 inhabitants). By 2010, agriculture will not an important outlet but all sludge will be landfilled. By 2020, a small proportion may be recycled to agriculture (up to 10%) while the rest is landfilled.

Netherlands

The following description is based on information provided by Kreunen for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Netherlands has already achieved high compliance with the UWWTD. Quantities of sewage sludge are not expected to increase over the next 15 years. There are 26 Water Boards providing wastewater services in the Netherlands. Recycling of sewage sludge in agriculture has been banned in the

Netherlands since 1996. Increasingly stringent standards for the application of sludge to land in the late eighties led to this ban.

A private company - GMB Sludge Processing Company has two composting plants which process about 15% of the total (dewatered) sewage sludge produced by municipal sewage treatment plants in the Netherlands, which amounts to approximately 1.5 million tons per year (with a total plant capacity of 1,370,000 PE). Since 2004, this granular product has been used as a biofuel in power stations, both in Germany and the Netherlands. The granules are used by the power stations either as an additive or as a stand-alone biofuel.

Of the remaining amount, approximately 58% is incinerated and 27% thermally dried. The product resulting from these techniques (composting, incineration and thermal drying) still requires further (final) processing.

There is no support in the Netherlands for application of sewage sludge into or onto the soil, or in agriculture. In addition, the animal manure surplus means that the farming sector is more likely to demand the exclusion of sewage sludge.

Norway

The following description is based on information provided by Blytt for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Norway is a country with a long coastline and is dominated by forests and mountains. Arable land covers only 3% and is mostly located near bigger cities and at the bottom of the valleys. Norway has 4.5 million inhabitants. During the seventies and eighties there was a major increase in the number of wastewater treatment plants, especially in the parts of the country with discharges to inland waters and narrow fjords. There are currently about 1,400 treatment plants, of which most are very small.

The sludge from smaller plants is usually transported to larger treatment plants. In total, 62 treatment plants have registered their treated sludge to be regarded as a fertilizer product. Total quantities of sludge produced and disposal outlet are presented in tds in the table below:

Year	Total production	Total utilization	Agricultural	Green areas	Mixed soil products	Top layer on landfill	Land filled	Other
?	86,030	86,484	56,055	10,198	13,178	2,934	2,957	1,162

More than 90 % of Norwegian sludge is used for land application as a soil amendment product; where one-third goes to parks, sports fields, roadsides, the top cover of landfills, and two-thirds goes to arable land within the agricultural sector.

In order to achieve this high rate of land applied sludge, stringent standards have been set for the content of heavy metals and pathogens, and the control of the odour nuisance has been given high priority. In fact the Norwegian regulation concerning sludge is stricter than those of most of the countries in Europe. Towards the end of the 1990s’, the policy to recycle organic waste increased, along with requirements to remove organic waste from landfills, in order to reduce emissions of methane and leachates. Applying sludge on arable land is considered by the Norwegian authorities to be the socio-economically acceptable and cost-effective way to utilise the sludge. This implies that farmers are willing to accept the use of sludge. The sewage sludge market is very sensitive to negative reports as farmers acceptance is influenced by many factors including opinions of retailers and consumers. Authorities and waste water treatment plants continuously work on risk communication. This helps to sort real facts from false and provides balanced information to the partners.

In the mid-seventies, a reform in the agricultural sector changed the agricultural production in the populated regions around Oslo and Trondheim from dairy farms with grassland to the production of cereals (barley, wheat, rye and oats) and oil seeds. Single-crop farming depletes organic material in the soil. Changes in the farm structure and land use are contributing factors to use of sludge on agricultural land. Sludge is not used in forests in Norway.

Several municipalities started to source separate kitchen waste for making compost. The ministries found it necessary to harmonize the parallel regulations for different types of recycled organic waste. In 2003 a new joint regulation *"Regulation on Fertilizers Materials of Organic Origin",* prepared by the Ministry of Agriculture and Food in cooperation with the Ministry of Environment and Ministry of Health was published. This covered all organic materials spread on land which was derived from materials such as farm waste, food processing waste, organic household wastes, garden waste and sludge. It was also believed that to promote and standardise waste such as sludge, higher treatment and quality control standards had to be implemented.

The 2003 regulation sets the following major requirements for organically derived fertilizers in general, with a few special requirements for sludge:

- All producers have to implement a quality assurance system.
- Quality criteria of the products include standards for heavy metal content, pathogens, weeds and impurities, in addition to a more general requirement of product stability (linked to odour emissions). There is a requirement for taking reasonable actions to limit and prevent contamination with organic micro-pollutants that may cause harm to health or the environment.
- Requirements on product registration and labelling before placement on the market;
- Special crop restrictions for sludge, including a prohibition on growing vegetables, potatoes, fruit and berries for three years, and on spreading sludge on grassland.
- Requirements for storage facilities before use. Cannot be spread on frozen soil – no later than November and not before 15 February. Sludge has to be mixed into the soil (ploughing) within 18 hours after application.
- Beside the limit values for heavy metals, the hygienic requirements are: no *Salmonella sp*. in 50 grams and no viable helminth ova. and less than 2,500 fecal coliforms per gram dry solids.

A farmer has to make a plan for all fertilizers to be spread on his fields, including sludge. The municipality has to be notified of sludge use at least three weeks before it is locally stored or spread. The wastewater treatment plant or the sludge transport company often helps the farmer with this notification. A farmer cannot apply sludge more frequently than every 10 years on the same field, but that will depend on to the sludge quantity and amount he uses.

Markets for sludge within the landscaping sector are increasing. New markets for green energy may enhance cultivation for energy crops. This may increase sludge application on these types of arable land. There are ongoing experiments and pilot trials making synthetic diesel from sludge and organic waste. It is becoming more common to co-digest sludge and food waste in order to increase the production of biogas (methane). This will lead to a sludge quality with lower metal content, but higher nutrient content.

Poland

The following description is based on information provided from a presentation by Twardowska in 2006 and a paper by Przewrocki et al 2004.

In 2001, 51.5% of population were connected to a sewage treatment plant in Poland. No recent update to this information has been supplied to the Commission.

Sludge production has steadily increased from 340,040 tds in 1998, 397,216 tds in 2001, 476,000 tds in 2004, 495675 tds in 2005 and 523,674 tds in 2006 (CEC 2006 and 2009). Compared with the 2001 figure, a doubling of sludge quantities is expected by 2015 and an amelioration of the quality of the sludge due to reduction of industrial pollutants discharged into sewers. Almost all of sludge is stabilised by anaerobic digestion or by a natural drying method,

The recycling of sewage sludge to agriculture has increased since 1998 from 8%, 14% in 2000, down to 12% in 2001 and up again to 17% in 2006 (44,819 tds in 2004, 42,558 tds in 2005 and 44,284 tds in 2006). Between 2000 - 2001 the amount of composted sludge increased from 25,528 tds to 27,591 tds (7%) while recycling to agriculture dropped slightly from 50,628 tds (14%) to 49,302 tds (12%). Industrial use (not specified) of sewage sludge increased from 19,815 tds (5%) in 1998 to 28,274 tds (7%) in 2000 and then fell to 24,220 tds in 2001 (6%). Quantities of sewage sludge sent to landfill have dropped from 191,600 tds in 1998 (56%) to 151, 618 t ds in 2000 and rose again to 198,630 tds in 2001 (50%). Quantities incinerated dropped between 1998 and 2001 from 14,389 tds (4%) to 6,937 tds (<2%).

According to a 2008 Eureau survey, sludge production in 2005 amounted to 790,900 tds; 147,000 tds (18%) sent to landfill; 80,600 tds recycled to agriculture (10%); 4,500 tds incinerated and 558,700 to other outlets (not specified).

The forecasts for sludge management routes prepared by the Ministry of the Environment are presented below:

- Proportion of municipal sewage sludge disposed of to landfill will rise to 45% in 2010 but will decrease to 39% in 2015.
- Proportion of sewage sludge incinerated should rise from 1.6% in 2001 to 5% in 2010 and to 8% in 2015. This will depend on new investments in incineration plants.
- Composting is the preferred method of sewage sludge treatment. It is estimated that 20% of sewage sludge could be composted; however, this requires building sufficient capacity of composting plants.
- Another route will be recycling to agriculture. The introduction of more effective and stringent regulations will limit the increase of sewage sludge to agriculture. In 2015, it is predicted that about 26% of sewage sludge will be recycled via this route. Sewage sludge use as fertilizers will reach 46%, including composted sludge.

Portugal

The following description is based on information provided by Duarte for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

In Portugal, there are wide regional differences in sludge production and sludge management as the number of inhabitants and the development of wastewater treatment varies greatly and soil and climatic conditions differ. Since the implementation of the UWWT Directive, there have been major upgrades of existing wastewater treatment plants (WWTP) and construction of new ones, leading to an increase in sludge production. However, by 2005, only 65% (6,572,000 inhabitants) of the total population of Portugal was served by a WWTP mainly with secondary treatment (43%); 24% had also tertiary treatment. The Southern regions (Algarve Alentejo and Lisboa e Vale do Tejo) had about 76% of the population served by a treatment plant and the Northern regions (Centro and Norte) about 58%. There are also industries discharging to these WWTPs producing a load of 50% and 70% respectively in the Southern and in the Northern regions where industry is more important. The generated load was estimated to be about 10,650,000 pe.

The available information on sludge production is scarce and dispersed. Based on field studies carried out in two different Portuguese regions: Algarve (2005) and Center Alentejo (2006), the amount of sludge produced has been estimated and is reported in the table below.

Region	**pe**	**Daily sludge production ratio (g DM/pe.day)**	**Sludge production (tds/year)**
Norte	3,500,300	80	102,209
Centro	2,404,800	50	43,888
Lisboa e Vale do Tejo	3,441,600	50	62,809
Alentejo	802,500	70	20,504
Algarve	499,500	40	7,293
TOTAL	**10,648,700**	**60**	**236,703**

The range assumed for the sludge range (40 – 80 g DM/pe.day) depends, mainly, on the sludge treatment process. For example, if the sludge is digested and if lime is added the upper limit is for non-digested sludge with lime addition and the lower limit is for digested sludge without lime addition. Quantities reported to the Commission are presented below:

Year	**Sludge production**	**Quantities recycled to land**	
	tds	**tds**	**%**
1995	145,855	44,000	30
1996	177,100	53,130	30
1997	214,200	64,260	30
1998	121,138	41,413	34
1999	374,147	66,547	18
2000	238,680	37,176	16
2001	209,014	69,853	33
2002	408,710	189,758	46

Until recent years, the most common disposal outlet for sewage sludge was landfill. However, this disposal option is becoming more restricted as regulations limit disposal of organic matter and the cost of landfilling is increasing. However, public opinion is against incineration and protest actions have taken place every time a waste incineration plant project has been presented. Thus agricultural use of sludge could play a major role in the future in Portugal. This is especially the case in the Centre and Southern regions of the country where soils are deficient in organic matter. Increasing numbers of operators have started to transport and apply sludge in agricultural and forest land. The main agricultural crop receiving sludge in Portugal is maize, followed by vineyards and orchards. Some sporadic applications occur in forage areas and in forestry after forest fires.

At the same time, other industries and activities such as agro-industries, municipal solid waste (MSW), manure and slurry from intensive livestock production are also relying on agricultural land for the disposal of their waste and are thus competing with sewage sludge for available land. This is especially the case in the Northern and Central regions where operators have more difficulties in recycling sludge to land for three main reasons:

- these are more populated areas, thus WWTP produce more sludge;
- the available agricultural area is reduced;
- more intensive livestock production occurs and thus production of manure and slurry competes for available agricultural land.

Future development does not support an indefinite increased of sludge recycling to agriculture, as continuous reduction of the cultivated area is happening, with wider areas devoted to forest or fallow land and consumers demanding more quality controls on agricultural products, reducing the desire in agricultural producers to use sewage sludge on agricultural land.

For our baseline scenario, we have assumed that by 2010, compliance with UWWT Directive will be achieved and that sludge production would have risen to a maximum of 420,000 tds and that recycling to agriculture will have reached 50%. The remaining sludge will be thermally treated (30%) and landfilled (20%) depending on treatment capacity. The situation is not expected to change by 2020.

Romania

Romania joined the EU in January 2007 and has been granted an extended period to comply with the UWWTD up to 2019. In 2005, 47% of generated load was collected but only 28% was treated by secondary treatment. Current sludge production has been reported to decrease between 2004 and 2006.

Year	Total production (tds/y)
2004	164,969
2005	134,322
2006	137,146

While there is currently no recycling of sludge to agriculture, it has been considered as an option for future management together with co-incineration in cement plants (Crac, 200?).

For our baseline scenario, we have assumed that by 2010, the situation in Romania will have not changed compared with 2006. We have assumed however that full compliance will be achieved by 2020 and that by 2020, sludge quantities will have risen dramatically to 520,000 tds (25*21 M inhabitants). By 2020, a significant proportion could be recycled to agriculture (at least 40%) while landfilling would be the second option unless thermal treatment capacity has been built.

Slovakia

The following description is based on information provided by Sumná for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Following the implementation of the UWWT Directive, it is estimated that sludge production will increase by approx. 20-40 % in Slovakia. During the period 2004-2006, about 55,000 tds of sludge was generated per annum.

Sewage sludge production (tds per annum) and disposal outlets in the years 2004 – 2006 (CEC 2009) is presented in table below.

Year	Total	Incineration	Agriculture 1)	Landfill 2)	Forestry	Other
2004	53,114	0	41,116	10,581	0	1,417
2005	56,360	0	34,784	17,236	0	4,340
2006	54,780	0	33,630	15,375	0	5,775

Notes:
1) While sludge was directly applied into the agriculture in 2004 and 2005, it was no longer the case by 2006 when large quantities were diverted for the production of compost.
2) Landfill also includes quantities of the sludge that were temporarily stored.

About 90 % of monitored sewage sludge production in Slovakia meets the limit values for PTEs as a result of reduction programmes for pollution due to industrial discharges to public sewers that has been implemented in Slovakia.

Recycling of sewage sludge to agriculture is the preferred option in Slovakia not only because it was relatively the cheapest option but also because it was recognised as the best environmental option for sustainable development. Direct application of sludge into agricultural land is regulated according to the Act on Sewage Sludge Application into Agricultural Land. This determines the conditions for sewage sludge application into agricultural and forest land without affecting soil properties, plants, water, or health of humans and animals. The Act authorises, under specific conditions, applications to arable land and permanent grass land and forestry (only soil in forest nurseries, in plantations with Christmas trees, fast-growing wood plants, energetic and intensive growths). It does not deal with the application to non-agricultural land or use of sludge in land reclamation.

Application of compost or soil supporting substance or growing media is regulated by the Act on Fertilizers. In this case, the product made on the basis of sludge is subject to certification and assessment whether properties of such fertilizer and its technical documentation are in line with related technical standards and generally binding legal regulations.

There are currently no suitable incineration capacities for sludge incineration. However, the national waste management plan for the year 2005-2010 is planning to increase these capacities and to promote energy recovery from waste. The capacity for waste co-incineration in two cement plants (others do not comply with the conditions of the Act on Air Protection) exists in the Slovak Republic, but currently it is reserved for the handling of industrial waste and co-incineration of animal waste. However with the decreasing production of animal waste, sludge could be considered as an alternative in the future in these facilities.

Disposal of sludge to landfill is the least favoured option for sludge management by the Slovak Government. However, due to lack of incineration capacity, it is the only alternative option for sludge disposal. It is expected that the proportion of organic waste disposed at landfills will be limited in line with the requirements of the EC Landfill Directive.

The aim of the Waste Management Programme of the Slovak Republic is to decrease the amount of landfilled waste to 13% out of the total amount of waste being generated in the SR, by the year 2010. Among the measures to be used to reach this are decreasing the quantities of sewage sludge disposed of into landfills and to increase the costs of landfill disposal of all materials.

For our baseline we have estimated sludge quantities by 2020 to amount to 135,000 tds. The proportion of sludge recycling to agriculture as compost to be 50% or more, landfilling will decrease down to 5% or less depending on the thermal treatment capacity, which could treat up to 40% of sewage sludge.

Slovenia

The following description is based on information provided by Grilc and Zupancic for the latest version Global Atlas (Alabaster and LeBlanc, 2008), a presentation given by Mayr and Zugman in 2005 and by Medved in 2006 and a paper from Vukadin and Podakar (from Environmental Agency) in 2007.

Slovenia was a part of former Yugoslavia until 1991 and in May 2004 it became a member of the EU. Wastewater treatment capacity has increased steadily since 2000 when Slovenia entered the process of accession to the EU. It is reported that, in 2005, only 53% of population was connected to a WWT plant but that 73% of generated load from agglomerations above 2,000 pe were collected; 51 % was treated by secondary treatment and 19% by more stringent treatment. Nearly 250 municipal wastewater treatment plants are now in operation, but only 10 % of them are larger than 10,000 pe capacity, (and only 5 larger than 100,000pe capacity). Their total capacity is about 2 million pe (similar to the the population of Slovenia), but part of the capacity is used to treat industrial effluents.

Sewage sludge quantities have increased from 15,000 tds in 2001 to 47,000 tds in 2006. The quantities reported by the Environmental Agency are much lower and were estimated to amount to only 20,000 tds in 2006 (see tables below).

	Gril and Zupancic, 2008	CEC, 2006	
Year	**Sewage sludge production (tds/y)**	**Sludge production (tds)**	**Quantities recycled to agriculture (tds)**
2001		8,200	500 (6%)
2002	14,767	7,000	1100 (16%)
2003	20,140	9,400	800 (9%)
2004	26,747	9,687	125
2005	39,366	13,580	71
2006	46,744	19,435	27

Figures from the Environmental Agency of the Republic of Slovenia (2007) are reported below:

Year	Sewage sludge production (tds/y)	Use in agriculture	Composted	Landfill	other	export
2000	8,800	300	1,000	7,500	Na	
2001	8,200	500	900	6,800	Na	
2002	7,000	1,100	900	5,000	Na	
2003	8,800	500	0	7,000	1,400	
2004	12,900	100	0	9,000	3,700	
2005	16,900	100	100	9,500	7,200	
2006	20,100	0	0	9,200	5,600	5,200

These figures show that the quantities of sewage sludge have increased steadily and have more than doubled over the last 4 years. The rate of increase will level off in the next few years as the construction of the largest plants is almost completed. It has been reported that by 2010, sludge production in Slovenia would amount to 40,000 tds per year.

Anaerobic digestion of sludge is relatively rare (10 plants only), mainly at larger plants, where biogas production contributes to the reduction of treatment costs. Some plants use combined input; that is, fresh sewage sludge and separately collected biodegradable municipal waste, food waste, and other similar materials. Filter presses and belt filters are mainly used at small plants, whereas continuous centrifuges are used at large plants.

Some wastewater companies dispose of the sludge on site (internally) (about 14% of total sludge produced). The main ‘internal’ outlets for dehydrated sewage sludge are land application and recycling after composting on the premises of treatment plants or of their operators (mainly non-arable land). This can only be performed sporadically. Composting is practiced on site at a small scale usually together with other types of municipal waste. The compost produced is used for maintenance of green areas around the treatment plants. Limited amounts of sludge are temporary stored, before the most appropriate (or cheap) method is found.

Disposal Methods	Internally		Externally	
	Quantities (tonnes	**%**	**Quantities (tonnes**	**%**

	DS/y)		DS/y)	
Temporary storage	321	<1	589	1
Recycling/Composting	2,831	6	4,030	8.5
Land use	3,288	7	0	0
Landfill disposal			13,967	30
Export (to incineration)			21,916	47
Other disposal types			123	2
				47,065

In 2006, the largest amount of sludge (47%) was exported abroad in granulated dry form for incineration. The reason for this method is the absence of proper incineration facilities in the country and tightening of the landfill requirements. The existing industrial thermal processes have not yet obtained permits to co-incinerate dry sludge as an alternative fuel. Co incineration in cement kilns is however not considered particularly attractive in Slovenia due to its relatively low calorific value (about 11-12 MJ/kg at 90% DM.). Sludge export for incineration abroad should, however, only be a temporary solution as new thermal treatment facilities for wastes and sludge are currently under construction.

Landfill disposal of dehydrated sludge has been the most traditional way of disposal and, is still the second route for disposal of sludge in Slovenia (30%). From 2008, sludge landfilling will decrease due to stricter waste acceptance criteria for landfilling such as total organic carbon content of less 18% DM and calorific value less than 6 MJ/kg. In particular the required TOC/DOC limit values are difficult to reach by conventional digestion/composting stabilization processes.

Composting of dehydrated sewage sludge is most often performed in combination with biodegradable municipal waste and other structural materials (bark, corn stalks). Compost is used in non-agricultural applications: for recultivation of landfill sites and land reclamation of degraded areas, public parks maintenance and other similar locations.

Agricultural use is almost inexistent due to the high content of PTEs in sludge, especially zinc, copper, chromium and lead. The available arable land in Slovenia is limited to 36% as 60% of the country is covered with forests and woods. Application of sewage sludge in forestry is prohibited.

For our baseline, the situation in 2010 will remain the same as in 2006 while by 2020 quantities produced are expected to increase to amount to 50,000tds. Over the next 10 years, the proportion of sludge being recycled to land will increase as sludge quality improves but will stay relatively low at around 15%, landfilling will also decrease to 5% while thermal treatment will remain the preferred option.

Sweden

The following description is based on information provided by Hultman et al (1999).

Sweden has a population of about 9.2 million people. The proportion of people living in urban, rural or in sparsely populated areas is about 85%, 5% and 15%, respectively. There are approximately 2,000 municipal wastewater treatment plants and 95% of the population in towns and agglomerations with more than 200 inhabitants are served by plants with tertiary treatment. Full compliance with the UWWT Directive is already achieved.

Sweden has gradually strengthened its rules concerning limiting values of metal concentrations in sludge. In addition there are also limit values for organic substances (nonyl-phenol, toluene, total PAH and total PCB).

There are also legal restrictions on disposal to landfill and, since 2005, organic wastes including sludge from wastewater treatment plants have effectively been banned from landfills. In addition, since 1 January 2000, a landfill tax has to be paid when sludge is disposed of to landfill.

Centrifuges are the most common by used dewatering equipment followed by belt presses. Other conditioning methods are used such as the KREPRO process which uses sludge conditioning by use of acids and heat. There is a growing interest to more efficiently use natural and biological dewatering methods, for example, by use of reed beds.

All large treatment plants use anaerobic digestion, while the other methods are used at small and medium-sized plants. There are also some examples of thermal drying.

Co-treatment of sewage sludge with solid wastes has been investigated in Sweden at different scales such as:

- Sludge incineration together with municipal solid wastes
- Anaerobic digestion of sludge together with other organic materials
- Large-scale composting of sludge together with other organic materials.

Sludge production has been relatively stable for the last 10 years at around 210,000 tds per annum (CEC 2006 and 2009) while quantities recycled to agriculture have fluctuated due to debate over the safety of the outlet but it seems to have reached a stable level at around 10 -15 %.

At the end of the 1980s, sludge disposal outlets in Sweden were agriculture (35%), landfill (50%), land reclamation (15%) and others (5%). Ten years later (1998) the agricultural use had declined to 25% and disposal to landfill had increased to 46 %. In 2006, the agriculture and landfill outlets had further been reduced to 15%, and 4%, respectively while other outlets (land reclamation, green spaces, co combustion, etc) were reported to have reached 81% (Eureau, 2008).

The reasons for the decrease in sludge recycling to agriculture were that, in 1990, the Federation of Swedish Farmers (LRF) recommended its members not to use sludge. A national consultation group was formed between LRF, the Swedish Water and Waste Water Works Association (VAV) and the Swedish Environment Protection Agency (SEPA) which reached agreements concerning agricultural use. However, at the beginning of 2000, LRF argued that agricultural spreading should be suspended because of the presence of brominated flame retardants in sludge and their possible negative effects on soils and organisms.

About five years ago VAV ordered a product certification system from the Swedish Testing and Research Institute (SP). The food industry requires that sludge be quality assured by a certification system. This however offers no guarantee that the sludge will be accepted for use in agriculture. A quality assurance system (ReVAQ) has been designed together by the concerned parties, water companies, farmers, nature conservation and the food industry but the future of agricultural use of sludge is still uncertain. Future use of sludges in agriculture may, however, decrease due to concerns of the food industries and the public. This is the most difficult to predict.

Landfilling had increased due to recommendations to avoid sludge in agriculture, but has now decreased to below 5% by 2005 due the legal restrictions on organic wastes going to land, the introduction of a landfill tax and the difficulties to find new land areas or getting permits for the disposal.

Incineration is a well established method in Sweden for solid waste treatment but not for sewage sludge. Co-incineration with solid wastes may be an interesting alternative to mono-incineration although it seems that most existing incineration plants for solid wastes do not have excess capacity to also burn sludge. Therefore, attention has been directed towards co-incineration with biofuels (wood, peat etc), coal power plants or plants producing building materials at high temperatures (cement, brick etc). Two factors will influence the use of incineration of sludge in Sweden: the potential introduction of a tax on incineration and the potential requirement that phosphorus must be recovered either before or after the incineration.

Other land uses of sewage sludge represent about 10-15% of sludge production in Sweden. Sludge based products and soil conditioners can be used on reclaimed land, parks, golf courses, green areas etc (there are about 400,000 hectares of green areas in Sweden). Sludge can also be used as landfill cover material. Sludge used in forestry has received some attention from forest companies. Sludge can be spread as dried sludge in pellet form on mineral soil to compensate for nitrogen losses due to soil acidification and intensive forestry.

Increased interest has been devoted to extraction of products from sludge. Two commercial systems are mainly under consideration in Sweden, namely the KREPRO and Cambi processes. The Cambi and KREPRO processes aim to see the dissolved substances as resources, either through improved methane production in the digester (Cambi) or by reuse of precipitation chemicals, production of a fertilizer (ferric phosphate), and separate removal of heavy metals in a small stream (KREPRO).

For the baseline study, sludge quantities are expected to increase slightly mainly due to population growth. By 2010, sludge quantities will remain at about 210,000 - 220,000 tds increasing to 250,000 tds by 2020. Over the next 10 years, the proportion of sludge recycled to agriculture will stay at 15% - 20% while recycling to other land uses is expected to be around 70-75%, landfilling reduced to 1% and 5%-10% for co-combustion.

United Kingdom

The following description is based on information provided by Matthews for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and relates mainly to the situation in the England and Wales.

About 96% of the UK population is connected to sewers leading to sewage treatment works (DEFRA, 2002). Most of the remainder are served by small private treatment works, cesspits or septic tanks.

Sludge quantities have increased steadily over the last 15 years (see table below) to amount to 1.6 M tds in 2006. Historically, about a quarter of sludge was either dumped at sea or discharged to surface waters. This was banned from 1998 under the UWWT Directive because it was considered environmentally unacceptable.

Sludge recycling to land is encouraged in England and Wales as a contribution to the environment by recycling valuable nutrients and organic matter. It is recognised by the Government as the BPEO in most circumstances. Requirements are defined in the 1989 Sludge Regulations (derived from the sewage sludge directive) and the associated Code of Practice, and have been made more stringent by the agreement – the Safe Sludge Matrix - between the British Retail Consortium, Water UK (which represents the UK Water Utilities), and ADAS (the Agricultural Development and Advisory Service), with the support of the Environment Agency.

The most common option in England and Wales and in the UK overall for sludge disposal is recycling to agricultural land at around 70% in 2006 (see figures reported by CEC 2006 and 2009 in Table below) followed by incineration with subsequent disposal of ash to landfill. Landfill, which was always the less preferable option, is now used less due to increasing restrictions from the 1999 Landfill Directive, lack of site availability and costs. Liquid sludges can no longer be disposed of into landfill sites. In Scotland and Northern Ireland, incineration is the most preferred option treating respectively 51,000 tds in 2005 in Scotland and 22,000 tds in 2004 in NI.

	CEC 2006, 2009	DEFRA web page			
Year	**Sludge production ($x10^3$ tds)**	**UK sludge**	**England and Wales($x10^3$ tds)**	**Scotland($x10^3$ tds)**	**Northern Ireland($x10^3$ tds)**
1995	1,120	1,124	993	93	34
1998	1,045	1,058	936	97	25
2001	1,187		1,137	-	-
2002	1,303	1,390	1,249	113	28
2003	1,360	1,422	1,280	113	29
2004	1,445	1,368	1,221	113	34
2005	1,511		1,369	140	. .
2006	1,545				

Year	**Quantities recycled to agriculture**		**Incineration**		**Landfill**		**Sea**		**Power generation**		**Land reclamation**		**Other**	
	($x10^3$ tds)	%	**($x10^3$ tds)**	%	**($x10^3$ tds)**		**($x10^3$ tds)**	%	**($x10^3$ tds)**	%	**($x10^3$ tds)**	%	**($x10^3$ tds)**	%
1995	550	49	82	7	115		254	22	-		-		125	11
1998	504	48	185	17	115		150	14	-		-		105	9
2001	709	60					0		-		-			
2002	761	58	232	17	65		0		52	4	84	6	196	14
2003	824	61	227	16	38		0		50	4	106	7	177	12
2004	878	62	265	19	15		0		0	0	150	11	60	4
2005	1,056	70	NI		NI		0						NI	
2006	1,050	68	NI		NI		0						NI	

Untreated sludge is no longer applied in agriculture. The extent of dewatering and stabilisation varies from site to site. A variety of treatment methods might be used depending on the local treatment facilities. There is no set treatment requirement and many factors are taken into account to meet the required treated sludge quality.

A common method of treating sludge at present is anaerobic digestion to standards that meet the terms of the Matrix. After a period of doubt in the 1990's about the future of anaerobic digestion, the process now has a secure central place in sludge strategies and design and operation of plants has developed significantly. The process has been extended to higher levels of efficacy and effectiveness to meet the terms of the Matrix by the use of additional stages. These can also have the advantage improving product quality (that is, releasing ammonia, improving consistency, and reducing smell), producing gas and reducing volume. When digestion is used, the value of the energy created from the methane in the sludge gas is becoming increasingly important. Most sludges are now dewatered using centrifuges or belt presses. There continues to be an interest in other thermal processes, such as pyrolysis and gasification, but these are not currently available.

The application rate onto agricultural land depends on the crops, which can be a cereal, but on a local basis could be maize, rape, or sugar beet, (uses for growing potatoes and other root vegetable have become much less frequent in recent years). A typical application rate would be 6-8 dry tonnes/ha/year.

In the past, small quantities of sludge have been supplied to the domestic and horticultural market. The practice has not been widely encouraged for the domestic market due to the difficulties of effecting realistic controls over application and the disproportionate costs. One opportunity to supply a product would be as compost, which incorporated sludge with other materials. Investigation of this continues but, so far, products including a straw-based compost have not proved to be an attractive or cost effective product. If such products are supplied, there is a move towards the much tighter standards produced by the British Standards Institution, such as PAS 100, for composts, and details can be found on the SORP website.

Only a small amount of sludge is used in forestry and this will probably not increase in the future. Untreated sludge is no longer used for any part of the forestry cycle.

Sludge has also been applied on energy crops such as willow and poplar or miscanthus in short rotation plantations. The harvested wood can be used for a number of purposes, including use as a fuel source. The use of untreated sludge is permitted for these crops.

It is unlikely that the use of sludge on conservation and in recreational land would ever constitute more than a small fraction of the disposal of sludge. This market might be bigger than that at present if sludges were composted or dried and pelletised. The soil criteria for agricultural land apply, and it is likely that only fully treated sludge would be used, particularly on recreational land.

There is some use of sludge for land reclamation (i.e. capping landfill sites and creation of woodland on brownfield sites) However, these tend to be opportunistic and will probably never constitute a significant outlet for sludge.

In the future for our baseline scenario, the two main options will continue to be recycling to agricultural land and thermal treatment. The issues of energy consumption/production and carbon footprint will become important in assessing the sustainability of operations.

The UK is in the process of reviewing sludge use legislation. The UK Government has proposed the incorporation of the Safe Sludge Matrix into Regulations and could incorporate further changes to reflect any developments of knowledge and attitudes. If implemented, the Regulations would make many of the restrictions explicitly mandatory, rather than placed in a Code context. However as yet there are no firm indications as to when the law will be changed. Nevertheless the Companies are incorporating the principles in their operations. There is a clear awareness of the issues of risk management and accredited quality assurance programmes and many schemes have been registered under ISO 14000 or 9000.

Some of the changes to the Regulations would be:

- Use of untreated sludge would be banned
- Treatment will be in accordance with definitions of conventional treatment and
- enhanced treatment
    - Conventional treatment is 99% (2 log) reduction of E. Coli and an MAC of 100,000 per gram DS
    - Enhanced treatment is 99.9999% (6 log) reduction of E. Coli and an MAC of 1000 per gram DS and an absence of Salmonellae sp
- Ban the use of conventional sludge on grassland unless it is incorporated
- Restrict access for harvesting or grazing for conventional sludge to 12-month intervals for field vegetables and 30 months for vegetables eaten raw
- Max limit for lead lowered to 200mg/kgDS
- Max limit for zinc in soils pH 5.5-7.0 would be 200mg/kgDS and for pH values above 7 with a calcium carbonate content more than 5% would be 300mg/kgDS

For our baseline, sludge production is not expected to increase over the next 10 years from the 2006 level of 1.6 million tds. Recycling to agricultural land will also stay at a similar high level at around

65-70% over the next 10 years; incineration may increase to 20-25%; land reclamation will increase to 15-20% and landfill will remain low at about 1%.

Country	1995					2000					2005				
	total sludge	agriculture	incineration	landfill	other	total sludge	agriculture	incineration	landfill	other	total sludge	agriculture	incineration	landfill	other
	tds/a	%	%	%	%	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	20,000	40		60		20,000	40		60		33,700	40	0	60	
Cyprus	7,000	10				7,000	10				7,586	47		50	
Czech Republic	146,000	20		50	40	210,000	45		30	25	220,700	10	10	10	60
Estonia												10			
Hungary	30,000					30,000					128,380	37	1	44	15
Latvia	20,000					20,000	37		38	33	23,942	37		38	33
Lithuania	48,000			90		48,000	10		90		71,252	23	0	77	
Malta															
Poland	340,040	8	8	56		397,216	14	6	50		523,674	14	1	18	70
Romania											137,145	0	2	98	
Slovakia								0			54,780	39	0	28	16
Slovenia											19,434	0	47	30	15
Austria	390,000	12	5	11		401,867	10	10	11	60	266,100	17	43	5	39.814
Belgium	87,636	32	34	32		98,936	13	76	14		102,566	12	81	3	14
Denmark	166,584	67	25			155,621	60	43	2		140,021	59	40		
Finland	141,000	33			66	160,000	15		6	80	147,000	3			90
France	750,000	66	15	20		855,000	65	15	20		910,255	58	16	20	3
Germany	2,248,647	42	30		30	2,297,460	37	34	3	20	2,059,351	30	38	2	29
Greece	51,624	0		95		66,335	0		95		125,977	0		95	
Ireland	38,290	11				35,039	40				62,147	63		17	20
Italy	609,256	26		30		850,504	26		30		1,070,080	26	7	31	40
Luxembourg	7,000	80			15	7,000	80			15	7,750	45	20		33
Netherland	550,000	0	100			550,000	0	100			550,000	0	100		
Portugal	145,855	30	0	70		238,680	16	0	84		408,710	46	0	54	
Spain	685,669	46				853,482	53				1,064,972	65			
Sweden	230,000	29		50	20	220,000	25		46	20	210,000	14	2	4	86.5
United Kingdom	1,120,000	49	7	35	9	1,066,176	55	21	5	16	1,544,919	66	19	1	15
EU12 % of total EU	8	1	0	4	1	9	2	0	4	1	12	2	0	4	5
EU15 % of total EU	92	36	19	14	12	91	34	22	11	12	88	36	21	9	18
EU27 % of total EU	100	37	20	18	12	100	36	22	15	13	100	38	22	14	23

Table 15 **Estimates of annual sewage sludge production and percentages to disposal routes, 1995 – 2005 (from data in this report)**

Country	2010 total sludge	2010 agriculture	2010 incineration	2010 landfill	2010 other	2020 total sludge	2020 agriculture	2020 incineration	2020 landfill	2020 other
	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	47,000	50		30	20	180,000	60	10	10	20
Cyprus	8,000	50		40	10	16,000	50	10	30	10
Czech Republic	260,000	55	27.5	10	25	260,000	75	20	5	5
Estonia	33,000					33,000				
Hungary	175,000	77	5	11	5	200,000	58	30	5	5
Latvia	25,000	30		40	30	50,000	30	10	20	30
Lithuania	80,000	30	0	70		80,000	55	15	30	
Malta	10,000			100		10,000	10		90	
Poland	520,000	38	5	45	12	950,000	26	10	18	46
Romania	165,000	0	2	98		520,000	40	10	50	
Slovakia	55,000	50	5	5	10	135,000	50	40	5	5
Slovenia	40,000	10	50	20	15	50,000	15	70	10	5
Austria	273,000	5	64	1	25	280,000	5	85	1	10
Belgium	170,000	9	90	0		170,000	9	90	0	
Denmark	140,000	50	45			140,000	50	45		
Finland	155,000	5			90	155,000	5			90
France	1,600,000	60	17	24	3	1,600,000	65	17	15	3
Germany	2,000,000	30	50	0	20	2,000,000	30	50	0	20
Greece	260,000	10		95		260,000	5	40	55	
Ireland	135,000	75		15	10	135,000	70	10	5	10
Italy	1,500,000	50	10		20	1,500,000	70	15		20
Luxembourg	10,000	90	5			10,000	80	20		
Netherland	560,000	0	100			560,000	0	100		
Portugal	420,000	50	30	20		420,000	50	30	20	
Spain	1,280,000	70				1,280,000	70			
Sweden	250,000	10	15	4	81	250,000	15	10	1	74
United Kingdom	1,640,000	65	25	5	5	1,640,000	65	25	5	5
EU12 % of total EU	12	5	1	5	1	19	8	3	4	4
EU15 % of total EU	88	40	25	7	11	81	40	25	4	9
EU27 % of total EU	100	45	26	12	12	100	48	28	8	13

Table 16 **Estimates of annual sewage sludge production, and percentages to disposal routes, 2010 - 2020 (from data in this report)**

Environmental, economic and social impacts of the use of sewage sludge on land

Interim Report describing the first consultation

milieu
ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by Milieu Ltd, WRc and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Anne Gendebien. Additional expertise was provided by Bob Davis, John Hobson, Rod Palfrey, Robert Pitchers, Paul Rumsby, Colin Carlton-Smith and Judith Middleton.

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Table of Content

1 Introduction

This report summarises the work done to date for the project "Study on the environmental, economic, and social impacts of the use of sewage sludge on land" (Contract Number: 070307/2008/517358/ETU/G4). It also summarises the responses received to the Commission's first stakeholders on-line consultation which was launched on 13 July 2009 for a 4 week period regarding possible revision of the Sewage Sludge Directive 86/278/EEC. Responses received up to 27 August have been considered.

This document presents a summary of the responses, including a breakdown by type of stakeholder. The two reports provided for the consultation provided a summary view of the current state of sludge production, treatment, use and disposal, and a view of the future amounts, treatment and disposal routes and possible influences (regulatory and public) upto the year 2020.

The report does not aim to provide a statistical survey of opinions. The consultants have responded to some comments with a short discussion, but have not intended to present a final view. The consultants do not necessarily agree with all the views expressed.

2 Scope and Objectives

The aims of the consultation were to invite stakeholders to review and comment on the two reports prepared for the Commission by the consultants. The first report summarised current knowledge on sewage sludge recycling to land. The second described sludge production, use and disposal assuming that no changes are made to the Directive up to 2020, as a baseline scenario. The Commission sought contributions from stakeholders which were structured around 3 general questions and 28 specific questions.

Respondents were invited to comment if they disagreed with the findings and/or to submit additional references to be included in the reviews. The consultation also sought to obtain more up to date information and to correct any misunderstandings or factual inaccuracies that had been reported in the descriptions of the situation in each specific Member State.

This report includes a list of respondents; a summary of their responses and a completed revised version of the country reports, main tables and figures published in the two reports. In addition, it contains additional sections to the original report when relevant additional references were provided. It does not include a revised full copy of the two reports nor the completed version of the responses. These remain available on CIRCA (http://circa.europa.eu/Public/irc/env/rev_sewage/home).

3 Facts and Figures

40 responses were received in time to include in this report. Some were joint responses and some originated from different organisations but reiterated some of the comments. 19 were received from governmental bodies, 18 from the private sector and commercial organisations or from associations with commercial interests, 2 were received from non-profit making organisations and 2 were from individual citizens with specialist knowledge.

Responses were not received from all the Member States (16 MS out of 27 + 1 non EU MS) but European representatives of commercial organisations from the agricultural, water and waste sectors as well as some of their national members were well represented. The ranking of the origin of the responses by nation is Germany, the UK and Belgium and France in the group of the top four countries. Due to the lack of response from certain organisations, the views of respondents described in this report do not necessarily represent the full range of opinions held by stakeholders within certain sectors (i.e. food manufacturers) of society or groups of the population (public citizens, environmental NGOs, etc).

Some respondents provided general comments whilst others provided detailed responses to all 28 questions and some additional material.

Table 17 Respondents to Public Consultation by Member State

Member State	Responses received	Public authorities	Organisations	General comments	Specific response to 28 questions
EU-15					
Austria	**2**	☺	☺	☺	
Belgium	**3**	☺		☺	☺
Denmark	**2**	☺	☺	☺	
Finland	**1**		☺	☺	☺
France	**3**	☺	☺	☺	☺
Germany	**6**	☺	☺	☺	☺
Greece	**-**				
Ireland	**-**				
Italy	**2**		☺		
Luxembourg	**-**				
Netherlands	**-**				
Portugal	**2**	☺	☺	☺	
Spain	**-**				
Sweden	**-**				
United Kingdom	**4**	☺	☺	☺	☺
EU-12					
Bulgaria	**-**				
Cyprus	**1**	☺		☺	
Czech republic	**1**	☺		☺	
Estonia	**-**				
Hungary	**1**	☺		☺	☺
Latvia	**1**	☺		☺	
Lithuania	**1**	☺		☺	
Malta	**-**				
Poland	**-**				
Romania	**1**	☺		☺	
Slovakia	**-**				
Slovenia	**1**	☺		☺	☺
EU	**7**		☺	☺	☺
Norway	**1**		☺	☺	☺
Total	**40**				

Table 18 Categories of Respondents

Respondent category	Total number	Sub-category	Number
Public authorities	**19**	National authority (MS)	11
		Regional authority (MS-R)	6
		Statutory advisor, agency, public institution (MS-A)	2
Organisations	**21**	International Professional association/federation (EF)	8
		National Professional association/federation (NF)	7
		Company/industry (IS)	4
		Consultancy	0
		Research/academic institute	
		NGO	1
		Other	1

Table 19 List of respondents

Name	Type	Country	Date Received
Official organisations			
IBGE-BIM (Brussels Institute for Environment)	MS-R	Belgium	14/07/2009
Leiter des Referts Vermeidung und Verwertung von Abfällen, Bayerisches Staatministerium für Umwelt und Gesundheit (Bavarian Ministry of Environment and Health)	MS-R	Germany	24/07/2009
Slovenian Ministry of Environment and spatial planning	MS	Slovenia	24/07/2009
Ministry of Environment/Waste Management department	MS	CZ	30/07/2009
Romanian Ministry of Environment	MS	Romania	06/08/2009
Danish Ministry of Environment- Environmental Protection Agency	MS-A	Denmark	07/08/2009
Baden-Württemberg - Ministry of Environment	MS-R	Germany	06/08/2009
North Rhine Westphalia Ministry of Environment	MS-R	Germany	07/08/2009
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (German Ministry of Environment)	MS	Germany	08/08/2009
UK Department of Environment, Food and Rural Affairs	MS	UK	10/08/2009
Agência Portuguesa do Ambiente (Portuguese Environment Agency)	MS-A	Portugal	10/08/2009
Lithuanian Ministry of Environment	MS	Lithuania	10/08/2009
Hungarian Ministry of Environment	MS	Hungary	11/08/2009
French authorities (secretaire general des affaires européennes- sgae)	MS	France	11/08/2009
Ministry of the Environment of the Republic of Latvia	MS	Latvia	18/08/2009
Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (Ministry of Environment)	MS	Austria	20/08/2009
Walloon Region Ministry of Agriculture, natural resources and Environment –Soil and waste department – soil protection direction (DGANRE-DSD-DPS)	MS-R	Belgium	10/08/2009
Flemish Region-OVAM (Flemish waste agency)	MS-R	Belgium	17/08/2009
Ministry of Agriculture, Natural Resources and Environment	MS	CY	26/08/2009

Name	Type	Country	Date Received
Commercial organisations			
FIWA (Finnish Water and Waste Water Works Association)	NF	Finland	10/07/2009
VEAS (Vestfjorden Avløpsselskap – Oslo water company)	IS	Norway	16/07/2009
Incopa (European coagulants producers)	EF	EU	23/07/2009
Ecosol (European producers of Linear Alkylbenzene)	EF	EU	23/07/2009
FederUtility (Federazione delle Imprese Energetiche e Idriche (Representative of local public utility companies)	EF	Italy	23/07/2009
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall (DWA) (German Association of Water)	NF	Germany	24/07/2009
Alan Srl	IS	Italy	24/07/2009
Water UK	NF	UK	27/07/2009
DAKOFA (Danish Waste Management)	NF	Denmark	27/07/2009
FP2E (Professional Federation of Water Companies) (EUREAU member)	NF	France	27/07/2009
EUREAU (European federation of national associations of drinking water suppliers and waste water services)	EF	EU	27/07/2009
Copa-Cogeca (European Farmers and Agri-cooperatives)	EF	EU	27/07/2009
Austrian Chamber of Agriculture (Part of COPA-COGECA response)	NF	Austria	27/07/2009
Aguas de Portugal	IS	Portugal	29/07/2009
EFAR (European Federation for Recycling in Agriculture)	EF	France	31/07/2009
InSinkErator (manufacturer of food waste disposers)	IS	USA/UK	31/07/2009
EWA (European Water Association)	EF	EU	07/08/2009
EuLA (European Lime Association)	EF	EU	10/08/2009
Bundesverband der Deutschen Entsorgungswirtschaft (BDE) (Federation of German Waste Management Industries)	NF	Germany	11/08/2009
Others			
CIWEM (Chartered Institution of Water and Environmental Management)	NGO	UK	27/07/2009
CEN (European Committee for Standardization)	Other	EU	30/07/2009

4 Summary of Comments

4.1 General Comments

Sewage sludge, for the purpose of this consultation, is the product of treatment of sewage (and sludges) brought into domestic or urban wastewater treatment works and other similar sludges. This is consistent with the definition of sewage sludge given in the directive.

The boundary for the destination of sewage sludge for this consultation was agricultural land, although impacts of other routes have also been described. The desire of respondents to extend the boundary of the directive to include uses beyond arable etc. land to areas such as reclamation, recreational and energy crops, should be seriously considered.

General statements

Have all important sources been mentioned in the summary report in the existing knowledge?

Many of the respondents commented that the reports and sources used provide a good overview of the current situation. However, some respondents believe that a number of key references and relevant international but mainly national research papers have been missed. Some respondents also submitted more up to date figures especially for sludge production and outlets which were taken into account in revising the country reports. These additional references are listed in Annex 1 – some of these papers are not available in English.

Do you find the baseline projections in summary Report 2 realistic?

The majority of official respondents agreed with the baseline scenario for their relevant country or region, offered some corrections or did not have any comments.

A few, however, disagreed strongly with some of the assumptions and proposed alternative figures. Based on these comments the country reports and the tables in reports 1 and 2 were updated as well as the relevant figures. The revised tables are included in Annex 1. The figures will also be updated and included in the final report.

Other general statements

The majority of comments both from official and commercial respondents were positive and commented that both reports were well structured and presented an interesting overview of the situation encountered at EU level and had provided a thorough analysis of current and future risks and uncertainties.

The summary below is divided into 2 parts: the first part reports comments on the potential revision of the Sludge Directive and the second part includes comments on the information and analyses presented in the two reports

The following improvements to the studies were suggested and have been summarised under the main headings of the reports:

Overall comments:

- Should also describe other outlets.
- Should include industrial sludges, and sludge produced by the food and paper industries should be integrated into the baseline scenario.
- Imbalance between the presentation of benefits of sludge land spreading and risks.
- Too UK orientated.

- One respondent supports the use of the term “Wastewater Biosolids” instead of sewage sludge or “sewage bio-waste”.

General comments on revision of Sludge Directive

The consultation has produced a considerable body of detailed comments and observations but little enthusiasm for major changes to the Directive. There is a general consensus amongst the respondents that the existing Directive has been demonstrably effective over many years and if they recognise a need to update the Directive, no fundamental changes to the principles used in the Directive are needed.

Most respondents support the need to revise the Directive while stressing that the current existing regime is safe and has guaranteed sufficient protection to health and the environment. However, the reasons for possibly revising the Directive and the extent of possible revisions varies greatly between respondents.

Most respondents support the recycling of sewage sludge to agriculture when carried out in accordance with appropriate standards. They stressed that the practice is safe and also represents by far the most sustainable option, particularly in the light of future challenges including climate change and declining phosphate (P) resources.

Some respondents strongly oppose the application of sewage sludge to land for precautionary reasons but favour the use of other sources of organic material such as high quality compost and the use of sludge in biogas production or other thermal treatment.

Some argue that any future policy changes should be proportionate to risk and that their potential climate change impacts should be balanced against potential benefits, others advocate the precautionary principle.

The majority of respondents support mandatory drivers such as the EC Directives as being useful, and to improve on the one hand the quality of sludges that are used on land, and on the other hand the management practices (soils to receive sludges, prohibition period before spreading and harvesting, etc.).

Several commercial respondents also stress the need for flexibility, notably with non mandatory drivers such as quality assurance schemes and different regimes for fertilisers derived from sludge: products (through the end-of-waste status), wastes; and the use of those fertilisers for food production under the waste regime should remain possible (with ad hoc standards, based on scientific risk assessment studies).

One respondent argues that as individual Member States have laid down stricter national limit values than those stipulated in the Sewage Sludge Directive this demonstrates that limit values in the Sewage Sludge Directive should be revised and extended.

Some would like a revision of the Directive to take into account technological developments (i.e. treatment processes), new research (i.e. contaminants and pathogens) and also to ensure uniformity with recent developments in European environmental legislation and policy.

Some or all of the following amendments were proposed by those who wanted revision of the Directive:

a) Extend the scope of application of this Directive to non-agricultural areas and to non-sewage sludge biowastes.
b) Revise current limit values for PTEs.
c) Introduce limit values for organic pollutants.
d) Introduce pathogen concentration limits.
e) Introduce a quality assurance system.

Scope of Directive

Several respondents argue that there is a need to extend the scope of the existing Directive, especially in the absence of a Soil Framework Directive , to take account of all land uses (both agricultural and non-agricultural). Although the use of biosolids in agriculture is regulated, there is no EU framework for the use of biosolids in forestry or for land restoration.

The revision of the Directive could also be an opportunity to harmonise existing regulatory regimes, by careful alignment with other areas, i.e. waste and resource efficiency, greenhouse gas and carbon accounting, energy, water quality and chemicals management and controls.

More than half the respondents considered that a potential revision of the Directive should also be extended to include all bio-wastes and argue that there should be a consistent framework of controls for all residuals applied to land.

The use of sewage sludge and other organic resources on land should be viewed from the perspective of the soil rather than from the origins of the materials. It is important to get away from "silo thinking" and take a holistic view of all aspects of organic resource. A recurrent argument is the fact that the spreading of manures and other residuals on land is not regulated although they can have similar environmental effects to biosolids, but they are 20 times greater in quantity than biosolids.

Sludge and soil quality

Pathogens link to health effects – only proposals that two levels OK; that reduced waiting periods for enhanced treated is appropriate.

The presence of some types of organic substances (OCs) in sewage sludge produced the greatest controversy between different respondents. Some respondents strongly promote the precautionary principle with regard to organic compounds arguing that lack of secure control on introduction of any substances into the sewage makes all sludges hazardous. The majority of those who commented did not have such strong views, and a significant proportion strongly argued that the currently applied conditions have not resulted in identifiable adverse effects on humans, agricultural animals or plants or the general environment.

The presence of potentially toxic elements (PTEs) as currently specified in the directive also led to opinion differences. Since generally PTEs have reduced, and there have been no demonstrated adverse effects, several respondents proposed that the number of controlled and reportable PTEs for sludge and soil should be reduced to two or three. The need for copper and zinc in some soils was also described and considered important not to unnecessarily limit concentrations of these elements.

Pathogens in sludge and soil were also discussed. In this case some respondents promoted the view that different standards should be harmonised, appropriate to different end uses, and that for the highest quality sludges the existing waiting periods between application and use should be reduced.

Overall there were no firmly described views on what appropriate standards should be present in a revised directive for any of organic substances, PTEs, or pathogens. There was also divergence between those who considered that a revised directive should have standards that all should meet, at a higher level than currently, and those that considered individual Member States should continue to take responsibility for setting their own individually decided standards more stringent than a revised directive.

The majority of respondents favour the option to keep sewage sludge as a 'waste' rather than a 'product' as it offers better control of the application under the waste legislation (traceability). Others are concerned that if treated sludge was defined as a product and fell under the REACH-regulation, all the requirements to fulfil the REACH regulations would be expensive.

Many of the respondents promoted the urgent need to have clear and linked legislation for combined treatment and use of manure, industrial organic waste, biowaste and sewage sludge.

Quality assurance

Some respondents favour the introduction of a quality assurance (QA) system but most do not see the need for an harmonised approach.

There are opposing views on listing treatment processes that may meet pathogen reduction requirements with some considering it necessary to list in a revision of the existing Directive possible treatment processes for the reduction of pathogens. Alternatively there is some support for HACCP[9] but not for a defined list of processes and their operating conditions. Use of HACCP to meet defined [risk-based] output standards is considered a much more robust and adaptable approach.

The double barrier principle is widely supported in which use-restrictions and level of treatment (e.g. with 2 categories: advanced treatment, and conventional treatment) are combined. This approach can be broadly regarded as a HACCP which has proven to be efficient and cost effective.

5 Comments on Reports

In this section respondents comments, discussion and criticisms of the contents of Report 1 and Report 2 are shown with short responses and observations. Example comments are included from individual responses to illustrate respondents views.

5.1 Sludge Quantity

Example respondents views include:

- *A clearer definition for the terms 'sewage sludge' and 'disposal' is needed to ensure that comparison between Member States is as accurate as possible.*
- *Concern about conflicting population estimates.*
- *Add quantities of sludge composted to the quantities reported to be spread on land to have the 'true' total of sludge recycled to agriculture and agricultural activities.*

Collating reported amounts of sludge production, and populations, from different sources led to some inconsistencies between values described in these reports. This highlights the importance of improving common definitions if it is considered important to maintain accurate ongoing publicly available statistics. Benefits would include the ability to identify the extent of differences between different Member States in production, treatment and disposal and so comprehend how EU and Member States mandatory and guidance requirements impact on different Member States, and consider what adjustments may be required to improve the route to common goals.

Although responses from respondents have enabled amendment of details, the overall impact on understanding amounts, processing and disposal routes has been small, and is not considered sufficient to revise the general conclusions. The absence of detail of some routes (composting, including use in horticulture, land reclamation, energy crops and forestry) was considered to be a defect in the report(s) which could lead to some underestimation of the total amount of sewage sludge used in beneficial soil recycling processes. In particular, reporting of the amounts of sludge used on agricultural land does not always include sludge used in composts that is then used on agricultural land (see details in country descriptions, Report 2). The reported agricultural route in 2005 used approximately 40% of

[9] HACCP – Hazard analysis and critical control point procedures – these have been prepared for some processes to identify measurement, sampling and analyses that provide information on process performance directly linked to achieving safety critical target values. For sludge treatment, control points might include temperature and retention times, to achieve treated sludge pathogen quality requirements.

EU sludge, and the reported amount of sludge that was composted was about 12% of produced sludge. From this it is clear that agricultural and similar recycling is the single largest ultimate destination for processed sludges.

There is a lack of clarity available at national summary level on the treatment history of sludges used in agricultural recycling. The purpose of the assessments was to provide an overview of routes and destinations rather than to fully account for all possible situations. Increased attention is now paid to the use of sludge for sophisticated renovation schemes, as well as for indirect uses, such as horticulture. Much of the sludge in the "other" category is used in forms of soil application not specifically described in the agriculture route. These conditions are likely to be subject to other planning or management conditions, including appropriate risk assessments or quality assurance schemes.

5.2 Sludge Quality Reporting

Example respondents views are:

- *Data on quality should cover all elements including pathogens and organics.*
- *Need to add a statement regarding the importance and purpose of presenting average sludge quality data.*
- *Lack of information in the report on the impacts of a possible revision/change of threshold values in PTE or OC in sludge. It is necessary to compare data for each country on sludge quality by size of WWTP or at least weighted taking into account the DS production. Described in this way great variations could be expected between EU 15 and EU 27 states.*
- *The range of P and N concentrations was questioned, particularly the extreme low and high values. The table did not show the designation of values (mg/kg DS, for PTEs, and % w:w for P and N).*

Comments on the relevance and importance of Potentially Toxic Elements (PTEs), Organic Contaminants (OCs) and pathogens in treated sludge and in soils are reported in sections 0, 0 and 0.

Opinions differ significantly on the importance of OCs in sludge and on the need to measure and limit them. These range from the strongly precautionary approach that would avoid risk from OCs by not using any sewage sludge on agricultural land, to the pragmatic approach that no evidence of harm from OCs has yet been demonstrated. A very wide range of OCs have been identified by different Member States, or regulatory bodies, as requiring measurement. It remains unclear what benefit has been gained by such monitoring other than a public perception that sludge quality is improved by using these controls. There may be an indirect benefit gained by ensuring that discharges from potential sources of the target OCs are better managed, leading to lower risks of damage to treatment processes.

A view was put to simplify PTE controls to limit regulation to 2 or 3 limiting elements, whilst continuing to monitor others for QA (quality assurance) purposes. Whilst this would support the principle of minimising regulatory requirements, the choice of PTEs for such regulation is unclear as there is no simple apparent link between a possible indicator PTE and the other currently measured PTEs (see Table 4, Report 1 for sludge PTE contents).

The current arrangements that require minimum standards, but allow Member States, or local regulators to create more stringent requirements have been widely accepted. Although sludge is not likely to be transported between agricultural areas to any significant extent, products from agricultural operations are increasingly moved between Member States.

5.3 Sludge Treatment and Current Practice

Example respondents views are:

- *Need to separate the proportion to "landscaping" from other outlets as it is an important route in a number of Member States.*
- *Important to distinguish between mono-incineration" and co-incineration", mainly because only mono-incineration makes it possible to recover phosphorus, from the ashes. Such recovery is increasingly important and the use of novel processes which also allow for phosphorus recovery such as super critical water oxidation should be considered.*
- *One cannot continue to present sludge incineration as a potential source of renewable energy. Sludge average dry matter content in Europe is probably circa 20 % which means that it will need energy to be burnt. Combustion of dried sludge is energy consumptive. Digestion is the only way to provide renewable energy during sludge treatment and has also the advantage of producing a final product that is easy to handle and odourless.*
- *A consideration that is elaborated upon less in the studies is the fact that the capacity for digestion and incineration in the EU-15 is expanding significantly. Encouraged by national financial incentives for the production of green electricity and green heat, the trend is that ever more sludge is digested (as pre-treatment) after which the dried sewage sludge is co-incinerated, in order to attain the European 2020 targets for renewable energy.*
- *Incomplete list of sludge treatment processes - Some treatments had not been considered or mentioned -i.e. solar drying combined with incineration which could have a positive impact – especially regarding greenhouse gases balance.*
- *Established and successful processes should be discussed equally to new processes and Annex 1 (Report 2) should describe all of the processes mentioned in the table on page 37 of Report 2.*

While several authorities and commercial stakeholders recognised the advantages of co-treatment of sludge (i.e. in co-incineration or co-digestion), some regard mono-incineration as the preferred option, in order to enable phosphorus recovery. Others disagree strongly with the statement that co-incineration in cement or coal fired powered plants should be considered as a recovery operation as ash can be used in brick or cement production.

Incineration use, costs, energy benefits and emissions are contentious with strongly held views for and against the use of incineration. Operators do use suitably prepared sewage sludge in modern incinerators to generate power, and assessments of energy balances show that appropriately chosen and operated systems are expected to provide a whole process energy benefit. Although the benefit is expected to be less than for anaerobic digestion a range of circumstances can justify use of incineration as a sludge powered generator.

In terms of any revision to the sludge directive incineration is a means of managing solids that otherwise would require unreasonably distant transport, and because sludges processed for and in incinerators are most likely to be derived from large conurbations that include surface and road drainage and industrial discharge content such disposal is an effective means of managing actual or perceived adverse contaminants. If the ash can also be used for mineral extraction (in particular, phosphorus) then an additional bonus can be gained.

There is expected to be a large increase in the amount of sewage sludge incineration, with some other thermal processes, throughout the EU to manage increasing amounts of sewage sludge, and limited availability of the agricultural recycling route in some areas. To reverse the trend towards more incineration would require either a ban on such a processing route or more substantial encouragement than could be envisaged in a revised sludge directive.

5.4 EC and Member States Legislation

Example respondents comments include:

EC legislation:

- *The lack of reference to the impact of the regulation on Animal By-products (EC Regulation 1774/2002 of October 2002).*
- *The lack of reference to the impact of the revision of IPPC Directive: the Industrial Emissions Directive.*
- *The lack of reference to the impact of an increase of sludge quantities from Landfill directive and WFD Directive and thus underestimation of sludge future quantities;*
- *Check description of Nitrates Directive.*
- *The European waste catalogue should be mentioned - urban sludge is referenced under the 190805 code.*
- *The fact that the EC Landfill Directive could have a negative impact and that the EC Incineration Directive could have a positive impact on sludge land spreading needs to be clarified. The Waste Directive could also have a negative impact on sludge land spreading if the composted sludge does not meet the end of waste criteria.*

Member States legislation

- *Some corrections and updates were provided and taken into account in the relevant country reports and summary tables and figures.*
- *Provide more detailed description of national voluntary quality assurance schemes and their multiple positive effects.*

Regulatory framework

- *A revision should maintain flexibility and give the opportunity to MS to enforce more stringent national rules to cater for the different local conditions of climate, soil conditions, and nutrient demand. For this reason, and in order to ensure sufficient soil protection, the Directive could be modified to take account of Article 175 EC.*

Respondents have suggested Directives or Regulations they consider likely to have effects on sludge treatment or disposal are either included within the reports with less than desirable detail and discussion, or are not included. This demonstrates the widespread links between existing legislation that affects sewage sludge treatment and destination, and hence the complexity involved in meeting all current or future requirements.

In Report 2 impacts of legislation have been categorised into positive or negative impacts on the amounts used on agricultural land; the impacts are not readily converted into amounts. There was some attempt in the judgements made on the amounts of sludge produced and the destinations described in Report 2 to take account of the impact of meeting the current nutrient removal requirements by all countries, as well as that of the reduction of availability of landfill.

5.5 Economics of Sludge Treatment & Disposal

Example respondents comments are:

- *Should have used more up to date data on costs.*
- *Sewage sludge use for biogas production and related renewable energy generated needs to be covered.*

- *Pyrolysis has proved so problematic so often that it is probably delusional to think that it holds promise for the future.*
- *Costs don't have to be broken down into transportation and dewatering or drying costs because decision making is on the global cost of each route. In some cases availability of farm land could be a more important criterion.*
- *Not included current costs, missing solar drying.*
- *Mono-incineration favoured for poor quality sludge to recover P.*

The costs described were used as an illustration of the effect of different treatment routes. They have been checked against WRc assessments of costs for some of the routes described and are in general agreement with the range of the costs. There are very substantial differences in precise costs related to factors that include different locations, sizes, and treatment requirements. Plant size is the most significant factor apart from the process and destination choice. The difference between a 50k pe works and a 200k pe works is likely to be in the region of x2 – x3 times more expensive (in NPC per tRwDS) for a 50k pe works. The costs shown include all parts of treatment and recovery including the value of energy recovery.

Although the costs were collated for 2002, it is WRc experience that the relative positions do not significantly change, and that adjustments for such guidance assessments can be made using inflation indices within reasonable periods of the initial assessments.

5.6 Agricultural Value of Sewage Sludge

Example respondents comments are:

- *Sewage sludge provides a predictable and reliable fertiliser response that has been well researched.*
- *Availability of P in sludges formed in bio-P removal is increased; reductions in P availability in chemical P removal sludges appear not significant.*
- *The description of P fertiliser use and availability in Report 2 has to be adapted to the EU context and shall not be limited to a global worldwide overview. It will then be possible to demonstrate that even with extended sludge land spreading only a small part of the crops needs in fertilizers will be covered.*
- *Much more emphasis on the decline in phosphate reserves is needed and the beneficial closed loop recycling sewage sludge contributes to the phosphate picture will be a vital part of the need to recycle to agriculture – it is becoming a need, not an option.*
- *A new phosphorus balance for Austria shows that P contained in sludge, meat and bone meal and not recycled biowaste can feed ~ 70 % of the whole crop area.*
- *Check P content as reported in Table 4, Report 1.*
- *The Nitrates Directive requires Member States to designate NVZs in which the limit of 170kgN/ha/year applies; other limits are set by local codes or regulations; the examples shown are for the UK using local circumstances to set limits.*

Few respondents considered that the risks considered by them to be associated with PTEs and OCs in sludge outweighed the benefits from nutrients and soil conditioning that could be achieved by using suitably chosen and treated sludge. The importance of the P content in sludge or that can be derived from sludge was described by many of the respondents. These benefits have been described in various sections of Report 1 and Report 2 (Section 2.7.1).

The amount of P in EU sludge (assuming P at 2% of dry matter) can be estimated at 11.8mt x 0.02 = 236,000 tonnes TP. Currently only about 40% of EU sludge is used on agricultural land (94,400 tonnes TP). Annual fertilizer P use in West and Central Europe is 1.381Mt TP (2006 data, IFA[10], converted to P from P_2O_5). Hence the amount of P in sewage sludge is insufficient to replace the

[10] http://www.fertilizer.org/ifa/Home-Page/STATISTICS

current demand, but making full use of sludge P would reduce the imported P requirement. Other biowastes could further supplement the P demand from recycleable sources. Respondents also commented on the value of recycling sewage sludge P in terms of reducing imported load of PTEs present in some P fertilizers, with particular reference to cadmium.

The range of P concentrations in sludge noted in Table 4 is reported to be wide and surprised some respondents. UK values are reported to be 3.5% P_2O_5 in digested cake or 1.5% as P; German values are reported by DWA as 3%-4% as P in DM. Reasons for differences have not been examined. One of the factors may be differences in the amounts of P removed from sewage.

5.7 Potentially Toxic Elements (PTEs)

Example respondents comments are:

- *Provide additional clear justification for adjusting soil metal limits for Cd and Zn and sludge limit for Pb.*
- *Dispute that the DEFRA study reported conclusion was that a precautionary change of Zn limit from 300mg/kg to 200mg/kg for soils of pH5-pH7 is appropriate.*
- *Decline in average reported PTEs (Table 4, R1) raises the question of whether it is necessary to regulate the current range of PTEs.*
- *There is a case to simplify the controls on PTEs in sludge and sludge-amended soil as concentrations of many of the elements that were important contaminants in sludge in the 1980s have declined below critical risk thresholds.*
- *One proposal is to keep in the statutory regime Zn and Cu as these are the largest concentration PTEs, and possibly Cd, whilst having just a monitoring of the other elements (e.g. Ni, Pb, Cr, Hg) for quality assurance purposes, in Member States where the concentrations in sludge are below risk thresholds, their specific regulation is no longer necessary.*
- *Any limit value for elements of copper (and zinc) in the sewage- sludge (and biowaste)-regulations must take into account the extent to which they are essential elements for plants and are deliberately added to some soils.*
- *In the identification of the costs and benefits of the Directive revision any tightening of soil limit values has to be assessed taking into account the existing data about heavy metal concentration in EU soils (particularly for nickel and cadmium).*

Many Member States have taken a more stringent approach in restricting permitted concentrations of some or all of the metals in soils and in sludges to be applied to soils. Some of the restrictions have effectively blocked sludge application to land.

No respondent offered clear proposed concentration values for limits to be set in any revised directive, other than by referring to the currently used values in individual Member States, and proposing that the Directive values should either be stricter, or relaxed for some of the metals.

5.8 Organic Compounds (OCs)

Example respondents comments are:

- *Give more detailed information on this topic and the associated risks.*
- *Chlorine solvents have been analysed over the last 20 years in Lombardy as routine and no trace of these substances has been found.*
- *Scientific evidence has not identified the need for statutory controls on organic contaminants at the European level to protect human health.*

- *Source control measures (e.g. REACH and WFD) will continue to have a positive effect on the chemical composition of sludge further reducing the risk of contamination with undesirable substances.*
- *Regulatory approaches – i.e. REACH - are not suitable to effectively control human exposure by restricting the accumulation of OCs in sewage sludge.*
- *Insufficient attention given to pharmaceuticals.*
- *Wide range of trace organic substances present in sludges whose effects are not known or substances like dioxins and dioxin-like PCBs underestimated; low concentration synergistic effects of substances not sufficiently certain to be assessed.*
- *New limit values for organic substances should be set (proposed values provided.)*
- *More thorough review of risks to humans due to leaching of contaminants from soils to groundwater, adverse effects on soil organisms and soil fertility, contaminant transfer into plants and surface water contamination. In particular, the risks associated with perfluorinated surfactants in the present study are not taken into account.*

There are strongly contested views on the need for limit values on specific organic compounds (OCs) in sewage sludge, backed by further studies submitted or referred to in the consultation responses that show risks sufficient to require limits or to support a precautionary approach of not recycling sludge to agricultural land (Rhine Westphalia, June 2005)[11], and that show risks insufficient to require any specific limits to be placed on organic contaminants (e.g. Norwegian Scientific Committee for Food Safety, August 2009)[12]. These two example contrary views are based on surveys of OCs in sludge that for many of the components appear similar in concentration.

Out of the 40 consultee responses, 8 would like OC limits, or stricter limits than currently in place in some location (with another respondent stating that any recycling is unacceptable), 5 argued that there is no evidence of sufficient risk to require limits on OCs, and another 4 that would prefer if limits are placed that they should be based on a common risk assessment and applied generally.

There were no common views amongst those responding in favour of introducing EU limits on OCs in sewage sludges on which substances should be regulated. The studies have not shown that any single or small group of substances could act as a marker for a larger range of substances.

There is no evidence that OCs currently in sludge have caused harm, and there are also indications that OCs concentrations have been reducing, possibly linked to improved discharge controls. A pragmatic approach which would retain pressure on producers to manage and minimise potential contents would be to introduce EU wide controls on one or two components, whilst retaining a principle that individual areas could impose additional restrictions on substances known in their area to have a particularly high likelihood of entering the system.

5.9 Pathogens

Example respondents comments are:

- *Although there have been many reported incidents of food-transmitted illness none has been associated with the use of sewage sludge on farmland by means that would comply with 86/278/EEC.*
- *Agricultural use of sludge treated to significantly reduce pathogens (but not necessarily to eliminate them) coupled with suitable land use restrictions, following the well established multi-barrier approach, is an acceptable and safe practice and should be maintained by the revised Directive.*

[11] Ministry of the Environment, Conservation, Agriculture and Consumer Protection of the State of North Rhine-Westphalia, June 2005. Characterization and assessment of organic pollutants in Sewage Sludge.
[12] VKM – Norwegian Scientific Committee for Food Safety (2009). Risk Assessment of Contaminants in Sewage Sludge Applied on Norwegian Soils. ISBN 978-82-8082-338-0

- *Dispute that there are uncertainties in pathogen inactivation in treatment processes and that viable but non-culturable pathogens (VBNC) exist*13*.*
- *There is no evidence of land with long-term sludge application having greater background levels of a wider range of pathogens.*
- *Research is required on the impact of agricultural management practices on pathogen development in soils and consequent risk for human and animal health.*
- *Agricultural use of untreated sludge should not be permitted and is no longer regarded as acceptable practice.*
- *Waiting periods for sludge treated to eliminate pathogens are unnecessary and reduce the flexibility in end-uses of sludge processed to this standard.*
- *Support the flexibility of the existing Directive which enables Member States to set limit values (taking account of local circumstances) provided that they meet the minimum criteria established by the Directive. Whilst Member States should be encouraged to adopt a scientifically robust approach to setting standards in relation to sludge, it should be on the basis that adopting tighter standards is not only required but that there is a demonstrable benefit in terms of safety and increased environmental protection. At the same time any tighter standards should not limit the opportunities for beneficial recycling of bio-solids.*
- *It would be politically unachievable to obtain agreement on a common quality level, and subsidiarity is the best approach.*
- *A common risk management system should be used with harmonised values, and common QA requirement.*
- *All sludges to be fully safe for all handling: disproportionate and unnecessary as long as manure is used on land without similar treatment, or for that matter irrigation water.*
- *Dispute comment that "Aerosol measurements…the studies has been limited". Extensive research on this topic in the USA in all of the climate zones and with all types of sewage sludge has been carried out and has been published by Pepper, Gerber, et al. in peer reviewed journals and includes detailed risk assessments.*
- *Pathogen controls should include different levels of microbiological quality according to treatment status and end use.*
- *Food waste disposal (FWD) might increase the number of plant pathogens but they will not affect presence or absence. The steps in sewage treatment, sludge treatment and restrictions on harvest intervals and cropping will provide adequate barriers to transmission to crops.*
- *Clostridia spp are not a suitable indicator as it is 'cosmopolitan' and it forms thermo*-tolerant *spores, so reduction is not indicative of the effectiveness of treatment and presence is not indicative of risk.*
- *The problem of spreading of antibiotic resistance has not been adequately considered.*

There is a wide range of comments from respondents discussing or contesting matters in this section. These cannot be discussed in detail but it is not considered that they would lead to significant changes to general understanding of the current state.

Seventeen respondents specifically mentioned or discussed pathogens in sludge. Most of these either inferred or specifically described the evidence that there has been no adverse health effects on humans, animals or plants whilst using sludge for agriculture treated and recycled in accordance with the Sludge Directive requirements. Five of the respondents specifically described a desire for pathogen controls to be based on different standards for different purposes, and possibly even adjusting requirements by location as well, whilst three respondents would prefer consistent or harmonised controls.

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[13] Examples of recent investigations of viable but non-culturable pathogens in biosolids and waters are reported in Alanya et al, (2009) Quantification of vbnc *E.coli* in dewatered biosolids through gene expression via RNA microarray - www.iwasludge2009.org.cn –Dunaev T, et al, (2008) Use of RNA based genotypic approaches for quantification of viable but non culturable *Salmonella* spp in biosolids Water Science and Technology 58 (9) pp1823-1828; Liu Y et al (2008) Detection of viable but nonculturable *E.coli* O157:H7 bacteria in drinking water and river water – Applied and Environmental Microbiology 74 pp1502-1507.

None of the respondents made any specific recommendations other than by referring to existing quality limits or more stringent recycling controls used in some Member States either as regulatory controls or as codes of practice.

Some countries have increased the level of controls, and a point has been made that the increased controls may have contributed to the lack of any observed adverse consequences. The precautionary approach was stressed, together with some particular concerns about antibiotic resistant bacteria pools retained in soils. On these matters, a couple of respondents have considerable concerns, stating that the risk has been greatly underestimated. Others put the counter argument that pathogen load in soils does not increase as a result of sludge recycling and that pathogens tend to be outgrown by the natural fauna.

Several respondents commented that public perceptions that sewage sludge use on agricultural land is significantly adversely influenced by odours generated during spreading operations. This can be translated into concerns about risks of contracting illnesses from pathogens in aerosols. Work on these has been carried out. One respondent considered that work carried out in the USA on health risks of aerosols has been sufficient and complete demonstrating no risk to the public. (The most recent publication from the group carrying out these studies has identified a small enhanced risk to operators, at a similar level to risks for a sewage treatment works operators (Tanner et al, 2008[14])). These reports are consistent with the lack of unequivocal epidemiological evidence of adverse health effects. The studies use good surrogates for potential bacterial and viral pathogens but inevitably suffer the disadvantage that assessment takes the form of infection rate prediction from concentrations of pathogens collected and assumptions of recipient sensitivity. It is more likely that public concerns will be managed by demonstrating that sludges distributed onto land are of a high and consistent quality, and provide real benefit to the soil.

There appears to be acceptance and desire for pathogen quality standards to be present in a revised directive. The desire expressed by some respondents for statements of suitable treatment methods may not be appropriate as it could lead to an undue reliance on the process principle rather than ensuring that the process is operated efficiently. However, that does not mean that a process could only be measured by the pathogen kill across the process. Determination of critical stages of processes required to maintain the required level of pathogen destruction and ensuring that they are met can provide sufficient management in conjunction with periodic pathogen concentration measurements.

5.10 Greenhouse Gases

Example respondents comments are:

- *The main assumptions taken into account to establish the comparison of greenhouse gas emissions need to be presented: dry matter content and the calorific value of the sludge used to establish the calculation have to be compared with the average quality of the European sludge for these parameters.*
- *Source study for Table 10 (Report 1) needs to be declared.*
- *Renewable Energy Directive should be considered.*
- *Several respondents argued that sludge recycling to land helps to reduce CO_2 emissions by building the so-called "sinks" - carbon sequestration in the soil (see Austria and Danish studies) while incineration of carbon, contained in ~25 tons (load of one lorry) of dried sludge, produces approximately the amount of CO_2 a middle class car emits by driving ~200.000 km.*
- *Greenhouse gas emission from mineral fertiliser production should also be taken into account in addition to the direct emissions from their application in the field.*

[14] Tanner BD, Brooks JP, Gerba CP, Haas CN, Josephson KL and Pepper IL (2008). Estimated Occupational Risk from bioaerosols generated during land application of Class B Biosolids. J. Environ. Qual. 37 pp2311-2321.

- *CO_2 from the combustion of biogas is short-cycle and therefore should not be counted, although obviously any release of unburnt methane does have global warming potential (GWP) 25x CO_2.*
- *The issue of N_2O seems to be exaggerated. N_2O is a 'leakage' product from nitrification (ammonia to nitrate) and from denitrification (nitrate to di-nitrogen gas). This is an 'inefficiency' of the biological pathway and unrelated to the origin of the ammonia or the nitrate. If sewage sludge supplies the fertilizer replacement equivalent of 100kg ammoniacal-N the N_2O release will be more or less the same as 100kg ammoniacal-N fertilizer. The fact that some organic N is not mineralized to ammonia in the first year and is not available to plants means that it will not be converted to N_2O either. Table 10 thus gives a very erroneous picture.*

The content of this section in Report 1 is derived from a variety of sources that include the UKWIR Carbon Accounting Workbook[15] and used by WRc in preparing comparative scenarios. Emission factors and methodology are founded on IPCC methods and emission factors.

The examples described in Table 10 are taken from a report that is not currently publicly available, but a similar scenario could be constructed for examination by respondents. The numeric examples are provided for illustration of the issues and are not designed to provide values for all circumstances within the EU. Nitrous oxide is recognised as an emission resulting from agricultural use of sludge (as well as from incineration) and measurements of the amounts have been reported (UKWIR CAW references). Estimates of these emissions are set against savings in emissions due to other fertiliser sources, as shown in Table 10.

The renewable energy directive (RED) encompasses sewage sludge as an energy resource. Assessment of the benefits of different processing and recycling options have not been carried out for this study but the examples and descriptions provided in this report, estimated in accordance with internationally accepted methodologies, are consistent with approaches described in the RED.

The amount and type of emissions from sludge treatment, recycling and disposal processes continue to be the subject of controversial discussion. There is a desire to act to minimise emissions from all stages whilst maximising energy recovery, for which anaerobic digestion is widely regarded as the most appropriate technology. There are disagreements and lack of secure comprehension of the factors that should be included in any comparative assessment. This includes the benefit that may be gained from using sludge as a carbon store in soil. If GHG assessments are to be included in a revision, definitions of the boundaries, and methods of assessments will be required.

Some respondents requested additional detail with regard to the content of the assessments summarised in this section and were unfamiliar with the concepts and values described. This was outside the scope of the section to develop to the extent that may be desirable.

5.11 Stakeholders

Example respondents comments are:

- *Policy owner to be included as principal stakeholders as well as agricultural merchants and supply chain contractors.*
- *The report should expand on this issue as food/retailer assurance schemes and customers are more reluctant to the spreading of organic waste-derived materials on land from sewage than to the spreading of organic waste-derived materials from animal origin (e.g. manure). Meanwhile media reports seem to become more sensational – all this could become a significant future risk and uncertainty so this issue is not addressed enough.*

[15] UKWIR CAW Carbon accounting workbook - http://www.ukwir.org/ukwirlibrary/92805 -Workbook for Estimating Operational GHG Emissions (09/CL/01/9)

- *The unfolding and main conclusions of the "conference citoyenne sur les épandages de boues" held by the French ministry of the environment shall be presented.*
- *Risks should be borne by the producer not the landowner or farmer.*
- *There are examples of special interest nature groups in favour of sludge to agriculture (BUND in Germany).*

The comments above reflect the observations in a number of the responses that public perceptions and specific interest groups are major drivers in accepting or rejecting use of sewage sludge on land. Examples of large landowners who have a general presumption against use of sewage sludge have also been provided, together with municipalities (the public) where requirements on quality reduce the incentive to use sludge.

From the description of stakeholders which has been described with their different roles and interests, this consultation has not received submissions from farmers customers, food processors, retailers, the general public, or the media. Food retailers and grain merchants have had particular influence on changes in practices in the UK. Special interest groups have been limited to organisations with professional interests in processing sewage and sludges.

5.12 Future Trends and Issues

Example respondents comments are:

- *Too general. More detailed and concrete analysis of other possibilities of sewage sludge disposal and the relating legislative tasks is necessary. For example, the fact that the capacity for digestion and incineration in the EU-15 is increasing significantly, encouraged by national financial incentives for producing green energy.*
- *C-sequestration might be an upcoming driver which is rather underestimated in the Summary Report 2. Besides the foreseen lack of P might be a more increasing driver than mentioned, but difficult to say when and how powerful.*
- *Provide concrete examples/justifications for potential restrictions on the type of crops being used for sludge landspreading.*
- *Provide information on how the forecast for the "other" routes has been established.*
- *German – expect increased demand especially with improved quality & QA.*
- *Increased fertiliser prices positive impact on sludge demand.*
- *P fertiliser + practicability of P recovery from dewatering.*
- *Carbon sequestration and P shortage.*
- *Increased AD, more recycling.*
- *Nitrates directive – co-composting with green waste.*
- *More co-digestion, reduced proportion of industrial input.*
- *Pyrolysis weak or delusional future prospect.*

Six respondents made specific reference to this section, and some others made general comments that link to this section. One respondent would have liked greater development of the summary items.

Respondents suggested that in addition to the content of the section, the following should be included or enhanced:

- *Increased demand for sludge as a P source, and as a fertiliser, in conjunction with improved quality and QA systems to assure quality; and extraction of P from sludge by a variety of methods to different purities for use in fertilisers; there were no comments about availability of P in sludges linked to works in which chemical removal of P from sewage is practised;*
- *Clarifying the nature of additional sequestration of carbon in sludge, so that use of sludge in recycling is a carbon sink; this could lead to further encouragement of digestion and recycling rather than incineration;*

- *Co-treatment of sludge with other wastes is likely to increase; but needs consistent treatment across all wastes.*

The comments demonstrate that respondents have a strong sense that sewage sludge, when treated and processed to appropriate quality standards, will continue to be used in a variety of beneficial procedures, including perception as carrier of a valuable fertiliser resource. For use in co-treatment the status of both sewage sludge and other waste materials may require either regulatory clarity, including consistency with biowaste derivations and permitted uses, or specific encouragement.

5.13 Monitoring, Record Keeping and Recording

Example of respondents comments are:

- *The frequency of sampling of sludge should be adjusted according to the size of the WWTW and according to the use of the sludge.*
- *The agronomical characteristics of the sludge and of the soils of the land spreading area have to be regularly monitored. This would allow the establishment of a land spreading rate adapted to crops' needs.*
- *Nutrient management planning is necessary to ensure that all types of fertilisers being spread on land are in accordance with crops' requirements.*
- *Regarding the information required to be made available it is necessary to integrate:*
    - *The spreading rate per land unit.*
    - *The supply of total and available fertilisers spread per land unit.*
- *Information given to the final user about the origin and the quality of the sludge and agronomical advice has to be defined in detail.*
- *Better definition of analytical methods.*
- *High quality sufficient management.*
- *Mandatory QA.*
- *Flexible QA.*
- *Lack of discussion of different sludge and soil analysis methods.*
- *Identify control and monitoring in sludge treatment.*
- *Make clear total and available fertiliser used.*
- *Strengthen reporting requirements in a revised Directive so that more recent information including annual data can be available to the Commission without having to rely on other external sources and estimated data.*

5.14 Other Comments

The following are further comments made by respondents that cover more than one of the areas described in previous sections:

- *There is a need to research the effects of pharmaceuticals, endocrine disrupters, brominated flame retardents and antibiotic-resistant bacteria at EU-level as well as by individual national or regional authorities.*
- *Disagree with the comment that the application of sewage sludge in agriculture and for other land uses would be enhanced if sewage sludge was recognized as a product and stressed that it is not justified to exclude sewage sludge from the regime of the waste law.*
- *The benefits of using sewage sludge as compost was highlighted by several respondents as providing more advantages. They claimed it can contribute to reduce greenhouse gases as well as providing fertilizer value, as it can act as carbon sink and reduce methane emissions from landfills when used as landfill cover. Composting also helps in reducing collection, transport and disposal costs. This is particularly the case in developing countries where landfill gas collection systems are too expensive or technically impractical to implement.*

- *A guarantee fund should be created and risks should be borne by the producer of the biosolids and not by the landowner. Those who supply biosolids (or other organic soil treatments) for use on land should indemnify landowners for an extended period (perhaps 20 years) against the possibility of adverse effects from the biosolids until the risk of such effects emerging could be considered nil.*
- *Where sewage sludge has undergone suitable treatment, there should be no barrier to it being awarded an eco-label and that the existing Decision should be reviewed.*
- *Using LCA as a tool to determine the best solution for sludge management as long as it is done according to a uniform manner all over Europe (method, parameters, etc.) taking account of the work of the JRC on these aspects.*
- *To ensure wider acceptance a high level of quality and control seems necessary. End-of-Waste criteria might be one of more possible solutions. Should recycling be promoted (in line with the new waste directive) high quality should be the key word and sufficient management systems for sludge not meeting the criteria should be in place.*
- *EC regulations for chemicals and water protection are not always adequately recognising sludge issues although it is more cost-efficient to make actions at the source of pollution. One example of this are restrictions on using detergents with phosphorus. How will the zeolite nanoparticles affect sludge use? In many cases the restriction to use chemicals is done in legislation. It is not up to the water utilities to decide what kind chemical substances can be used in household chemicals or what kind of emissions enter the sewage work through air emissions.*

6 Responses to Specific Questions

The full copy of the responses is available on the CIRCA website http://circa.europa.eu/Public/irc/env/rev_sewage/home. The summary of the comments and the main points are presented below under each question.

The majority of official respondents have not provided responses to the specific 28 questions but have concentrated their comments on updating information pertinent to their country. Comments were submitted from the regional Flemish and Walloon authorities of Belgium, France, Germany, Hungary and Slovenia. For some specific questions, some official authorities (Germany, UK) referred to the information submitted separately by their national industrial federations.

Q1 – What are the special reasons in your country that result in a reported sludge production rate of less than 23kg/pe/year or greater than 28 kg/pe/year?

The official sludge production per Member States are presented below:

Member State	***Sludge production rate***
Belgium – Flemish region	17 kg DS/**pe**/y
France	20 kg DS/**capita**/y [a)] 16.6 -18.7 kg DS/**capita**/y [b)] 31,6 kg/capita/y [c])
Hungary	25.8 kg DS/**pe**/year.
Slovenia	10 kgDS/**capita**/y – wastewater systems not completed; 60% of population connected to 223 WWTW; 40% to cesspools.

a) The production of sludge per capita connected to the collection systems and wastewater treatment waste for a census population in 2006 of 63,235,568 inhabitants

b) By adding the theoretical sludge production from individual treatment systems

c) By adding quantities of sludge generated by industrial plants not connected to a network public collection and processing waste water

The commercial stakeholder comments are presented below:

State	***Sludge production rate***
France	18-19 kg/pe/y - lower values possibly due to old data and incompletely reconstructed treatment works.
UK	23.7 kg DS/**capita**/y
UK	The range of 23 to 28 kg/pe/year is actually quite low, equating to 63 to 76 g/hd/d. Production rates may be less than 23 kg/pe/yr where an aerobic digestion is effectively achieved during secondary treatment such as a nitrifying oxidation ditch, or where poor levels of treatment are achieved and solids are discharged.
Portugal	Estimate at WWTW of 22 – 23 kg DS/capita/y

Q2 - What change in the rate of sludge production do you expect will take place up to 2020?

The official comments on sludge production per Member State are presented below:

Member State	***Future sludge production (2020 (tds/y))***
Belgium – Flemish region	Slight increase
Belgium-Walloon region	Increase up to above 50,000 tds
France	*Increase of 17% to 1.4Mt ds*
Germany	No change
Hungary	Agree with assumptions
Slovenia	Agree with assumptions

The commercial stakeholder comments are presented below:

State	***Future sludge production (2020 (tds/y))***
Finland	The rate of sludge production will very probably grow in the future.
France	The forecast for French production seems unrealistic, and should reviewed. The estimated amount of 1,600 kt DS/year in 2010 (Table 5, p; 17) is too high, and should be lowered to 1,300 kt DS/year; this will be equivalent to a rate of 20 kg DS/capita. But this amount of 1,600 kt DS/year may be kept for 2020 (21 kg DS/capita).
Germany	A constant sludge production rate or maybe a slight decrease.
UK	Shift from 25 to 28 kg DS/capita as more sites are required to meet phosphate consents and this may be compensated by increasing solids destruction rates in sludge treatment, especially as the trend to more effective biogas production continues.
Portugal	In 2015 expect 750,000 tds/a (> report prediction of 420,000 tds/a).

Q3 - Why would any change in the reported rates of sludge production per person take place?

The official comments per Member States are presented below:

Member State	***Comment***
Belgium – Flemish region	Nutrient removal
Belgium-Walloon region	Population increase and progressive compliance with UWWT Directive

The commercial stakeholder comments are presented below:

State	***Future sludge production (2020 (tds/y))***
Finland	Onsite Wastewater System Decree (542/2003) came into force on 1.1.2004. The Decree sets minimum standards for wastewater treatment in the area outside agglomerations. The treatment of wastewater in rural areas with no centralized sewerage system will be improved greatly over the coming years due to this decree. The requirements in the Decree apply immediately to all new buildings, while wastewater treatment systems of buildings completed before 1.1.2004 must in most cases be upgraded to fulfil the new standards by 1.1.2014. To fulfil requirements a lot of new sewers will be constructed increasing the amount of wastewater and

	sludge. The number of onsite systems will also increase with a resultant increase in sludge generation. It is estimated that 90 % of the sludge from onsite systems will be transported for treatment in wastewater treatment plants. This will result in an increased sludge production per capita.
France	The improvement of treatment capacities and sewage systems will increase the sludge production.
Germany	Structural changes will continue (slowly) in Germany: Production of goods will go back in support of service industries. Thus less wastewater and sludge may be produced. Modernization in industrial production processes will lead to techniques which produce less wastewater or which are effluent free. More operators of wastewater treatment plants aim to establish new techniques to reduce the amount of sludge e.g. sludge disintegration.
UK	Increase due to implementation of WFD, EQS Directive 2008/105/EC and Landfill Directive but if legislative and economic incentives are used to encourage an increased use of anaerobic digestion this could slow the rare of increase in sludge production.
Portugal	Accomplishment of UWWTD with provision of advanced treatment.

Q4 – What proportion of total sewage sludge reported here is due to industrial sources in your country? Is this expected to change, and to what proportion?

The majority of respondents did not have that information but some were able to estimate the share between domestic and industrial sources.

The official comments per Member States are presented below:

Member State	***Comments***
Belgium – Walloon region	100% domestic
Belgium – Flemish region	No information
France	Current estimates load from domestic origin: 50 million pe compared with current received charges of approximately 75 million pe = domestic origin 2/3 and 1/3 of industrial origin. This proportion is however variable in the space and the time depending on developments in life and economic activity.
Germany	About 20% of the sludge production is due to industrial sources (no formal data, repeat estimate from commercial respondent): Total sludge production (TSP) in Germany : 2, 06 Mio t /y (ds) Raw Sludge production per inhabitant is about 80g/pe*d (ds) After digestion (>90% is stabilised by anaerobic treatment): 55 g/pe*d (ds) 82.000.000 pe * 55 g/pe*d * 365 d/y = 1,65 Mio t /y (ds) N 80% of TSP => ; 20 % of TSP is due to industrial sources.
Slovenia	No information

The commercial stakeholders comments are presented below:

State	***Comments***
Finland	At the moment many industries are connected to the sewer system. There is no reason to assume any major change to the current situation.

France	Only a small part of industrial effluents (from very small and small industries as food industries), since industries get their own WWTP).
Germany	The following estimation signifies, that in Germany about 20% of the sludge production is due to industrial sources: • Total sludge production (TSP) in Germany : 2, 06 Mio t /y (ds) • Raw Sludge production per inhabitant is about 80g/pe*d (ds) • After digestion (>90% is stabilised by anaerobic treatment): 55 g/pe*d (ds) • 82.000.000 pe * 55 g/pe*d * 365 d/y = 1,65 Mio t /y (ds) N 80% of TSP; 20 % of TSP is due to industrial sources
UK	Proportion of industrial effluent is unlikely to change however the composition may change due to improved practices and increased pre-treatment.
UK	The industrial contribution to the wastewater system is understood, but how much gets through sludge treatment and how much secondary sludge is generated from treating industrial inputs is difficult/impossible to model.
Portugal	Expect decrease in industrial wastewater.

Q5 – What proportion of your country is likely to have sewage effluent consents for: Total Nitrogen - Phosphorus ?

Information provided by official respondents is summarised below per Member States:

Member State	***Proportion of nutrient removal***	
	Nitrogen	***Phosphorus***
Belgium – Walloon region	Data not submitted.	Data not submitted.
France	By the end 2011: 90 to 95 % of the capacity of wastewater treatment.	By the end of 2011: 70 % of the capacity of stations wastewater treatment.

Information provided by commercial respondents is summarised below:

State	***Proportion of nutrient removal***	
	Nitrogen	***Phosphorus***
Finland	About 63 % of waste water nitrogen load. [a)]	Phosphorus - all country 100%.

a) Total Nitrogen removal is required in wastewater treatment plants where PE is over 10,000 and effluent is discharged to nitrate vulnerable water areas. Nitrogen removal 63% (based on assumption of 72% reduction in nitrogen removal plants, 40% (average) removal in other plants and 90% (voluntary) removal in Viikinmäki WWTP. Phosphorus 0.35 mg/l, removal 96,5 %.

Q6 – What are the likely consent values?

- ***Total Nitrogen < 15 mg/l – for what population***
- ***Total N < 10 mg/l, P < 2 mg/l – for what population***
- ***Total N < 10 mg/l, P < 1 mg/l – for what population***
- ***Total N < 10 mg/l, P < 0.2 mg/l – for what population***

Information provided by official respondents is summarised below per Member State:

Member State	***Population proportion***			
	Total N<15 mg/l	***Total N< 10 mg/l/ P<2mg/l***	***Total N<10 mg/l, P<1mg/l***	***Total N<10 mg/l, P<0.2 mg/l***
France	90 to 95% of the treatment capacity more than 2000 pe.	70 to 80% capacity treatment over 2000 pe.	70 to 80% capacity treatment over 2000 pe.	No processing unit sewage service. Some French facilities reach these results averaged annual data.
Slovenia	Requirements linked to WWTW population size			
UK	EA is regulator – consultation period insufficient to collate data			

The commercial stakeholder comments are presented below:

<table>
<tr><th rowspan="2">State</th><th colspan="4">Population proportion</th></tr>
<tr><th>Total N<15 mg/l</th><th>Total N< 10 mg/l/ P<2mg/l</th><th>Total N<10 mg/l, P<1mg/l</th><th>Total N<10 mg/l, P<0.2 mg/l</th></tr>
<tr><td>Finland</td><td></td><td>Total N < 10 mg /l – 63 % connected population = 2,8 million people.</td><td>P < 1 mg/l – connected population 15 % = 675 000.</td><td>P < 0,3 mg/l – connected population 50 % = 2,3 million people
P < 0,5 mg/l – connected population 35 % = 1,6 million people.</td></tr>
<tr><td>Germany</td><td colspan="4">Consent values are given in Annex 1 of the Waste Water Ordinance (Abwasserverordnung). An abstract is given as follows:
<table>
<tr><th>Size range
[kg/d BOD]</th><th>Total Nitrogen, sum of Ammonia, Nitrate and Nitrite (N-total) [mg/L]</th><th>Total Phosphorous (P-total)
[mg/L]</th></tr>
<tr><td>< 600</td><td>-</td><td>-</td></tr>
<tr><td>600-6.000</td><td>18</td><td>2</td></tr>
<tr><td>> 6.000</td><td>13</td><td>1</td></tr>
</table>
BDE has no statistical data available on the respective proportions in Germany.
Your suggestions for demand targets on Nitrogen and Phosphorus that go below 10 mg N-total per litre and 0.2 mg P-total per litre are beyond the understanding of BDE, as these requirements seem to be rather too ambitious.</td></tr>
<tr><td>UK</td><td colspan="4">No comment</td></tr>
</table>

Q7 – What other combinations of consents may have significant impact on treatment processes?

Information provided by official respondents is summarised below per Member State:

Member State	***Comment***
UK	Requires information from EA

The commercial stakeholder comments are presented below:

State	***Comment***
UK	If regulators were to impose consents for endocrine active substances or other organic compounds they might increase or decrease sludge production; they would certainly increase the global warming potential of wastewater treatment. If consents are imposed for "heavy metals" to meet the WFD [literal] objective it would increase sludge production. Sidestream recovery of fertilisers (struvite and ammonium sulphate) from dewatering liquors seems to be fast becoming a practicable and commercial possibility that will have some impact on sludge production.
UK	Stringent BOD, suspended solids standards, ammonia standards will lead to increased sludge production. The tighter EQS Directive requirements will also lead to increased sludge production.

Q8 – How will these consents be achieved? Biological nitrogen removal Tertiary nitrogen removal using chemical addition (methanol) Biological nitrogen and phosphorus removal Chemical phosphorus removal Combination of chemical and biological removal Other likely common process combination

Information provided by official respondents is summarised below per Member State:

Member State	***Biological Nitrogen removal***	***Tertiary nitrogen removal***	***Biological nitrogen + phosphorus removal***	***Chemical phosphorus removal***	***Combination of chemical and biological removal***	***Others***
Belgium – Flemish region					√	
France	More than 90% of agglomerations ≥2000 pe	approximately 10 million pe	Exclusive biological phosphorus removal is marginal, usually coupled to chemical removal	widespread	30 million pe - typically implemented to achieve less than 2 mg/l because it minimizes sludge production and use of reagents	

Information provided by commercial respondents is summarised below:

State	*Biological Nitrogen removal*	*Tertiary nitrogen removal*	*Biological nitrogen + phopshorus removal*	*Chemical phosphorus removal*	*Combination of chemical and biological removal*	*Others*
Finland					√	
UK	All processes in use; other combinations may be required to meet the EQS Directive					

FI Practically all plants are using a combination of chemical and biological removal. Nearly all plants are using chemical phosphorus removal with ferrous chemicals. These will be used in the future as well to be able to achieve the consents for phosphorus removal. Only very few plants are using biological phosphorus removal.

Total Nitrogen removal is usually achieved trough biological nitrogen removal process. In Viikinmäki WWTP nitrogen is also removed in tertiary nitrogen removal using chemical addition (methanol). Population Equivalent of Viikinmäki is ca.1.000.000 people.

Q9 – In your country, what are the special conditions that encourage or discourage the amount of agricultural recycling?

Information provided by official respondents is summarised below per Member State:

Member State	*Encourage*	*Discourage*
Belgium – Walloon region	Political incentives. Confidence in sludge quality. Price of fertiliser.	Complexity of regulatory rules. Confidence in sludge quality. Price of fertiliser.
Belgium – Flemish region		The financial incentives for green power and heat make it financially more interesting to digest sludge (as pre-treatment) with a view to the production of biogas and then to dry and to incinerate as renewable energy.
France	Long experience of recycling sludge to agriculture. Availability of arable land. Interests of farmers for these materials. Strict regulatory framework, traceability of practices. Monitoring and expertise by qualified independent organization. Implementation of a risks guarantee fund to urban and industrial sludge application. Best economical and environment option. National support from some consumer and environmental organisations.	Negative public perception. Local lack of availability of suitable surface areas (i.e. vineyard, forestry, vulnerable zones, etc). Lack of confidence from farmers in some practices (sludge under status "product" exception to the rules). Restrictive requirements by food industry Variability of the sludge agronomical quality.
Germany	Increase in fertiliser prices	
Hungary		Ban in Natura 2000 areas. Nitrates directive requirements in vulnerable

		zones.
Slovenia	Future improvement in effluent and sludge quality; desirability of sludge fertiliser replacing cost of chemical fertilisers. Cost of exporting sludge to incineration. Ban on landfilling of sludge.	Current sludge quality with high metals content.

Information provided by commercial respondents is summarised below:

State	***Encourage***	***Discourage***
Austria	Regional differences in policy.	Regional differences in policy. Marketing programs of retailers, sugar industry, the Austrian Agrarmarketing Agency and organic farming are examples how to limit the use of sludge on land even under controlled conditions. Acceptance of sludge is low.
Finland		Environmental support includes limits and rules for phosphorus per hectare. Nitrates Directive is followed in the entire country and in some cases the nitrogen may be the limiting factor. Agricultural ministry decree 12/2007 allows maximum spreading amount of 1,5 g Cd/ha/a in agriculture as a 4 year portion which means 6 g Cd/ha/ spreading at one time. In some cases this is the limiting factor. The association of farmers is against sludge use in agriculture. In certain areas a lot of manure is available and thus there is no demand for sludge in the agriculture.
France	Stringent regulation framework accompanied by knowledge diffusion, transparency, chemical analysis and traceability of sludge recycling to land. Recent high prices of mineral fertilisers have been a very intensive driver for farmer's demand. Large land bank available.	"prohibition clause" in the terms and conditions from the Food industries, which, at regional level, may impact very negatively the agricultural recycling. Odour management is also important.
Germany	All requirements that guarantee a certain security on planning and disposal as well as enjoy the reliance of the user on NP-fertiliser products encourage the use of sewage sludge on land. Public confidence can be improved, for instance through mandatory quality assurances and quality management systems.	Requests by some pressure groups, which go beyond the legal demands, have a restrictive and thus discouraging effect on the use of sewage sludge on land. As an example, mill organisations or several potato producers in Germany generally object to the fertilisation with sewage sludge.

Germany	Policy Owners decisions (EC, Member State Governments and Regulators) that encourage or discourage agricultural recycling of sewage sludge will have the most influence on the amount of sewage sludge used as a fertiliser in future. In Germany the future amount of agricultural recycling of sludge will be decided by the legal regulations which are to be defined in future legislation, particularly with regard to the announced amendment of the German Sludge Ordinance as well as the fertilizer regulations.	Incineration appears to be a more reliable disposal route; co-incineration is economically priced even if transport of several hundred kilometres required.
Italy		Regional implementation (i.e. Emilia Romagna restricting utilisation in agriculture or the Veneto Regions which imposes severe criteria concerning WWTP sludges in compost production on a “precautionary principle”).
Italy	Regional differences. Landfill Directive.	Regional differences. Nitrates Directive – supporting availability of land for livestock wastes.
UK	Stakeholder agreements of 1998	Odour - ‘not causing odour nuisance’ should be a legal requirement. Another weakness is that the ‘Safe Sludge Matrix’ has not been incorporated into the Sludge Regulations. A third weakness is that treatment and recycling of other organic residuals are regulated under different legislation and this inhibits co-treatment, which would otherwise be a good solution.
UK	Clear leadership from UK government as being the BPEO. Safe sludge matrix and involvement of key stakeholders in process of establishing the Matrix plus continuous engagement with them.	Perceived risks from supply chain particularly the grain sector.
UK	Availability of land for land spreading, suitable treatment capacity available and overall cost per tonne recycled.	Availability of land for land spreading, suitable treatment capacity available and overall cost per tonne recycled.
Norway	Lack of manure creates a demand for sludge for soils with little organic matter.	
Portugal	Unavailability of landfill. Anticipate improved processing controls and QA will improve public acceptability.	Sludge quality, lack of land bank near production sites, availability of organic materials with greater public acceptability, eco-label and restrictions on sludge recycling.

Q10 – What change do you expect to take place in the rate of agricultural recycling by 2020?

Information provided by official respondents is summarised below per Member State:

Member State	Increase	Decrease	Status quo	Other
Belgium – Walloon region	+ - reversing current trend			
France	Up to 75-80%			
Germany				Increased extraction of nutrients from sludge to apply with reduced contaminants
Hungary	+ (increase arisings and better quality)	- due to digestion and composting		
UK	Agree predicted effects and trends			

Information provided by commercial respondents is summarised below:

State	Comment
Austria	No change
Finland	It is very difficult to predict the future in agricultural use. The association of farmers is against sludge use in agriculture. At the moment only 3% of sludge is used in agriculture, but few years ago use was 10 - 17%.
France	Increase of sludge landspreading due to decrease of landfill disposal for which additional taxes are going to apply. Total amount of sludge recycled to land, and so the agricultural surfaces concerned, will increase but the proportion for agricultural recycling, will decrease to around 50%.
Germany	Following adoption of revised and more stringent German Sludge Ordinance, the amount of sludge marketed for agricultural uses will most probably decrease to 20% or less.
Italy	Stable situation regarding the agricultural landspreading.
Italy	Increasing difficulty in agricultural recycling.
UK	It will remain the same in ds terms but increase in tonnage terms as drying is phased out.
UK	With increased anaerobic digestion of bio-waste, and incentives on renewable energy and heat recovery, we would anticipate agricultural recycling to increase.
UK	The current 71% to agriculture will stabilise or reduce as utilities attempt to reduce exposure to the agricultural route.
Portugal	Medium term sustainability of agricultural recycling is small with competition from other organic wastes, reduced agriculture, and increased incineration capacity.
Norway	No change, increased QA and controls on pollution prevention.

Q11 – How will the existing regulations noted above affect your recycling and other disposal routes?

Information provided by official respondents is summarised below per Member State:

Member State	**Landfill Directive**	**Incineration Directive**	**IPPC**	**Waste Directive**	**Renewable energy**
Belgium – Walloon region	+				
France	Positive: reorientation of flows to agricultural recovery and incineration.			Negative: due to loss of traceability to the plot related to the output of the status of waste.	Neutral: Increase in the quantities of sludge processed by digestion (estimate) (delicate).
Belgium – Flemish region	Flemish legislation prohibits use of sludge in agricultural applications, from 2006.				
Germany	The EC and national regulations on sewage sludge will have a bigger impact than any of the mentioned directives.				

Information provided by commercial respondents is summarised below:

State	
Finland	European legislation does not have much influence in Finland since sludge use is mainly limited by national legislation and rules.
France	Landfill directive will not have a negative impact on sludge landspreading. The incineration directive will not have a positive impact as its implementation will globally increase the costs of the different sludge outlets. Composted sludge shall be integrated in the thinking about the end of waste criterion establishment for compost as it is currently considered as a product in France.
France	End-of-waste (EoW) status for compost is a key point for France, where, about 15% of the recycled sludges to land are composted. The existing EoW status (mandatory standard NFU44-095) for composted sludges has clearly been a driver for the development of composting ; in parallel, because composted sludges are without odours when spreading, because demand for soil improvers is increasing, and because storage is easy, composting has taken a key role in France. The IPPC regulations may affect not the development for composting or anaerobic digestion, because more stringent conditions have been set up for France in the past. But this could change the evolution of process for the new plants, according the future definition content for the “waste treatment BREF”.
Germany	The existing European regulations will have no additional impact in Germany, as the requirements imposed by European law are already completely met. No correlation with IPPC, as sewage sludge is not subject to the Directive.
Italy	Large increase in the cost of the different ways of sludge disposal (3-5 more in the last 5 years).
UK	RED and WFD will have a beneficial impact The Industrial Emissions Directive (old IPPC) will lead to unnecessary increased

	treatment cost and have a detrimental effect on recycling.
UK	There will be very little impact other than if lower PTE levels for soils are adopted.
Norway	No significant demand for eco-labelled sludge.
Portugal	Difficult within 86/278/EC to recycle sewage sludge to agriculture.

Q12 – Will the Nitrate Directive and the WFD have a significant effect on restricting or reducing the availability of land for agricultural recycling of sewage sludge? How much of an effect?

Information provided by official respondents is summarised below per Member State:

Member State	**Nitrate Directive**	**WF Directive**
Belgium – Walloon region	Difficult to evaluate but a slight decrease may occur at local level with maybe some increase in transportation costs.	
France	No as only approximately 3% of the available area is necessary for the application of sewage sludge. Some reductions locally, in vulnerable areas.	
Germany	Sewage sludge in Germany has to meet all the regulations laid down for fertilizers in general – so there will be no special effect of the nitrate directive for sewage sludge.	The discussions about the effects of the WFD are in Germany still in progress.
Hungary	Some impact on the rate of application of sludge per hectar.	Rules on the surface-, and groundwater protection contain territorial limits for the use of sludge.
Slovenia	Could have a significant effect on restricting and reducing the availability of land for agricultural recycling of sewage sludge. Also compete with manure and compost utilisation.	Could have a significant impact and reduce/restrict land availability for sludge recycling.

Information provided by commercial respondents is summarised below:

State	**Nitrate Directive**	**WF Directive**
Finland	In place so no further effect.	Current use of sludge in agriculture is very little and thus WFD is not going to affect it.
France	Has already impacted the sludge landspreading outlet mainly by the reduction of spreading rates and spreading periods. We do not expect additional impacts.	For the WFD see our remark above.
France	No real impact.	No real impact.
Germany	Has had the effect of reducing the available landbank but this reduction did not lead to serious reduction of the rate of sludge recycling to land.	Could lead to reduced localised sewage sludge application rates due to high soil phosphorus from artificial fertilisers. We do not expect this reduction to be widespread.

Germany	No additional changes for the agricultural recycling of sewage sludge.	No additional changes for the agricultural recycling of sewage sludge.
Italy	Reduction in availability of land in Northern Italy for a precise political decision to support and to facilitate the use of animal effluents although the landspreading represents < 5% of the available lands.	The application of the WFD will increase the production of sewage sludge in Italy.
Italy	Will be a negative effect on agricultural recycling. The indicated trends in local legislation are a clear signal.	Will be a negative effect on agricultural recycling. The indicated trends in local legislation are a clear signal.
UK	UK already operates within the Nitrate Directive restrictions and thus it will have no further impact. There is a real danger that the misinterpretation of Nitrogen application levels (Total versus Available) limits application rates to nonbeneficial levels when the negatives of soil compaction and low levels of Phosphate addition are taken into account.	
UK	Has significantly affected the availability of agricultural for sludge application.	Has to a degree affected the availability of agricultural for sludge application. The impact in relation to P requirements remains uncertain. This could lead to localised lowered sludge application rates due to high soil phosphorus content.
UK	May drive technology down the route of composting sewage sludge with green waste to produce a compost with low nitrogen availability. Will influence the return frequency to a particular piece of land and also the application rate, but it will not prevent sludge use.	Will influence the return frequency to a particular piece of land and also the application rate, but it will not prevent sludge use. The WFD is in a number of instances in conflict with the overall concept of sustainability by driving wastewater treatment solutions to ever more energy-consuming technologies.
Portugal	Reduce use as the ND only applies to organic fertilizers like sludge.	
Norway		More balanced use of fertilizers required linked to crop; further research on management practices to avoid excess P & N.

Q13 – In your country what are the most significant local restrictions on sewage sludge quality that affect the availability of land for sewage sludge recycling?

Information provided by official respondents is summarised below per Member State:

Member State	***Local restriction***
Belgium – Walloon region	PAHs and restrictions on sludge originating from STW that have treated leachates from landfills.
Belgium – Flemish region	Limit values on heavy metals, PAHs and other organic substances.
France	Metal content.
Slovenia	Heavy metal content in sludge.
Hungary	Extended metals list, plus limit values on PAH, PCB, TPH.

Information provided by commercial respondents is summarised below:

State	***Local restriction***
Austria	As stringent regulations have already significantly help in improving quality of sludge more stringent regulations would not affect the availability of land so much. Only copper could cause problems because of increasing contents.
Finland	Quality is not a limiting factor.
France	Spreading rates are mainly determined by the agronomical value of the sludge and are in very limited situations driven by PTE flows over 10 years. Soil heavy metal concentrations due to background level can affect the availability of land and lead to the establishment of a derogation file submitted to the local authorities as specified within the French regulation.
France	Some possible restrictions imposed by food industries or food retailers. Either on pollutants (for crops) or pathogens (for meat or cheese production) especially on grazing lands.
Germany	The revised version of sludge ordinance will most probably distinguish between three different types of soil: clay, loam/silt, and sand. That distinction will limit the use of sewage sludge in the near future. The main limiting factors in Germany include lead and cadmium.
Italy	Soil heavy metal concentrations due to background level can affect the availability of land and other general restrictions issued by national and regional authorities (such as distance from houses or from rivers and lakes or public wells). Strict regional limits on As reduce the use of some sludges.
UK	Nitrate Vulnerable Zones, Phosphorus Indices and Odour are the most significant local restrictions affecting availability of land for recycling in the UK.
UK	Rate of application is governed by N content determined by NVZ controls and crops requirements. Increased regulatory pressures from waste legislation on sludge application Specific restrictions from grain merchants.
UK	Sludges that have raised PTE levels (very rare nowadays) and soils with naturally occurring high PTE levels (e.g. Mendip Hills).
Norway	Soil phosphorus limits.
Portugal	Requirements for sludge pasteurisation, industrial effluents contamination of sludge, high odour.

Q14 – What changes to local statutory or practice requirements do you expect up to 2020 (in terms of limits on quality, etc.)?

Information provided by official respondents is summarised below by Member State:

Member State	*Change*
Belgium – Walloon region	Maybe introduction of P index for soils. Improvement of sludge quality due to better waste prevention and selective collection. Improvement in industrial discharge – increase sludge confidence. New rules in water protection zones.
Belgium – Flemish region	New limit values.
France	Increased control, tracking and information on sources, processing and disposal of sludge and materials used in forming the sludges.
Hungary	No comments.
Slovenia	No change.

Information provided by commercial respondents is summarised below:

State	*Change*
Austria	There are a lot of statutory and practice requirements and changes will be only marginal.
Finland	Legislation for fertilizer products, also for composts, soil improvers, growth medium or other type of materials made from sludge, was renewed in 2006. Any new changes are not expected locally.
France	None
Germany	The Sewage Sludge Regulation is currently under revision; the Fertiliser Regulation has been revised in 2008 and includes limiting values and restrictions for sewage sludge. If these requirements remain existent, we will face in Germany a shift towards thermal treatment of sewage sludge - simply for reasons of secured planning.
Italy	We expect new limits on organics pollutants by regional authorities.
UK	Implementation of WFD. Increase competition from industrial biowastes, composts and digestates following diversion of biodegradable waste from landfill. End of waste status could increase the range of opportunities and market outlets.
UK	By 2020 there might at last be quality assurance and independent audit, which were two of the promises in the 1998 stakeholder agreements.
Norway	Quality limits already strict, with already low organic micropollutant concentrations, so no major change expected.
Portugal	National limits on quality will become more stringent, including organic compounds and dioxin limits, and sludge pasteurisation requirements.
EU	Pathogen free sludge, use of recovered contaminant free P.

Q15 – To what extent do the current requirements in the EU sludge directive affect the availability of land for sludge recycling? To what extent are the requirements believed to be unsuited to current farming and public needs?

Information provided by official respondents is summarised below per Member State:

Member State	***Impact***
Belgium – Walloon region	Limited as regional regulations is more stringent than 86 Directive. Intermediate storage and quantity of N allowed to be applied are the real constraints.
Belgium – Flemish region	Existing limit values are not stringent enough to meet food standards.
France	Soil quality limits on nickel and soil pH in particular areas, but these are regarded as suited to current needs.
Hungary	Limited as additional restrictions are imposed under the national regulation, and current directive limits are the minimum required.
Slovenia	No change.

Information provided by commercial respondents is summarised below:

State	***Impact***
Austria	No impact as more stringent regulation in Austria than the current EU sludge directive. A new EU sludge directive should give more stringent requirements but also a need for enabling the use of sludge on land.
Finland	No impact on the availability of land for sludge recycling as sludge is recycled as compost used in landscaping or as soil improver outside the scope of the Directive. Revision of the EU legislation should include sludge compost and use in landscaping use.
France	Not enough requirements on the sludge quality control and on the traceability and monitoring of the sludge landspreading operations.
France	The current sludge directive does not reduce the availability of land in France.
Germany	No impact as stricter requirements under German regulations. A quality assurance is urgently needed as part of revision of the Sludge Directive.
Germany	No effect. However, previous pronouncements about imminent revision has created doubts in the supply chain if the current Directive is fit for purpose. This we believe may have led to some local erosion of confidence and the landbank. We believe that the current Directive is sufficient to prevent pollution/contamination from occurring when treated sludge is recycled to agricultural land thus preventing any long term damage.
Italy	Further reduction has been expected in 2009 as new rules will be applied on regional basis.
UK	No problem with land availability under current sludge Directive. However, potential revision has led to some uncertainty among stakeholder – need public statement from EC that the current Directive is fit for purpose.
UK	The only significant improvements needed in the sludge directive are a) to oblige ‘no odour nuisance’ when sewage sludge is stockpiled or applied to land and b) to revise the pathogen reduction requirements similar to the ‘Safe Sludge Matrix’ and require treatment to be based on HACCP. It would be foolish to introduce requirements to monitor organic substances of

	concern because surveys and risk assessments have shown that they do not pose risk to humans, crops, animals or the environment. It would be a waste of money to analyse for these substances routinely. However, occasional surveys and risk assessments of the results should continue.
UK	The omission of pathogen controls and cropping restrictions (as laid out in the UK Safe Sludge Matrix) does not allow full public confidence in agricultural sludge use.
Norway	Norwegian requirements are more stringent than the Directive requirements.
Portugal	The Directive allows different national interpretations on contaminant levels. There should not be national differences.

Q16 – In your country what changes to the concentrations of metals in sludges do you expect up to 2020?

Information provided by official respondents is summarised below per Member State:

Member State	*Comment*
Belgium – Walloon region	Slight decrease
Belgium – Flemish region	Slight decrease
France	Better control following implementation of WFD
Germany	Slight decrease

Information provided by commercial respondents is summarised below:

State	*Comment*
Finland	Major changes are not likely but some improvement and lower concentrations can be achieved locally.
France	Slight decrease, but it is likely we are reaching the background concentrations in sludges.
France	Slight decrease.
Germany	Any further reductions on current levels of metals are unlikely to be significant.
Germany	Some further potential to decrease for some metals. Nevertheless, due to diffuse and non-point sources, copper and zinc may increase, as they are still used as construction materials or in gardens.
UK	Continued decrease at a slower rate than the past 10-15 years. A more pro-active approach to small / medium industrial sites would reduce concentrations further.
UK	Improvement is possible but it will not happen unless there is encouragement, for example by publishing the sludge analysis data (anonomysed) so that companies (and stakeholders) can see how they perform.
UK	There is no scientific or agricultural evidence to suggest the lowering of any PTE soil levels but there seems to be an intention to do this.
Norway	Minor decreases as concentrations already very low.

Q17 – What changes to concentrations of the nutrients nitrogen and phosphorus do you expect up to 2020? Will changes to sewage effluent phosphorus concentration requirements affect the balance of nutrients in sewage sludge?

Information provided by official respondents is summarised below per Member State:

Member State	***Information***
Belgium – Walloon region	N content stabilised since 2005. However due to some treatment (i.e. liming) N content could decrease (due to dilution). Same for P as effluent quality improves but some treatment could have the opposite effect.
Belgium – Flemish region	Removal of nutrients (N and P) is mandatory in the Flemish region for wastewaters of agglomerations > 10.000 population equivalent (Flanders is 100% vulnerable area). Since 2006, all sewage stations in Flanders are equipped for nutrient removal.
France	No clear trends – Prohibition of use of phosphates in detergents should offset, in terms of national balance, the increase in requirements of treatment of phosphorus.
Slovenia	With improved waste water treatment system the concentrations of the nutrients nitrogen and phosphorus should continuously decrease (in sewage).

Information provided by commercial respondents is summarised below:

State	***Information***
Finland	New nitrogen removal wastewater treatment plants will be built. Phosphorus removal requirements will be more strict in the future for wastewater treatment plants. However, any major changes in sludge nutrient concentrations are not expected.
France	Higher concentrations of phosphorus are expected.
Germany	We do not expect major changes in nitrogen and phosphorus concentrations.
Germany	Since 1995, the concentration of Nitrate (N-total) in municipal sewage sludge increased from 34 to 44 mg per kg of sewage sludge dry substance. Regarding Phosphorus, the increase happened to be from 21 to 24.5 mg. It is assumed that the concentrations will also increase in the future. As Phosphorus is a highly valuable and finite resource, a future use of the resource through sewage sludge recycling is reasonable.
UK	Increase P removal will see increased P in sludge from those sites and this is likely at some locations to reduce the rate of application. An increased N removal is unlikely to lead to any significant increase in N content in sludge.
UK	As anaerobic digestion increases, the availability of nitrogen (N) will increase. Assuming that digested sludges will generally be dewatered, nitrogen as ammonia shall require either side-stream or main-stream treatment. Depending on the liquid effluent discharge standard, nitrogen will be released into the atmosphere as di-nitrogen via denitrification. Where chemical P removal is used, volumes of iron and phosphate-rich sludges will increase. Where advanced sludge treatment is used at P removal sites, iron dosing will have to be replaced to remove the risk of vivianite formation. Chemical P removal will have to be replaced with biological P removal, and forced struvite harvesting will have to be used to prevent recycling of phosphate rich liquors. In other words, N will be lost to the atmosphere. P will be bound as struvite in sludge, or harvested as struvite as stand-alone slow release fertiliser. Of course if drinking water were not dosed with P, if laundry and dishwasher detergents did not contain P and if P were recovered [as struvite] from dewatering liquor, the P concentration in sewage sludge would decrease.

Norway	No major changes.

Q18 – What are the proportions of your sludges that are treated with the following main processes: Anaerobic digestion (AD) / Advanced anaerobic digestion / Drying / Lime treatment

Information provided by official respondents is summarised below per Member State:

Member State	***Anaerobic digestion***	***Advance anaerobic digestion***	***Drying***	***Lime treatment***
Belgium – Walloon region	ND	ND	ND	ND
Belgium – Flemish region	49% anaerobic digestion (pre-treatment)		88% drying for incineration	
Slovenia	Agree with report estimations. Main process currently is drying.			
Germany	Refer to DWA paper on proportions of sludge treatment processes.			

Information provided by commercial respondents is summarised below:

State	***Anaerobic digestion***	***Advanced anaerobic digestion***	***Drying***	***Lime treatment***
France	60 to 70 plants (sources vary) and produce 345 GWh.th + 45 GWh.e	Not widespread	No data.	In 1997, the amount of sludge mixed with lime was estimated at 250,000 t DS, i.e. 30% of the French production (ADEME, 2001). No up-dated data is available, but on a sample of 600 WWTPs, a ratio of 15-20% is reported.
Norway	20%	20%	4%	42%
Germany	Detailed statistic data is given in: • Statistisches Bundesamt – Fachserie 19 Reihe 2.1 "Umwelt – Öffentliche Wasservesorgung und Abasserbeseitigung - 2004 " See Annex 1. DWA-Themen: „Stand der Klärschlammbehandlung und –entsorgung in Deutschland- Ergebnisse der DWA-Klärschlammerhebung 2003", see Annex 4.			
UK	Where possible anaerobic digestion (AD) should be used as almost the default sludge treatment process. Most, but not all AD sites will benefit from Advanced AD. Where there are existing spare assets, or there are low levels of primary sludge, Advanced AD appropriate. The overall may not be sustainability of Advanced AD over AD needs to be assessed on a site-by-site basis. Co-digestion would be very desirable if the [unnecessary] barriers to co-treatment were removed. Drying can be used to give a robust disposal route where an advanced treated sludge is required (under the sewage Sludge Matrix). Otherwise the sustainability of drying is questionable and it is likely to decrease because of the cost of energy and better dewatering of advanced AD sludge. Liming will decrease because of the cost of lime and the odour involved. Exceptions may be small rural sites, or emergency liming only.			

Q19 – What are the proportions of sludge converted or disposed of using: Incineration / Landfill / Other thermal processes (gasification, pyrolysis, wet oxidation)

Information provided by official respondents is summarised below per Member State:

Member State	*Incineration*		*Landfill*		*Other thermal processes*	
	Current	**Future**	**Current**	**Future**	**Current**	**future**
Belgium – Flemish region	88%	No increase	12% as landfill cover			Other techniques will be used such as wet oxidation. The use of sludge in agriculture will decline even further.
Germany	50		0			
Hungary			24	5.5	10	35.2(a)
Slovenia	25		50			
a) including incineration, biogas and renewable energy.						

Information provided by commercial respondents is summarised below:

State	*Incineration*		*Landfill*		*Other processes*	
	Current	**Future**	**Current**	**Future**	**Current**	**future**
Finland	Small amount	May increase			7% ***	
Sweden					3.5% ***	
France	18		12		nd	
Germany	49.4*		0.2		**	
UK	17		1		0	
Portugal	0	50			0	0
Norway	0		<1		0	

* thermally treated

** Gasification, pyrolysis and wet oxidation are no common techniques in Germany for sludge treatment.

*** Kemicond process – not thermal

Q20 – What are the likely impacts of the Nitrates Directives on the current sludge recycling proportion in your country? By how much?

Information provided by official respondents is summarised below per Member State:

Member State	*Impact of Nitrates Directive*
Belgium – Walloon region	Medium impact only in some areas.

Belgium – Flemish region	Large impact as the whole of Flanders has been designated as a vulnerable area – no application of sewage sludge in agriculture.
France	Marginal impact.
Hungary	The Nitrate Directive in itself does not limit the size of the agricultural lands suitable for sludge use, however other rules on the surface-, and groundwater protection contain territorial limits for the use of sludge. The Nitrate Directive has impact on the quantity of spreadable sludge. In Hungary the 170 kg nitrogen ha/year restriction is also applied for sludge.
Slovenia	The Nitrates Directive could be a significant restricting factor for the application of sewage sludge to land locally, in regions where nitrates vulnerable zones have been identified and intensive animal production zones, due to the fact that Slovenia has an intensive animal production.
UK	Detailed study required for definitive answer.

Information provided by commercial respondents is summarised below:

State	***Impact of Nitrates Directive***
Austria	No effect by ND because sludge and sludge compost are not considered a manure. Time and N limits exist since ~ 20 years by the national water regulation.
Finland	No impact.
France	No impact.
France	Very limited impact except potentially a slight increase of the spreading areas.
Germany	The Fertiliser Ordinance limiting rate for the use of sewage sludge is 40 kg NH_4-N or respectively 80 kg N-total in autumn, when the sewage sludge includes reasonable amounts of Nitrogen; there is a retention period for application in the winter.
UK	Unlikely to have an overall impact on the proportion and quantities of sludge recycled to land observed in the past 5 years. The main impact will lead to increase the distances travelled to application sites.
UK	The Nitrates Directive will drive the industry to produce thicker, drier sludges to minimize storage capacity outside of the closed period in nitrate vulnerable zones.
UK	No impact.
Norway	Little impact.

Q 21 – What local codes of practice or other restrictions related to land use have the greatest impact on sludge recycling to agricultural land in your country?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Ban on sludge recycling on land growing vegetables.
Belgium – Flemish region	The administrative provisions in the Flemish waste legislation.
France	The obligation for sludge producers to plan applications and monitor the agronomic factors has the most impact on the sludge route. This is positive since this has

	improved confidence in sludge application.
Hungary	Range of statutory restrictions on use locations and crop restrictions including measures designed to avoid groundwater contamination or nutrient or toxic element enrichment.
Slovenia	The legal restrictions and public acceptance.

Information provided by commercial respondents is summarised below:

State	
Austria	Different regulations in federal countries, production contracts by food industry, retailers and Austrian Agrarmarketing Agency, organic farming.
Finland	Environmental support includes limits and rules for phosphorus per hectare for all fertilizers and also for sludge. According to the rules of environmental support 40 % of phosphorus in sludge is considered to be available to the plants and allowed amount of sludge to be applied to the fields is calculated accordingly. Typically amount of phosphorus is the limiting factor in agricultural use of sludge. Also nitrogen directive is followed in the entire country and in some cases the nitrogen may be the limiting factor. The decree issued by the Ministry of Agriculture 12/2007 allows maximum spreading amount of 1,5 g Cd/ha/a in agriculture as a 4 year portion which means 6 g Cd/ha/spreading at one time. In some cases this is the limiting factor.
France	Soil threshold value in heavy metals. Specifications of production contracts set out by food industries or retailers.
France	Additional restrictions from food industry on contaminants or/and pathogens.
Germany	Further restrictions imposed by e.g. marketers (i.e. potato producers) and land owners (i.e. the church) affect the use of sewage sludge on land. As already stated in the report, further restrictions exist for organic farming.
Italy	Sludge limits regarding As and other organic contaminants like MBAS and NPE.
UK	Safe sludge Matrix, Code of Good Agricultural Practice (2009), Code of Practice for Agricultural Use of sewage sludge (1996); The Application of HACCP procedures in the Water Industry: Biosolids treatment and use on agricultural land (Water UK 2004).
Portugal	Decree 118/2006 revised the transposition of the Directive into Portuguese law.
Norway	Measures to restrict soil erosion and loss reduce land available as sludge must be ploughed in after spreading.

Q22 – What changes in land use are likely to affect sewage sludge recycling?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Same rules apply to recycling of sludge to agricultural and non agricultural land so no impact.
Belgium – Flemish region	The prohibitions to use sewage sludge for market vegetable, beet crop, etc.
France	An increase of agricultural land used for organic farming is expected, to reach 6 % by 2012. Sewage sludge cannot be used on this land. The impact is limited as the area required sewage sludge recycling in France is only about 3 % of the available

	agricultural area.
Hungary	Increase in forestation could reduce the agricultural areas suitable for sludge application. Organic farming may increase in smaller extent which can lead to narrowing of agricultural areas can be used for sludge application.
Slovenia	There are no changes in land use expected which are likely to affect sewage sludge recycling.

Information provided by commercial respondents is summarised below:

State	
Austria	Areas with high percentage of organic farming cause higher requirements on sludge treatment and extended transport distances.
Finland	Considerable amount of sludge is used as a landfill cover nowadays. In the future many landfills will be closed and new incineration plants will be built for municipal waste. In the future there will be no demand for sludge as a landfill cover.
France	Limited effect with the development of organic farming (up to 20% of agricultural land by 2020) as only 4%-5% of available land is used for sewage sludge and industrial wastes.
Germany	In the fruit and market gardening, on permanent grassland and in the forest, the application of sewage sludge is in Germany generally forbidden. With a different share in the cultivated land, namely more forest rather than arable land, the use of sewage sludge can theoretically be influenced, although changes are rather unlikely to happen. Organic fertilisers can be applied to the 2 million hectares of land used for energy crops in Germany.
Germany	We expect that changes in land use, e.g. increased cultivation of energy crops or more organic farming will only have minor effects on the rate of sewage sludge compared to the effects of future legislation.
UK	No changes foreseen that might influence agricultural recycling.
UK	The unlikely increase in organic farming area.
Portugal	Any change in land use will dramatically influent the rate of agricultural recycling.

Q23 – Will the lack of eco-label qualities (including organic farming) affect the use of sewage sludge in your country? By how much? Would other standards improve desirability?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	No effect as there are already certication in place.
Belgium – Flemish region	No effect.
France	The current level of recycling sludge in agriculture in France indicates that the presence or absence of ecolabel does not significantly affect use.
Germany	The effect of an ecolabel is expected to be limited. Rather promote quality assurance labels and quality assurance institutions.
Hungary	Products made of sewage sludge can only be marketed with permission in

	Hungary. By improvement of the quality of sludge it is easier to fulfil the requirements of product parameters.
Slovenia	The high quality standard of sewage sludge as the product is the only aspect which can improve interest and public acceptance.

Information provided by commercial respondents is summarised below:

State	
Finland	This is not an important issue in Finland.
France	The lack of eco-labels (on product containing sludge) does not impact reduce sludge recycling in agriculture. The main standard for improving desirability is the EoW (End of Waste) status for composted sludge.
Germany	As the eco-label excludes sewage sludge, no cause for concern. Quality assurance systems for sewage sludge have been developed and have led to a increased user confidence in the quality of the organic fertiliser; once established in the market they will have a positive impact on the use of sewage sludge.
UK	Current eco-labelling schemes or controls on organic farming have no impact on agricultural recycling in the UK. There are proposals to develop a BSI/ISO accredited standards for sludge and this would have a positive influence.
Portugal	Improving sludge quality standards will increase agricultural use.
Norway	Organic farming rules that prevent use of sewage sludge are opposite to a sustainable system.

Q24 – Are further restrictions needed on types of crops and or specific land areas (i.e. forest) or longer harvesting intervals?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	No additional restrictions are required as local regulations more stringent than the Directive.
Belgium – Flemish region	Yes. In Flanders there is no real quality assurance system in this regard.
France	Sludge recycling in forestry is currently under review. The use of sludge in land reclamation projects or recovery of soil is also envisaged. National restrictions in place for application before and during growth of food crops, with reduced restrictions if the sludge is pasteurised.
Hungary	Ban on sludge application in forests in Hungary. Set longer waiting periods as specified in Hungarian legislation (i.e. use of sewage sludge is prohibited in the year of growing and the previous year on the ground intended for the cultivation of vegetable crops and fruit which are in direct contact with soil. The Directive set a period of 10 months preceding the harvest of the crops and during the harvest itself. We find reasonable to maintain our national legislation taking into consideration the food-safety implications.
UK	Member States have produced their own further restrictions and are expected to continue to do so. It is better to share knowledge and experience.

Information provided by commercial respondents is summarised below:

State	
Austria	Crop production has to be based on fertilization plans and nutrient balances. Restrictions by special conditions (sandy soils, steep slopes, close to open water, etc.) have to affect every fertilizer.
Finland	One interesting option in the future would be using sludge in the forest fertilization. This is studied at the moment. Forests cover more than 70 per cent of the land area of Finland. A total of 20.3 million hectares is available for wood production. In Finland hygienization is required and other quality parameters are already in place for fertilizers and soil improvers also when used in forests. Thus there is no need for further restrictions.
France	No, the current requirements at EU level are quite good. Flexibility should be left to Members States to set up more stringent conditions, based on farming practices (grazing, etc), climate conditions, types of soils, local crops, etc.
France	No unless if there is a well demonstrated threat for human being or animals health.
Germany	The regulations in Germany are already quite strict and to some extent excessive. A loosening of these regulations would be desirable, especially with regard to an established quality assurance system (control of discharger and sewage sludge treatment, product analysis and application control) that would enable - under the respective local conditions - an opening for some restrictive areas**.**
Germany	The German sludge Ordinance already specifies several restrictions on types of crops and specific land areas in § 4 "Application bans and restrictions" (see Annex 5). We believe those restrictions should be revised employing scientific risk assessment methods and restrictions should be lifted or at least modified for sludge that has undergone advanced treatment to reduce pathogens.
UK	This is an area where the Directive could be strengthened and developed. Appropriate land use restrictions should consider the extent of sludge treatment and the microbiological status of treated sludge (in a similar way to how the current Directive differentiates between treated and raw sludge). Sludge treated to an enhanced standard to remove pathogens could be used without restriction, whereas that treated to a conventional standard would keep to the 10 month waiting period currently stipulated for all treated sludges (irrespective of the extent of sludge treatment). There is a need for better definition and explanation of the uses and types of crops that are suitable for the application of different sludge types and this should incorporate an expansion of the end uses of sludge to include land restoration and forestry. The UK Safe Sludge Matrix could provide a suitable framework for adapting the harvesting intervals; the adaptation would need to consider the range of conditions across the EU.
UK	There is no evidence that further restrictions are required.
UK	No
Norway	Any restrictions should be based on sound science and risk assessments.

Q25 - Should formal risk management methods be consistent throughout the EU?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Not necessarily; subsidiarity should prevail.
Belgium – Flemish region	A quality assurance system (and corresponding appropriate environmental standards for input sludge) should be made mandatory before allowing the use of sewage sludge in agriculture.
France	Maybe relevant. A uniform system could include the 3 level: -Level 1: controls on the introduction of pathogens or hazardous substances in sewer networks. -Level 2: monitoring wastewater treatment plants and regular analyses of the specified substances in sludge. -Level 3: traceable activities from production of sludge till recycling to agriculture development, with strict technical guidance for application.
UK	Risk management methods need to be tailored to individual Member States. It is difficult to see how a fully harmonised approach could be designed or appropriate. Exchange of information with a view to dissemination and sharing of best practice in this respect is likely to be most helpful.
Hungary	Considering the different agro-ecological situations between the Member States, we do not prefer a formal common risk management approach throughout the EU.
Slovenia	The formal risk management methods should be consistent throughout the EU.

Information provided by commercial respondents is summarised below:

State	
Austria	Risk management has to be done by a quality assurance system. CEN/TC 308 should create a standard as a basis for a consistent regulation throughout the EU.
Finland	Risk management can be handled in a various ways. In Finland the focus is on the quality of the final product. Quality control has to be in place but it is up to the plant owner to decide points of monitoring and the implementation. Since quality control is used there is no need for new systems. New formal risk management methods would probably just add bureaucracy and work without real benefit. Information and guidance for risk management is useful, but any formal requirements would just add a new layer of regulations on the top of the existing ones.
France	Yes, it should be the basis for setting up thresholds on pollutants and pathogens concentrations in sludges, on dosage permitted per ha, on practices, restrictions, etc.
France	Yes and it has to be the basis used for the determination of threshold values.
Germany	As soon as European-wide criteria for the use of sewage sludge on land are set up it is definitely reasonable to adhere to uniform evaluations and standards.
Germany	Risk management is carried out differently throughout in the EU at the moment. National legislation and local regulators have approved current practices. If quality control is in place there is no need for new systems and new formal risk management methods. This would probably just add bureaucracy and costs without real benefits. Information and guidance for risk management is useful, but any formal requirements would just add a new layer of regulations on the top of the existing

	ones.
UK	Some guidance could be useful but it should be flexible enough to provide a consistent basis for assessment while allowing Member States to make their own decisions based on their own situations.
UK	There should be consistency at least to the extent that biased risk assessments are not used as justification for unnecessary or disproportionate controls.
UK	Yes, to avoid the unnecessary restrictions the oft used Precautionary Principle imposes.
Portugal	Management methods should be the same throughout the EU, but the risk assessments should take into account differences in climate and soils. The importance of public health and the environment is the same for all states.
Norway	Yes.

Q26 – Is sewage sludge likely to be used as a replacement for inorganic fertilizers? To what degree is the use of sewage sludge influenced by the market for inorganic fertilizers? Are the qualities of sewage sludge as a replacement for inorganic fertilizers sufficiently well understood to increase the demand for sewage sludge recycling onto agricultural land

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Yes, sewage sludge is likely to be used as replacement for mineral fertilizer. Market prices for fertilizers has a great influence on the use of sewage sludge in agriculture.
Belgium – Flemish region	No, sludge cannot function as a substitute for artificial fertiliser. Artificial fertiliser works quickly and targeted, but its effect does not last long. Sludge shows results on the longer term (comparable to compost). Sludge and artificial fertiliser are therefore complementary rather than replacement for each other.
France	Only partial replacement of mineral or other organic fertilisers. Only partial impact of price of mineral fertiliser as sewage sludge contribute to about 1% for N and 5% for P of annual nutrient needs in France. Regular information on sludge production and application is collected and published.
Germany	The increasing prices for inorganic fertilizers will have a positive effect on the demand of plant nutrients from sewage sludge.
Hungary	Sewage sludge use – taking into consideration its compounds – will probably not replace the use of fertilizers, maybe can reduce it in a smaller extent. In Hungary farmers usually do not pay for the sewage sludge, but may cover the transportation costs. Bulk of costs is financed by the sewage plant. In spite of this sewage sludge use has minimal impact on the fertilizer market. The need using sewage sludge for agricultural purposes is emerging from the sewage plant and not from the farmers. Therefore several plants seek to make such kind of sludge which can be sold the compost as a product. In our view use of fertilizers can not be replaced by greater sewage sludge use because they have to meet different agrotechnical requirements and needs. Because of the quality and technological requirements certain intensive cultures require the use of inorganic fertilizers.
Slovenia	Sewage sludge could be used as a replacement for inorganic fertilizers if high quality standard for the product are enforced. In Slovenia in the last years the use of mineral fertilizers decreased due to the Nitrate Directive entered into force in

	2004 and Rules concerning good agricultural practice for fertilizing. The mineral fertilizers were replaced with farm fertilizer. The qualities of sewage sludge as a replacement for inorganic fertilizers are not sufficiently well understood in order to increase the demand for sewage sludge recycling onto agricultural land.

Information provided by commercial respondents is summarised below:

State	
Austria	Sewage sludge is one of several fertilizers to deliver nutrients and organic matter required by soils and plants. Fertilization plans and nutrient balances give exact information about limitations or the amount to be combined with manure or mineral fertilizers. Limitations by high nutrient contents in soils can be detected with analyses. High nutrient loads by high animal stocks or alternative waste fertilizers (compost, residues from food production, etc.) can be detected by nutrient balances.
Finland	There has been growing interest to use sludge in agriculture due to the increase of fertilizer prices.
France	Sludge is used as a replacement for inorganic fertilizers and is influenced by the price of inorganic fertilisers. To enhance the understanding of the agronomical value of the sludge by the farmer it is necessary to provide him with more information on: the sludge quality, the total and available quantity of fertilizing elements brought by sludge spreading on each plot of land, soils analysis results integrating fertilizing elements.
France	The use of sewage sludge in agriculture is based on its fertiliser value: without such a value, and without having proved it, it doesn't make sense to use it on land. The price of mineral fertiliser is of great impact on sludge demand: see the past-period 2007-2008. The higher is the price of N and P, the higher is the demand. More research should be done in order to improve the technical knowledge on agronomical value of sludge (organic matter, N, P, K, CaO, MgO, SO3, etc.), with special attention on the impact on the real bio-availability for crops (or soil) according the process (thermal drying, composting, liming, etc.). The more we advise farmers to manage their N fertilisation, and so manage the right dose of N-mineral, the better it is for the credibility of sludge use in agriculture as a fertiliser.
Germany	Sewage sludge is already used as organic NP-fertiliser in agriculture and replaces the use of mineral fertilisers. At the same time, there is no competition between those fertilisers, as the need for fertilisers in Germany is much higher than it could be covered by sewage sludge alone. According to calculations, phosphorus that is available in the total amount of municipal sewage sludge/wastewater can cover 20 to 30 percent of the need of phosphorus in the agriculture in Germany. Establishing a comprehensive concept for quality assurance helps to increase the acceptance for sewage sludge fertilisation.
Germany	In Germany, according to fertilizer regulations, sewage sludge that fulfils legal requirements for agricultural use is classified as a normal fertilizer. The contents of nutrients must be considered in the same way as those of inorganic fertilizers. Thus any sludge application to agricultural land must be regarded as a replacement of other kinds of fertilizers, including organic fertilizers. The nutrient content of sewage sludge is well known and appreciated by farmers.

UK	Sewage sludge is always used as an inorganic fertiliser replacement and the sales value responds to inorganic fertiliser price movements. The replacement value of sewage sludge compared to inorganic fertilisers is thoroughly understood and only normally qualified fertiliser practitioners (FACTS scheme) sell sewage sludge to agriculture.
UK	Yes, sewage sludge is used primarily as a replacement for fertilisers. Increasing inorganic fertiliser costs will undoubtedly increase farmer interest in using sludge as an alternative cost-effective source of nutrients. Extensive field and laboratory based research has defined the agronomic properties of the principal conventional and enhanced treated sludge types recycled to farmland and this information has formed the basis of detailed fertiliser guidance available to farmers and operators. In the UK, for example, data from recent research programmes on the agronomic value of sewage sludge has been used to update the fertiliser guidance on sludge in a revised Fertiliser Manual to be published shortly.
UK	Sewage sludge should be used as an alternative; indeed it is already used as a (partial) replacement for mineral fertilisers. There is already good information on fertiliser value. Due to different nutrient balances, quaternary treatment processes such as forced struvite harvesting may have to be used to produce a good quality product as an alternative as slow release ammonium phosphate fertilizer. With a good reliable product, sewage sludge should be capable of driving the market of inorganic fertilizers, instead of the market of inorganic fertilizers driving the use of sewage sludge. Complete fertilizer replacement may not be achievable because of the balance of nitrogen to phosphate.
Portugal	Probably not as inorganic fertilizers are more efficient and do not have contaminants. As organic material has no market value farmers will only accept sludge at zero cost. There will be very large competition with compost after 2011.
Norway	Biosolids field trials have demonstrated their potential to replace inorganic fertilizers to some extent. The increases in price of inorganic fertilizers has increased demand for sludge; rising awareness of P as a finite resource will increase value of sludge. There is good understanding in the agricultural community of sludge qualities, but too many misunderstandings of safety of sludge.

Q27 – How will public opinion in Member States that currently send high levels of sludge to landfills (e.g. EU12) react to greater use of sewage sludge on land?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Landfilling of organic waste is banned since 2007.
Belgium – Flemish region	This depends on the quality of the sewage sludge and on the quality assurance system in place.
France	No comment.

Hungary	According to the Act on Waste Management No. 2000 of XLIII.) until 1st of July 2009 the biodegradable municipal waste going to landfills must be reduced to 50 % of the total amount (by weight) of biodegradable municipal waste produced in 1995 and to 35 % until 1st of July 2016. Taking into consideration the reduction of organic compounds contained in other waste flows we do not plan the co-treatment of sludge with municipal solid waste.
Slovenia	The acceptance for use the sewage sludge on land could be achieved with high quality of the product, public awareness, presentation of good practices, etc.

Information provided by commercial respondents is summarised below:

State	
Austria	In all areas where sludge is used on land under controlled conditions, the public acceptance is very high. People who are informed that sludge is compost derived from their wastewater accept the use on land when the benefits for protecting resources and reducing energy consumption by short transport distances and standard treatment are shown properly.
France	The public is generally not aware of the exact quantity of sludge spread on land. Increase of sludge quality control and deeper monitoring of sludge landspreading operation is the best means to increase public confidence.
France	No comment.
Germany	Sewage sludge contains fundamental nutrients that should be made available and that should be used also for reasons of resources protection. In Germany, only high quality sludge is in fact disposable for recycling, and successful concepts on how sewage sludge qualities can be improved are already in place. The use of sewage sludge of lower quality for thermal treatment is desirable, as it embodies two main advantages: 1. Generation of energy (heat and electricity) from renewable sources. 2. Recovery of valuable resources out of the incineration ashes (currently only realisable after mono-incineration and with high financial burdens).
Germany	If the switch from landfill to agriculture in EU12 is correctly managed and compliance with process/protocols is maintained, then it will be perceived as the ‘right thing to do’ and the best practical environmentally option and be seen as a fully sustainable solution.
UK	Not relevant to the UK. In countries where landfill is currently the dominant disposal route for sludge, consumer acceptance of agricultural recycling will require a suitable education programme, investment in upgrading treatment processes to control odours and pathogens, measures to reduce contaminant inputs and field scale demonstration to farmers.
UK	It is difficult to gauge the overall likely public opinion across Member States that currently send high levels of sludge to landfill and it is likely that there will be marked differences. Public perception of the use of sludge on agricultural land is considered to be a key challenge which must be addressed in the future. Use of more appropriate terminology (“biosolids”), the use of quality assurance schemes and education regarding the benefits of harnessing renewable energy, and supplementing fertilizer usage has to be maximised. Odour is also a key issue and must be addressed. If the sludge “stinks”, the public will be hostile. If it does not smell objectionable and if the benefits are explained (i.e. that instead of squandering P, it is going to be conserved) then the public will be likely to accept.
UK	Initially there will be resistance but with education there will be acceptance.

	The decline in phosphate resources needs emphasising as does the damage landfill emissions cause the environment.
Portugal	Public acceptance of sludge use in agriculture is low mainly because of poor stabilisation, odour release and poor practices.
Norway	It is a challenge to communicate and build confidence on these matters.

Q28 – Will the co-treatment of sludge with municipal solid waste become an important path for the future?

Information provided by official respondents is summarised below per Member State:

Member State	
Belgium – Walloon region	Yes co-treatment via co-digestion or co-incineration will increase.
Belgium – Flemish region	In Flanders, co-incineration of sewage sludge with high calorific waste represents 40% of the treatment of sewage sludge via incineration.
France	Co-treatment would be one option for specific situations. Quality control of all inputs and through all the process route is necessary particularly with variability of other solid wastes.
Hungary	There is no plan for co-treatment of sludge with municipal solid waste.
Slovenia	Co-treatment of sludge could become an important path, when composted with biodegradable waste (quality management!) or in anaerobic digestion plants with energy recovery. It would be necessary to distinguish between sewage sludge from the municipal sewage plant and from industry or combined sewage plant which strongly influence the product quality.

Information provided by commercial respondents is summarised below:

State	
Finland	Finland is a country with scattered dwellings and small population. It is very natural due to these circumstances to develop co-treatment projects to have enough input material to have economically and ecologically viable solutions. Co-treatment of manure and sludge and co—treatment of sludge and municipal or industrial waste are relevant in Finland. We believe this is an important path and should be encouraged in EU regulations.
France	Interesting in order to reduce cost of capital (waste treatment plant as composting e.g.), to develop a real territorial waste management approach and to combine technical synergies (optimal CHP for energy recovery, optimal humidity for AD, etc.). In order to develop, some barriers have to be broken: – Financial burden: because sewage sludge and municipal solid wastes (MSW) are often managed by different authorities, innovative entities have to be set up, as public private partnerships (PPP) in order to gather and to make contribute all the stakeholders to the capital cost for treatment plants. – Administrative burden: the regulation framework is currently too conservative and brings artificial borderlines (for example, the proposed biowaste directive excludes sewage sludge from its scope, even when sludges are recycled according the same principles of other organic

	fertilisers as biowastes). – Technical burden: from the past experiences we know, co-treatments which have been implemented have to over pass technical barriers linked to the mix of inputs having different characteristics (calorific power mainly).
Germany	Mainly depend on the regional conditions and the respective waste targeted for cotreatment. For separately collected biowaste, the co-treatment in WWT digesters is often too complex, and also other efficient treatment practices have been established (e.g. composting, digestion). Not expected to be a reasonable development in the future. Cost-effectiveness can especially be given for paste-like organic wastes. General interest of the operators is of course to exhaust their full capacities and thus to co-treat adequate waste streams. In Germany, a separate authorisation is hereby needed, as the added waste then underlies water laws rather than waste legislation.
Germany	Co-digestion of food and other adequate organic wastes is an ecologically worthwhile method to significantly improve energy balances of wastewater treatment plants. Unfortunately very complex legal requirements (in particular Directive 1774/2002 concerning animal by-products) handicap a widespread implementation of co-digestion.
Italy	No, we don't think that this will be an important path for the use of the sludge in agriculture.
UK	Co-treatment of sewage sludge and biowaste is a critical path for the future and can play an important role if unnecessary regulatory barriers in the UK are removed. It is already practised in some other Member States (most notably Denmark), but the UK inhibits co-treatment by different barriers, which could be removed with no detriment to the environment. The potential volume of biowaste sludge by far exceeds the volumes of sewage sludge. Bio-sludges without the badge 'sewage' will compete for recycling routes making recycling of sewage sludge harder. The treatment of sewage sludge in the water industry is well established, and there is a high degree of expertise already operating. The water industry needs to use its skills, and take advantage of the opportunities presented by the co-digestion of sewage sludge and bio-waste. Sewage sludge contributes a good nutrient medium and carrier / dilution medium to be used in conjunction with commercial bio-waste.
UK	Co-treatment, particularly co-digestion and to a lesser extent co-composting are likely to increase in future. Co-digestion could maximise use of the existing infrastructure operated by the Water Industry for waste treatment and increase renewable energy production and co-composting could produce soil improver products that may meet end-of-waste criteria. The threat to these co-treatments lies in a regulatory regime which continues to see treated sewage sludge as a waste to be tightly controlled rather than as a resource to be used.
Portugal	Yes, co-treatment in some circumstances is the best available solution. Co-incineration with energy recovery will be practised in Portugal after 2013.
Norway	Seems unlikely.

13 Annex 1 – Additional references suggested by respondents

The following references are listed as supplied by respondents. Relevent references have been reviewed and will be included in the final report.

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The reports published by the French national veterinary health monitoring unit on sewage sludge land spreading (put in place in 1997) (http://www.ademe.fr/Collectivites/bois-energie/pages/Filiere/cellule_veille/default.htm).

The following CEN reports :

- CR 13846:2000: *Recommendations to preserve and extend sludge utilization and disposal routes*

- A report on risk assessment related to sludge management, published in 2007 :
CEN/TR 15584: 2007: *Characterization of sludges - Guide to Risk Assessment especially in relation to use and disposal of sludges*

The following CEN technical reports might also be of particular interest for your study.
All three belong to a series of guidelines of good practice for sludge management (see also Fig.1 p.4).

- A guideline of good practice for hygienisation of sludge (also known as Guide 10):
CEN/TR 15809: 2007: *Characterization of sludges – Hygienic aspects – Treatments*

Two CEN guidelines of good practice for sludge management have been reviewed and their revised version will soon be submitted to validation.

- The first of them, utilisation in agriculture is already listed in Table 14 in its current published version (CR 13097: 2001, also known as Guide 4):
prCEN/TR 13097: *Characterization of sludges - Good practice for sludges utilisation in agriculture*

- The second is not yet listed in Table 14, it touches all use & disposal routes:
prCEN/TR 13714: *Characterization of sludges - Good practice for sludges management in relation to use or disposal* (current published version: CR 13714: 2001; also known as Guide 2).

Arthur Andersen (1999) - Audit environnemental et économique des filières d'élimination des boues urbaines Audit environmental and economic channels urban sludge disposaltudy water Inter-agences

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IRH environnement – février 2007 - Contamination potentielle des échantillons de stations d'épuration (eaux brutes, eaux traitées, boues) et effluents d'élevage par des molécules pharmaceutiques à usage humain et vétérinaire.

Programme HORIZONTAL programme de recherche financé par l'UE (DG ENV) caractérisation des sols, des boues et des composts. Pour plus d'informations : http://www.ecn.nl/horizontal/index.php

Guide technique élaboré par un groupe de travail **"Dérogations relatives à la** réglementation sur l'épandage des boues de stations d'épuration - Comment formuler une demande pour les sols à teneurs naturelles élevées en éléments traces métalliques ? " (mobilité et la biodisponibilité des éléments traces dans les sols)

Pesticides dans les boues. le rapport en français est disponible à l'ADEME

Base de données ANADEME qui est disponible, et le rapport qui sera publié l'année prochaine. Le tout peut servir pour évaluer les impacts des valeurs "seuils" choisies pour les sols, en fonction du pH. Cette base de données regroupe les données d'analyse de sols effectuées dans le cadre du décret boues de 1997 (notamment ETM) et représente environ 11 000 échantillons géoréférencés pour la plupart. Le rapport présente de nombreuses statistiques et cartographies, issues des traitements des données à différents niveaux (départements, national). pré-rapport final à disposition

ADEME/SOGREAH: mars 2007 Bilan des flux de contaminants entrant sur les sols agricoles de France métropolitaine – Bilan quantitatif de la contamination par les éléments traces métalliques et les composés traces organiques et application quantitative pour les éléments traces métalliques http://www.ademe.fr/Collectivites/bois-energie/pages/Filiere/cellule_veille/default.htm

SIGEMO (Système Informatisé de Gestion des Epandages de Matières Organiques) Les ministères en charge de l'agriculture et de l'écologie ont confié au CEMAGREF la conception d'un outil de suivi des épandages d'effluents organiques (boues de stations d'épuration urbaines et industrielles, effluents d'élevages, composts), inter opérable et appuyé sur un système d'information géographique – SIG, et ouvert à des utilisateurs variés (administrations, collectivités territoriales, bureaux d'études …) via le réseau Internet

http://www.cemagref.fr/le-cemagref/lorganisation/les-centres/le-centre-de-clermont-ferrand/ur-tscf/systemes-d2019information-agri-environnementaux-communicants/sigemo-systeme-informatise-de-gestion-des-epandages-de-matieres-organiques

Plaquette de présentation communicable au format pdf.

ERESFOR– mars 2007 - Epandages expérimentaux de produits résiduaires sur parcelles boisées – Bilan et synthèse des expérimentations menées en France et recommandations techniques

14 Annex 2 – Country files

Reviews of individual EU countries are presented, with summary tables of annual sludge production and percentages to different disposal routes shown as Table 1 (1995-2005) and Table 2 (2010-2020).

Austria

The following description is based on information provided by Kroiss for the latest version Global Atlas (LeBlanc *et al*, 2008) and a presentation given by Doujak in 2007. *This report has been revised following comments received from the Ministry of Environment during an on-line consultation in August 2009.*

At the end of 2006, there were about 1,500 agglomerations including 641 agglomerations ≥ 2000 pe in Austria with a generated load of 19,712,580 pe. At the end of 2006, the rate of collection and treatment improved up to 98.8% of the total generated load and 95.6% had more stringent treatment. The remaining population has individual treatment systems (for example, septic tanks, cesspits). A 100% connection rate is not considered realistic in Austria (BMLFUW, 2008 as reported in Olivia *et al*, 2009).

The annual sludge generation is reported to vary between 11 to 32 kg DS per capita per year (Doujak 2007). In the period 2001 to 2007, municipal sewage sludge quantities increased at an average rate of 1% per annum. This can be related to population growth, increased sewer connection and higher standard of living. The quantities of industrial sludge increased at an average rate of 2.3% per annum over the same period.

In 2005, municipal sewage sludge production in Austria amounted to 266,000 t DS in 2005 including 28,000 tds of imported sludge ; 47% were incinerated; 18% was recycled to agriculture, 1% sent to landfill and 34% by other routes such as composting (77%); landscaping (12.3%), intermediate storage (2.4%) and unspecified. In addition, there was also 155,000 tds of sewage sludge from industries mainly cellulose and paper industry being produced in 2005, mainly incinerated (83%) or sent to landfill (13%); 3% was recycled to agriculture and 1% to other outlets.

	2001	**2005**
Total sludge produced (tds)*	399,000	420,000
Agriculture (%)	10	12
Landfill (%)	12	1
Incineration (%)	43	60
Other (%)	35	27

Note: * Include municipal sludge, exports and industrial sludge.

The most recent set of figures for Austria has been published by the Ministry of Environment for the year 2006 (Olivia *et al*, 2009). The figures are reported below for municipal sewage sludge, industrial sludge and imports/exports respectively. In 2006, total sludge production in Austria amounted to around 430,000 tds; including about 252,800 tds of municipal sewage sludge and 177,000 tds of industrial sludge (mainly from the cellulose and paper industry).

In 2006, about 40% of municipal sewage sludge was incinerated; 16% was recycled to agriculture, less than 1% sent to landfill and 44% disposed by other routes such as composting; landscaping, intermediate storage and other unspecified outlets. Industrial sludge was primarily incinerated (62%), disposed of to other outlets (32%), recycled to agriculture (3%) or disposed of to landfill (less than 1%).

Quantities (tds/y) of municipal sewage sludge in 2006:

Region	Sludge production	Agriculture	Incineration	Landfill	Other (inc. composting, landscaping, intermediate storage and unknown)
Burgenland	7,957	4,900	ND	ND	ND
Kärnten	12,600	850	ND	ND	ND
Niederösterreich	44,400	8,000	4,800	ND	ND
Oberöstereich	47,240	17,700	8,500	ND	ND
Salsburg	13,300	0	ND	ND	ND
Steiermak	27,100	3,900	ND	ND	ND
Tyrol	23,900	ND	ND	ND	ND
Voralberg	10,200	2,800	100	0	5,200
Vienna	66,100	0	66,100	0	0
Total	**252,800**	**38,400 (16%)**	**96,600 (40%)**	**24 (>1%)**	**106,100 (44%)**

Quantities (tds/y) of industrial sludge in 2006:

Region	Sludge produced	Agriculture	Incineration	Landfill	Others
	I	I	I	I	I
Burgenland	2215	ND	ND	ND	ND
Kärnten	ND	ND	ND	ND	ND
Niederösterreich	ND	ND	ND	ND	ND
Oberöstereich	80,231	0	74,430	0	5,800
Salsburg	ND	ND	ND	ND	ND
Steiermak	ND	ND	ND	ND	ND
Tyrol	ND	ND	ND	ND	ND
Voralberg	ND	ND	ND	ND	ND
Vienna	0	0	0	0	0
Total	**177,000**	**4,800 (3%)**	**106,700 (62%)**	**200 (>1%)**	**61,500 (35%)**

Quantities (tds/y) of sludge exported/imported in 2006:

	Export	**Import**	**Export-import**
Municipal	15,100	3,400	11,700
Industrial	3,700	0	3,700
Total	18,800	3,400	15,400

Doujak (2007) estimated that, by 2010, the connection rate will have increased to 92% rising to a maximum of 94% by 2015. Annual municipal sludge production is estimated to rise to 273,000 tds by 2010, reaching 280,000 tds pa by 2015 and remaining at that level as 100% connection is not expected. Total sludge production including municipal and industrial sludge is estimated to reach 440,000 tds by 2015.

For our baseline scenario, we have accepted the assumptions from Doujak as realistic and that by 2010 in Austria, the quantities of municipal sewage sludge will amount to 273,000 tds and that the proportion going to the different outlets will remain stable – i.e. 15% recycled to agriculture; 45% composted to be recycled to land reclamation projects or treated in MBT plants and 40% thermally treated followed in some cases by phosphorous recovery.

By 2020, municipal sludge production will amount to 280,000 tds per annum and proportion going to agriculture will decrease to 5%; 10% will be treated by MBT and 85% will be thermally treated with subsequent phosphorous recovery. Sludge from industries will amount to 160,000 tds and be entirely thermally treated by 2020 (100%).

The development of sludge disposal routes in Austria is strongly influenced by the regional regulatory framework for sludge and waste management.

There are stringent restrictions on the application of sewage sludge and compost on agricultural land specified in the Austrian regulations. These requirements vary according to the federal state: three of the 9 federal states have, for example, banned sewage sludge application in agriculture. Where it is allowed, sludge has to be treated and at least dewatered. At the treatment works, up to 6 months storage capacity is necessary to fulfil the requirement that sludge must not be applied during late autumn and winter. Direct application of sewage sludge on grass land has little relevance today in Austria. The use of sludge on forestry in Austria is forbidden by law.

There are additional restrictions imposed on the use of sewage sludge and compost in agriculture due to product quality requirements for different markets (for example, organic farming, eco-labelling, and retailer requirements).

As the legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are less stringent; an increasing part of sewage sludge, mainly after composting, is used for this purpose especially where the agricultural reuse is no longer accepted.

In recent years, there has been an increase of sludge-drying facilities with different processes (drum dryers, solar drying) to reduce storage volume and transport load. On a national scale this method still has low relevance. There is also an increase of adding other organic wastes into anaerobic sludge digestion to increase biogas production. Mechanical Biological Treatment plants (MBT) have been proposed as a suitable option for sewage sludge composting in combination with other organic materials. The output from MBT plants is than landfilled.

While in the past 11% of sewage sludge was sent to landfill for disposal, since 2004, material must meet the following criteria for landfill disposal:

- Less than 5% TOC related to total dry solids
- Less than 6000 MJ/kg dry solids.

These criteria cannot be met by conventional sludge treatment and stabilization processes; only the output from MBT plants and the ashes after incineration meet the requirements which means that sludge disposal on landfill sites is effectively banned and no longer has a major role in Austria.

During the last 10 years, waste incineration capacity in Austria has increased. The overall capacity is still dominated by the fluidized bed incineration plant on the site of the Vienna Main Treatment Plant where about 25% of the total sewage sludge production in Austria is incinerated. For the remaining, sludge is mainly co-incinerated with other wastes in coal-fired power plants and cement kilns. Mono-incineration is however favoured by the authorities in order to enable subsequent phosphorus recovery.

The current debate in Austria on sludge disposal is dominated by soil and food protection from potentially hazardous organic micro-pollutants and sustainable phosphorus management.

In Austria there is general requirement for treatment plants > 1000 pe for P-removal which results in a ~80 to 85% transfer of P from wastewater to sewage sludge. It has been estimated that the P-load in sewage sludge could replace up to ~40% of P-market fertilizer imports to Austria.

There are two clear options in the debate on sludge disposal. The first favours incineration as organic pollutants are destroyed. The second favours sludge application in agriculture as this is the least-cost solution for recycling phosphorus and favours mono-incineration of sewage sludge with P-recovery from the ashes. It does not favour co-incineration with cement coal and wastes as it interferes with P-recovery.

Under waste legislation, energy recovery from sewage sludge has a lower priority compared to nutrient and organic material recycling. However, the Austrian authorities commented that incineration of sewage sludge could be justified when it constitutes the best option for the environment, health and for phosphorus recovery. The political discussion on sludge treatment and disposal is increasingly focused on possible risks for soil and food due to application of sewage sludge that may contain organic micro-pollutants. Thus public acceptance of incineration is increasing.

Belgium

The situation in Belgium has to be described separately for the 3 regions. The description below is based on information provided by DGRNE 2005, IRGT 2005 and from a presentation given by Leonard in 2008. *This report has been revised following comments received from the relevant authorities from the 3 regions during the first on- line consultation in August 2009.*

At the end of 2005, there were 384 agglomerations ≥ 2,000 pe in Belgium with a generated load of 9,701,500 pe. 97.5% were reported to be collected; 66% treated by secondary treatment and 49% by more stringent treatment while 0.3% were reported to have individual treatment and 2.2% were reported to be not collected and not treated.

<u>Wallonia</u>

Since 2000, a public water management company (SPGE) has been coordinating and financing wastewater treatment in Wallonia. About 80% of the population are located in agglomerations ≥ 2,000 pe and are connected to sewer; about 9% are in agglomerations less than 2,000 pe also connected to sewer while about 12% of the population (400,000 inhabitants) live in areas without municipal sewer connection.

In 1999, only 38% of wastewater was treated in Wallonia, however at the end of 2008, 146 treatment plants (≥ 2,000 pe) were in operation with a total treatment capacity of 3.1 M pe or about 75% of the 2005 UWWT target (i.e. 4.2 M pe). In addition 44 plants were under construction and 57 were being designed. In addition, 209 small plants (<2000 pe) had been constructed, 8 were being built and others were being designed. It is estimated that full compliance will be achieved by 2011 with the construction of 428 plants (≥2000 pe) and 600 small plants (<2000 pe) with a combined total capacity of 4.561 M pe.

In 2008, 62% of the 146 plants were small or medium-sized (2000≤pe≤10,000 pe) with only 7 plants with a capacity ≥ 100,000 pe, most having secondary treatment. Treatment capacity is reported to be over designed by 20% to allow for population and industrial growth. From 3,413,978 inhabitants in 2006, population is expected to grow up to 3,450,555 by 2011 and to 3,551,351 inhabitants by 2020.

The whole territory has been designated as a sensitive area which means that all the plants with a capacity of more than 10,000 pe have to have been equipped with tertiary treatment by 2008 at the latest.

According to CEC (2006) and regional authority (DSD/DPS) (2009, personal communication), municipal sewage sludge production amounted to 18,514 tds in 2001, 20,300 tds in 2002 and 23,520 tds in 2003 and reaching 31,380 tds in 2007 (see table below).

It is expected (IRGT, 2005 and Leonard, 2008) that, by 2010, when Wallonia will have completed investment for the UWWT Directive, sludge production will rise to 45,000 tds. This is significantly lower than an estimate of 80,000 tds based on 25kg per capita, 3.5 M inhabitants and 88% connection to sewer.

The regional authority commented that a sludge production rate of 25 kg per capita seemed unrealistic for the Walloon situation. Based on the official predictions proposed below; the maximum sludge production rate will only be at about 15 kg per capita. The two different official estimates are presented below:

- Constant linear increase: 35,204 tds by 2010 and 50,140 tds by 2020
- SPGE study (2004): 404 treatment plants producing 50,370 tds of sewage sludge by 2010 and 428 treatment plants producing 52,101 tds of sludge by 2020.

For our baseline scenario, we have adjusted our estimate to the official figures of 35,000 tds by 2010 and a total sludge production of 50,000 tds by 2020 as population growth and industry expansion is expected to be limited.

In Wallonia, recycling to agriculture has traditionally been the preferred option although the quantities recycled have stayed constant since 1999 at around 10,000-11,000 tds per annum. The proportion of total sludge recycled has dramatically decreased over the last 10 years from 75% in 1995 to 60% in 2000 before stabilising at about 35%.

Quantities sent to landfill have increased from 18% in 1998 to a maximum of 45% in 1999 before decreasing to 34% in 2000 and 0% as landfilling of organic waste was prohibited in 2007.

The proportion of sludge sent to MSW incinerators has dramatically increased since 1999 from 2% to 64% in 2007. This was a direct consequence of the dioxin crisis (1999) which damaged farmer’s confidence in sludge quality at the time, despite the high quality of the sludge. The quality of sludge has continued to improve (see table below) and a study (Valbou 2004) has shown that 85% of sewage sludge meets the regional standards (defined as B2 class) and could be recycled to agriculture. Other outlets such as long-term storage are also used (less than 1%).

In addition, in 2007, 47,947 tds of sludge from industrial treatment plants was also recycled to land (DSD/DSP, 2009, personal communication) (see table below). These quantities seem to have decreased since 2003. It is reported that this was due to problems with compost quality, changes to legislation and lack of installations available.

Leonard reported there to be a growing interest in drying facilities and methods to improve dewatering of sludge.

In the future, the agriculture outlet (after composting) should continue to play an important role in sludge management and is expected to increase again despite some fear and opposition from the population. When recycling to agriculture is not possible, energy recovery will be favoured through anaerobic digestion with biogas production or co-incineration of sewage sludge and municipal solid waste. There are also plans to dispose of sludge in cement works, power plants or to dedicated incineration plants.

For our baseline scenario we have assumed that the proportion of sludge recycled to land will increase for the next 15 years to reach 45-50% by 2020 and thermal treatment for the remaining 45 to 50% including co-incineration with MSW and cement plants.

Wallonia - Municipal sewage sludge arisings and outlets (from 1995 till 2007):

Outlets	**1995**	**2000**	**2005**	**2007**
Total sludge produced (tds)	14,330	18,228	30,285	31,380
Agriculture	10,686 (75%)	10,773 (59%)	10,506 (35%)	10,927 (35%)
Landfill	3,644 25	6,236 (34%)	3,486 (11.5%)	0
Incineration	-	1,127 (6%)	16,217 (53.5%)	20,134 (64%)
Storage-other	-	132 (>1%)	76 (>1%)	319 (1%)

Wallonia - Quantities of industrial sludge recycled to agriculture (tds per annum):

Industrial sector	**2003**	**2006**	**2007**
Slaughterhouse	987	1,053	945
Food	2,426	2,802	3,046
Beverage	167	137	63
Brewery	2,940	3,193	2,586
Limestone	3,521	1,398	1,670
Dairy	1,340	1,124	949
Paper	36,240	35,947	32,832
Potatoes	1,473	1,221	1,387
Drinking water	3,810	4,195	3,956
Tannery	553	394	513
Total	**5,3456**	**51,463**	**4,7947**

Wallonia - Trends in quality of municipal sewage sludge recycled to agriculture:

Parameter	**2001**	**2003**	**2006**	**2007**
Cd (ppm DM)	1.5	1.4	1.5	1.2
Cu (ppm DM)	174	162	167	159
Ni (ppm DM)	29	28	25	24
Pb (ppm DM)	116	102	79	72

Zn (ppm DM)	947	848	688	672
Hg (ppm DM)	1.6	0.9	1	0.8
Cr (ppm DM)	62	56	54	45
N (%DM)	3.7	3.7	2.9	2.8
P (%DM)	2.6	2.5	2	2.3

The general organic waste management in Wallonia is organised through the Waste Plan published in 1998 which was updated in 2006. The plan supports the development of separate waste collection for organic waste and treatment technologies (i.e. incineration with energy recovery, composting, anaerobic digestion, drying processes). There is political support for recycling to agriculture but due to the lack of infrastructure, incineration is currently the predominant outlet.

The legislation regulating the recycling of sewage sludge to agriculture is the Order of 12 January 1995. Although there are no limits for organic contaminants, the authorisation for spreading sewage sludge depends in practice on the results of monitoring of some organochlorines (BTEx, styrene, PAH, PCB, AOX, LAS, DEHP, NPE, PCCD/F, EOX, pesticides, chlorobenzene, chlorophenols, cyanides). Similarly, monitoring of pathogens (*Salmonella* sp) is carried out and the authorities may impose stricter restrictions if present. There are also restrictions imposed such as spreading at a minimum distance of 10 m from wells, springs and drinking water storage or irrigation water. Sludge cannot be spread on frozen ground

There is also a decree pending on compost and digestates which sets rules for better traceability and defines different classes of compost according to origin (open or closed streams) and quality. The decree will restrict the recycling to agriculture for compost of the highest quality (class A and B). This system is already applied through the delivery of certificate of use for compost and other organic waste (AGW of 14 June 2001).

Flemish region

In the Flemish Region, in 1990, approximately 78% of the wastewater from households was collected via sewer systems, but only 30 % was treated in a wastewater treatment plant. By 2002 collection and treatment rates had increased up to 86% and 60% respectively. By the end of 2005, treatment levels amounted to 64.4% (VMM, 2006) and by the end of 2006, the level of collection and treatment had reached 80.6% (short by 1.4% of the 2005 target) and 66.6% (2.2.% short by the 2005 target) respectively. There were 216 treatment plants in operation in the Flemish Region including 107 plants for agglomerations > 10,000 pe; 68 with 2,000<pe<10,000 pe and 41 for agglomerations less than 2,000 pe. As the whole region has been designated as a sensitive area all 107 plants > 10,000 pe have nutrient removal treatment in place.100% collection is not expected by the Flemish region.

From the figures submitted to the Commission, sludge production amounted to 81,351 tds in 2001, 82,871 tds in 2002 and 76,072 tds in 2003 (CEC 2006). From the latest reports (CEC 2009, personal communication), sludge production was reported to amount to 87,382 tds in 2004, 76,254 tds in 2005 with no figure available for 2006. From the latest figure submitted via the consultation the total sludge production is reported to have increased steadily since 2003 to amount to 101,913 tds in 2006 (equivalent to 16.7 kg per capita per year) (see table below).and is estimated to reach 107,600 tds in 2008 (equivalent to 17.35 kg DS per capita) (OVAM 2009, personal communication). The sludge production ratio is low due to preventive measures.

Flanders - Trends in municipals sewage sludge production (tds) and disposal outlets (CEC, 2006 and OVAM 2008)

	Total production	**Recycling to agriculture**	**Landfill**	**Incineration**	**Other**
1995	73,325	13			
2000	80,708	0			
2005	92,504	12		72	16 *
2006	101,913	0	0	88	12*

Note: * As landfill cover

According to OVAM (2009, personal communication), it is expected that when Flanders should have completed investment for the UWWT Directive by 2010, sludge quantities will increase to about 110,500 tds which is lower than our estimates of 135,000 tds based on 25kg per capita, 6.1 M inhabitants and 88% connection. It is expected that the sludge production will remain constant till 2020.

Due to very stringent legal restrictions on PTEs, quantities of sludge recycled to agriculture have decreased sharply since 1998 from 22% down to 7% in 1999, 0% in 2000/2001 and 2 % in 2002. In addition, since 2006, untreated sewage sludge was no longer allowed to be recycled to agricultural land and the recycling of treated sludge was not economically viable. It is reported that 95% of sewage sludge did not comply with the stringent limits set in the Flemish legislation (see table for sludge quality). In addition, it is reported that the toluene and mineral oil content in sludge is a problem. There is an on-going study looking at possible new limit values for sludge recycled to land and estimates being made of the proportion of sewage sludge which could meet the new criteria.

Quantities of sludge sent to landfill have decreased steadily since 1998 from 35% down to 3% in 2002 while quantities sent to incineration have risen, from 43% in 1998 to 95 % in 2002 and up to 88% in 2006. 40% of sludge is co-incinerated with MSW. Other outlets such as landfill cover represented 12% in 2006. The financial incentive for the production of green energy is reported to make it more beneficial to digest sewage sludge (as a pre-treatment) and produce biogas (49% of sludge) and then to dry (88%) and to incinerate with energy recovery. In the future, it is reported (OVAM, 2009 personal communication) that incineration is unlikely to increase and other techniques such as hydrostab will be used.

Flanders-Trends in average quality of all municipal sewage sludge between 2000 and 2006 (OVAM 2008):

Parameter	**2000**	**2002**	**2003**	**2004**	**2005**	**2006**
Cd (mg/kg ds)	3.8	4.2	4.6	3.7	4	4.1
Cu (ppm DM)	310	308	345	354	329	317
Ni (ppm DM)	45	39	70	48	40	33
Pb (ppm DM)	177	171	164	173	166	160
Zn (ppm DM)	1,174	1,150	1227	1258	1,255	1,383
Hg (ppm DM)	1.6	1.4	1.3	1.2	1.2	1
Cr (ppm DM)	77	74	118	84	74	72
N (%DM)	3.5	4.4	5.3	5.2	4.6	4.5
P2O5 (%DM)	4.6	4.5	5.1	5.7	4.8	5.6

For our baseline scenario we have assumed that there will be no sludge recycled to agriculture in 2010 and in 2020 all sludge will be thermally treated.

Brussels region

In the Brussels region, it is currently estimated that 90% of inhabitants are connected to the sewage system. It is expected that, by 2015, 100% of inhabitants will be connected. The first (and only) wastewater treatment plant with a capacity of 360,000 pe started operation in 2000. The second treatment plant with a capacity of 1.1 M pe started operating in 2008.

Sludge at the Northern plant is treated by thermal hydrolysis/anaerobic digestion followed by wet oxidation reducing sludge quantities by 99%. The final product is sent to landfill or used in construction materials. Information submitted by the regional authority (IBGE/BIM 2009, personal communication) on the quantities of sewage sludge produced in the Brussels region is reported below:

Brussels region - Annual quantities of sewage sludge arisings and outlets in 2006 (tds)

	Production	Incineration	Landfill	Agriculture	Other
Southern plant	2,967	1,720 (58%)	1,247 (42%)		
Northern plant	0	-	-	-	-
Total	2,967				

In 2002, sludge produced at the first works was recycled to land (32%), sent to landfill (66%) and incinerated (2%). However, by 2006, with no recycling of sewage sludge in agriculture, 58% was incinerated and 42% was landfilled.

For our baseline scenario we have assumed that there will be no increase in sludge arisings by 2010, there will be no recycling to agriculture and sludge will be treated by wet oxidation and disposed of for other uses, and that the situation will not change by 2020.

Bulgaria

The following description is based on information provided by Paskalev for the latest version Global Atlas (LeBlanc *et al*, 2008) and various other reports including MoEW 2003 and UNDP/GEF Danube Project 2004.

The population in Bulgaria was around 8.1 M in 2000 decreasing to 7.8 M in 2002. The forecast is for continued decline: from 7,785,091 inhabitants in 2003 to 7,323,708 inhabitants in 2014 that is a 6% decrease of population (MoEW, 2003).

Bulgaria joined the EU only recently (January 2007) and has been granted an extended deadline until December 2014 to comply with the UWWT Directive. The transition period for implementing the Directive 91/271/EC in Bulgaria is as follows:

- By 1 January 2011 - construction of sewerage systems and WWTPs for settlements with more than 10,000 pe;
- By 1 January 2015 - construction of sewerage systems and WWTPs for settlements with 2000-10000 pe.

In 2002, the proportion of the population connected to a public sewer network and to a wastewater treatment plant was 68.4% and 38.6%, respectively. There were 55 existing treatment plants of which 43 plants had biological treatment while the remaining had only mechanical treatment. Half of these are in need of reconstruction and modernisation.

The Government plan to connect an additional 2.4 million people and to build about 1,000 new treatment plants to treat up to 85% of wastewater generated by the population as part of the plan to meet the EU UWWT Directive between 2003 and 2015. 80% of these new treatment plants will be of medium size (2000-10,000 pe) with the rest larger than 10,000 pe. (MoEW 2003 reported by UNDP/GEF 2004).

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Total**
New WWTPs >10,000 pe:	1	2	7	22	43	53	48	33	0	0	0	0	209
New WWTPs for 2,000-10,000 pe;	0	0	0	0	0	19	87	129	177	196	154	87	849
WWTP for completion	6	8	7	9	8	5	2	2	0	0	0	0	47
WWTPs for reconstruction and modernisation	6	16	18	29	30	32	20	23	4	2	0	0	180

At the end of 2005, there were 429 agglomerations ≥ 2000 pe with a generated load of 10,265,153 pe.

Sludge production was reported to amount to 31,300 tds in 2004, 33,700 tds in 2005 and 30,000 tds in 2006. This is equivalent to only 4 kg DS per capita (CEC 2009, personal communication).

Based on the above table, by the end of 2010, Bulgaria is expected to have completed 50% of its construction of new treatment plants (mainly above 10,000 pe) and to have upgraded existing plants. Thus sludge production is expected to increase by 50% compared with 2004, amounting to around 47,000 tds. By 2020, compliance should be achieved and sludge production has been estimated to reach 151,000 tds (85% of 7.1 M @ 25 kg/capita and per year).

In Bulgaria, there is a National Plan for sewage sludge which recommends the development of a programme for recycling of sewage sludge in agriculture and forestry, as well as in land reclamation projects. The Plan requires that sludge be at least, mechanically dewatered for treatment plants with more than 10,000 pe; and treated by anaerobic digestion for treatment plants with more than 150,000 pe. It is also planned to incinerate sludge using fluidized bed furnace units for treatment plants with more than 500,000 pe.

The majority of sludge is currently sent to landfill after stabilization, usually by mesophilic anaerobic digestion. Aerobic digestion is rarely used. Current practice for landfilling is to partition special cells for sludge at the landfills. There are no sewage sludge incineration plants in Bulgaria. A project for the incineration of waste produced in Sofia is under development. This could potentially also handle sewage sludge.

Although there was no experience of recycling sludge on land in Bulgaria in 2006, 40% of sludge was reported to be used in agriculture. There have been only a few cases of sludge recycling in land reclamation and it is considered in Sludge Management Plans. There are no special regulations for the use of sludge in land reclamation and there are other possibilities of reuse on non-agricultural land.

For our baseline scenario, we have assumed that by 2010, the outlets for sludge will be 50% recycling to agriculture; 30% going to landfill and 20% to other outlets. By 2020, recycling to agriculture will increase together with recycling to land reclamation at a rate of 60% and 20% respectively. Disposal of sludge to landfill will decrease to 10% and incineration and co-incineration will increase to 10%.

Cyprus

The following description is mainly based on information provided from different presentations by Anonymous in 2000, Mesimeris in 2004 from the Ministry of Agriculture, National Resources and Environment (MANRE). *This report has been revised following comments received from the Ministry of Agriculture, Natural Resources and Environment during the first on- line consultation in August 2009.*

Cyprus joined the EU in May 2004 and has been granted an extended period until 2012 for full implementation of the requirements of the UWWT Directive. At the end of 2005, there were 57 agglomerations equal or above 2000 pe with a total generated load of 860,800 pe. 49% of these were reported to be collected and treated by at least secondary treatment while 34% received more stringent treatment. It is expected that by 2012 Cyprus would have completed its implementation programme for wastewater connection and treatment. In 2007, wastewater treatment plants were in operation for the 4 largest agglomerations on the coast of Cyprus.

It was reported that previous to 2004, no data were available on sludge production and disposal routes and that only limited quantities were recycled to agriculture. The quantities produced and recycled to land as reported to the Commission for 2004-2006 (CEC 2006) are presented below:

Year	Total production	Agriculture	
	Tds/annum	Tds/annum	%
2004	4,735	3,134	66%
2005	6,542	3,427	52%
2006	7,586	3,116	41%

The future sludge production estimates reported by the official authority (2009, personal communication) are presented in the table below. They are based on a survey of the sewerage boards of Cyprus and the Water Development Department. Total sludge production will amount to about 10,800 tds in 2010 and 17,620 tds by 2020. This is equivalent to a sludge production rate of 12 kg per capita in 2010 and 18.5 kg per capita by 2020. We have used these figures for our baseline scenario.

WWTP	Future sludge production (tds/y)	
	2010	2020
Vathia Gonia	2,000	2,000
Nicosia (Vathia Gonia WWTP)	800	720
Limassol	2,500	4,700
Nicosia (Anthoupolis WWTP)	800	2,400
Larnaca	1,100	2,100
Agia Napa/ Paralimni	1,000	1,700
Paphos	2,600	4,000
Total	**10,800**	**17,620**

Some studies have considered alternative disposal outlets for sewage sludge such as use as an alternative fuel at cement kilns. Trials have started at Vassiliko Cement Plant (Cyprus)

(Zabaniotou and Theofilou, 2008). Reclamation of disturbed mine land with sewage sludge has also been investigated (Kathijotes, 2004).

For our baseline scenario, we assumed that the proportion of sewage sludge being recycled to agriculture will stay at around 40 to 50% in 2010 and 2020 and that the remaining quantities will mainly be co-incinerated in cement plants.

Czech Republic

The following description is based on information provided by Michalova, 2004 and Jenicek for the latest version Global Atlas (LeBlanc *et al*, 2008) and reports submitted to the Commission. *This report has been revised following comments received from the Ministry of Environment during the first on-line consultation in August 2009.*

The Czech Republic joined the European Union in 2004. There are about 2000 municipal wastewater treatment plants in operation and compliance with the UWWT Directive is expected to be achieved by 2010,

Estimated sludge production has increased by about 50% from 146,000 tds in 1995 to 220,000 tds in 2006 (see table below based on data from Michalova, 2004, CEC 2006, CEC 2009, personal communication).

Compliance with the UWWT Directive is expected to be achieved by 2010, and future sludge production is estimated to increase by about 20% by 2010 and to stabilise at that level (263,600 tds per annum) for the next 10 years as population growth is predicted to be limited during that period.

Year	**Annual sludge production ($x10^3$ tds)**	**Quantities recycled to agriculture**		**Quantities sent to landfill**	
		($x10^3$ tds)	**(%)**	**($x10^3$tds)**	**(%)**
1995	146	35	24	70	50
2001	146	62- 70	42-48	40	19
2002	206	0.2	>1	45	22
2003	211	0.3	>1	25	12
2004	206	33	16	Ni	
2005	211	8-35		Ni	
2006	221	8-25		Ni	
2007	231	60	26	NI	

Ni – no information

Historically, sludge was typically sent to landfill (40%) and recycled to agriculture (25%).

Direct sludge application to land has decreased in recent years due to stricter rules concerning sludge quality in terms of heavy metal and pathogens content. At the same time the, application of composted sludge has increased. While in 2001, more than 60,000 tds of sewage sludge produced was reported to be recycled to agriculture, there was nearly no recycling in 2002 and 2003. From the latest report to the Commission (CEC 2009, personal communication), since 2004, the quantities recycled to agriculture have risen again to 60,000 tds (26%) in 2007. However, it is reported that about 2/3 of sewage sludge produced is ultimately recycled to agriculture, mostly after composting.

The amount of sludge landfilled in the Czech Republic has steadily decreased over the last decade from 50% to 10-15 % of annual production.

A negligible amount of sludge is incinerated. At present, only one municipal wastewater treatment plant has such technology. Sludge is also incinerated in cement plants. A slow increase in the market share of more expensive technologies, such as incineration or other thermal treatment methods can be expected. However, this increase will probably be lower than in Western Europe.

For our baseline scenario, we consider that recycling of sludge to agriculture will remain high at about 75% mainly after composting and that by 2020, landfilling will only cover 5-10% and thermal treatment will rise to 15-20 % of annual production.

Denmark

The following description is based on information provided by Jensen (2004), the Commission report (CEC 2006) and via the Eureau survey (2008). *This report has been revised following comments received from a commercial stakeholder during the first on- line consultation in August 2009.*

Denmark has achieved high level of compliance with the UWWT directive. At the end of 2005, there were 415 agglomerations ≥ 2000 pe with a generated load of 11,769,028 pe; 100% collected and 99.8% treated by more stringent treatment.

By 2010, based on a sludge production of 25kg/capita, the increase in annual sludge production should be limited to 141,500 tds. As population growth is limited, sludge quantities should not change between 2010 and 2020. No recent figures on sludge quantities have been submitted to the Commission for Denmark, but past records (see table below, CEC 2006) showed that sludge production has decreased significantly since 1995 from 167,000 tds down to around 140,000 tds in 2002. This is reported to be due to different ways of reporting content of dry matter rather than an actual reduction in production. According to Eureau survey, in 2008, sludge production only amounted to 77,530 tds. Similarly, sludge quantities and proportion recycled to agriculture have also decreased from 67% in 1995 to 59% in 2002.

Year	Annual sludge production ($x10^3$ tds)	Quantities recycled to agriculture	
		($x10^3$ tds)	(%)
1995	166,584	109,369	67
1996	161,717	104,095	64
1997	151,159	94,250	62
1998	153,780	96,200	62
1999	155,621	95,500	61
2000	-	-	-
2001	158,017	83,292	53
2002	140,021	82,029	59

There was a target for 2008 for 50% recycling through agriculture, 45% incineration corresponding to 25% incineration with recycling of ashes in industrial processes and 20% “normal” incineration. However, it was reported during the consultation that the 25% of sludge treated by incineration with recycling of ashes in industrial processes were based on a new technology which did not succeed which may lead to a reduction of incineration. On the other hand, the Government has recently changed tax on incineration which will mean that, by 2010, lower tax will apply for ‘normal’ incineration of sludge which could lead to an increase of incineration.

For our baseline scenario, we have assumed that sludge production will remain constant at about 140,000 tds in 2010 and 2020 and that recycling to agriculture will remain at around 50% for 2010 and 2020 and incineration at around 45%.

Estonia

Limited information was found for Estonia. Sludge quantities recycled to agriculture reported to the Commission (CEC 2009, personal communication) amounted to 2,640 tds in 2000; 3,575 tds in 2004 and 3,316 tds in 2005. No figure was provided for total quantities produced.

At the end of 2005, there were 46 agglomerations ≥ 2000 pe with a generated load of 1,488,789; 89% were reported to be collected and at least treated by secondary treatment and 64% with more stringent treatment. Based on 20 kg/pe and 90% collection and treatment, sludge production in 2005 was estimated to amount to 26,800 tds. This means that recycling to agriculture accounts for 12% of estimated sewage sludge production.

For our baseline scenario, we have assumed that future sludge production would increase to around 33,000 tds and that recycling to agriculture would remain low at around 10-15% while the remaining going to other unspecified outlets.

Finland

The following description is based on information provided by Rantanen for the latest version Global Atlas (LeBlanc *et al,* 2008) and data provided to the Commission. *This report has been revised following comments received from a commercial stakeholder during the first on- line consultation in August 2009.*

Finland (as of 2005) has a small population of 4.4 M inhabitants living in scattered dwellings (Santala *et al*. 2006). More than 70% of its territory is covered by forests, equivalent to 21.3 M ha.

Finland has achieved a high level of compliance with the UWWT Directive. At the end of 2005, there were 177 agglomerations ≥ 2000 pe with a generated load of 4,984,100 pe; 99% was collected and treated by more stringent treatment while the remaining 1% relied on individual treatment systems. Following the implementation of the UWWT Directive in Finland, 63% and 100% of population will have N and P removal respectively. Decree No542/2003 on individual wastewater system came into force in 2004 and sets minimum standards for wastewater treatment in rural areas where there are no centralised wastewater treatment plants. There are plans to transport 90% of the sludge produced by these on-site systems to centralised plants.

The total amount of municipal sewage sludge produced in Finland was about 150,000 tds in 2004 and 2005 (see table below). Quantities seem to have decreased since 2002.

Although 17% of sludge was recycled to agriculture in 2003, by 2006 only 3% was used in agriculture the rest being used in landscaping including landfill cover (Syke, 2007). Although the concentrations of heavy metals have decreased and were well below the limit values specified in the Sludge Directive and the more stringent Finnish requirements, the proportion of sludge recycled to agriculture has diminished and has shifted to landscaping operations. The most common sludge treatment process in Finland is composting. 73% of the wastewater treatment plants compost their sludges in open pile or windrows and 21% in closed reactors (Sänkiaho and Toivikko, 2005). Mesophilic anaerobic digestion is common in the largest cities. The use of other methods such as lime stabilization, thermal drying, incineration, thermophilic digestion and chemical treatment are marginal.

Future sludge production is expected to increase to 154,000 tds by 2010 with proportions for the two main outlets remaining constant, with less than 5% recycled to agriculture and 90% recycled to other land after composting. Recycling in forestry is currently being investigated as a possible new outlet, and incineration of sludge could also become more popular.

Year	Total amount of municipal sewage sludge (tds per annum)	Sewage sludge used in agriculture	
		(tds per annum)	%
1995	141,000	47,000	33
1996	130,000	49,000	38
1997	136,000	53,000	39
1998	158,000	23,000	14
1999	160,000	23,000	14
2000	160,000	19,000	12
2001	159,900	25,000	16
2002	161,500	22,000	14
2003	150,000	26,000	17
2004	149,900	11,600	8
2005	147,700	4,200	3

In 2006, Finland passed new legislation, [Government Decree (539/2006)], concerning the use of organic fertilizers including sludge. The Decree regulates potentially harmful elements, pathogens and pathogen indicators by setting limit values in products as well as rates of application. The amounts of nutrients are also regulated. The Decree also stipulates which treatment methods are suitable for producing products of high hygienic quality. For sludge treatment these are thermophilic anaerobic digestion, thermal drying, composting, lime stabilization and chemical treatment. Other methods can also be validated if they can be demonstrated to produce a product with a consistently good hygienic quality.

Previous legislation regarding the national implementation of Sludge Directive is still enforced. More can be found in *http://www.finlex.fi/fi/viranomaiset/normi/400001/28518*, in Finnish and Swedish.

France

The following description is based on information provided by papers published by the Agences de l'Eau (2004), by ACONSULT (2007), data provided to the Commission (CEC 2006) and by Eureau (2009, personal communication). *This report has been revised following comments received from the French Authorities during the first on- line consultation in August 2009*.

France has a large population, estimated at 63,235,568 inhabitants in 2006. In 2004, it was reported that there were 16,400 treatment plants with a capacity of 90M pe. 19% of the population was not connected to sewer and 17% relied on individual treatment systems (i.e. cesspool) (IFEN 2008). At the end of 2005 (CEC 2009), there were 3,004 agglomerations ≥ 2000 pe with a generated load of 67,180,943 pe; 100% was collected with 93% treated by at least secondary treatment with 54% undergoing more stringent treatment. At the end of 2008, there were 17,500 treatment plants including 3,083 above 2000 pe, of which 36% apply secondary treatment, 61% apply more stringent treatment and. 268 are not in compliance with the UWWTD. A national action plan is in place to ensure full compliance by 2011. About 67% of effluent is from domestic origin.

In 2002, (CEC 2006) sludge quantities amounted to about 910,000 tds of which 60% was recycled to agriculture. According to the Agences de l'Eau, the quantity of sludge produced in 2004 amounted to 807,000 tds per annum; 62% being recycled to agriculture, 20% disposed of to landfill, 16% to incineration and 3% to other outlets. According to Eureau (2009, personal communication), in 2008, there were 963,800 tds of sludge produced in France; 55% being recycled to agriculture; 24% sent to landfill; 17% incinerated; and 3% disposed of to other outlets.

More recent figures submitted by MoE during the consultation (2009, personal communication) showed that, in 2007, sewage sludge production amounted to 1.12 M tds of which 69% was recycled to agriculture; 18% incinerated and 12% sent to landfill. Since 2002, there has been a steady increase in the quantities recycled to agriculture, a proportion of which being composted (21% in 2006; 24% in 2007 and 28% in 2008).

Although the land area receiving sludge has increased to about 240,000 ha per annum, which represents about 3% of the total arable land, the rate of application has decreased to about 2.5 tds per ha per annum.

The improvements in treatment capacity and level of connections have and will continue to lead to an increase in sludge production which has been estimated to amount to (FP2E, 2009 personal communication) 1.3 Mtds/annum for 2010 (i.e. 20 kg/pe) and 1.6 Mtds/y by 2020 (i.e. 21 kg/pe). Although the quantities recycled to land will increase as sludge production increases, the proportion will probably decrease from 70% down to 50% by 2020 as volumes sent to incineration increase especially for new large treatment plants located in large agglomerations. In addition, it is reported that the potential sludge production from individual treatment systems could amount to 21,000 tds per annum.

The official authority estimates (MoE 2009, personal communication) that, by 2020, sludge production will increase by 17% to about 1.4 M tds as compliance with the UWWT Directive is achieved. This takes into account improved wastewater treatment (increase of sludge production) and increased sewage sludge treatment (decrease of sludge production). That is anaerobic digestion for treatment plants >20,000 pe which is expected to reduce sludge production by 30% as well as the installation of advanced treatment at one of the largest treatment plants in Achère, treating wastewater from Paris, which is expected to reduce sludge quantities by 50%.

The levels of sludge recycled to agriculture is expected to continue to rise up to 75-80% in the future (MoE, 2009 personal communication). There are also some on-going trials looking at recycling of sludge to forestry.

Data submitted to the Commission (CEC 2006) are presented below:

Year	**1995**	**1998**	**1999**	**2001**	**2002**
Total production (tds/y)	750,000	858,000	855,000	893,252	910,255
Recycled to agriculture (tds/y)	494,000 (66%)	554,000 (65%)	552,000 (65%)	509,250 (57%)	524,290 (58%)

Data from the Agences de l'Eau survey (2004) are presented below:

Region	Sludge production (x10[3] tds)	Agriculture (%)	Landfill (%)	Incineration (%)	Other (%)
Artois picardie	57	90	10	0	0
Rhin Meuse	82	46	23	24	7
Loire Bretagne	160	68	19	13	0
Seine Normandie	192	81	4	9	6
Adour Garonne	70	63	22	8	7
Rhone Mediterranee Corse	246	36	34	28	2
Total	**807**	**62**	**20**	**16**	**3**

Data from the Ministry of Environment (2009, personal communication) are presented below:

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008 ***
Total production (tds/y)	946,700	989,054	1,021,472	1,027,168	1,118,795	1,166,048
Recycled to agriculture (tds/y)	537,387 (57%)	573,889 (58%)	633,812 (62%)	624,923 (61%)	776,305 (69%)	846,004 (73%)
Including composted (tds/y)				210,781	263,377	322,129
Area needed (ha)	223,392	233,889	249,937			
Incinerated (tds/y)	188,991 (20%)	197,658 (20%)	215,684 (21%)	203,031 (20%)	204,592 (18%)	215,328 (18%)
Landfilled (tds/y)	193,494 (20%)	180,345 (18%)	132,255 (13%)	199,214 (19%)	137,898 (12%)	104,716 (9%)

- preliminary figures

Trends in quality of sludge recycled to agriculture between 2003-2005 is presented below:

Parameter	2003	2004	2005
Cd (mg/kg ds)	1.8	1.5	1.3
Cu (ppm DM)	305	280	272
Ni (ppm DM)	24	23.5	21
Pb (ppm DM)	64	57	50
Zn (ppm DM)	641	632.5	598
Hg (ppm DM)	1.3	1.2	1.1
Cr (ppm DM)	48	36	43
Tot N (%DM)			6.4
Tot P (%DM)			5.5

Since 1998, there have been strict regulations in place for recycling of sewage sludge to agriculture (Order of 8 January 1998, Circulars 14 March 1999 and 18 April 2005). For example, the limit values in sludge and for soil treated sludge are usually lower than the minimum values specified in the 86 Directive and there are limits for some organic contaminants. There is a detailed system of traceability in place. There is a guarantee fund (Decree of 18 May 2009) to pay compensation to farmers if their land became unsuitable for agriculture due to recycling of sludge.

For our baseline scenario, we have considered that future sludge production will continue to increase and should amount to 1.3 million tds by 2010 with levels stabilising at 1.4 M tds by 2020. The proportion of sludge recycling to agriculture will continue to increase at around 75-80% over the next 15 years while landfilling continues to decrease down to 5% by 2010. Incineration is expected to remain at around 15% with the remaining sludge being recycling to other non-agricultural land.

Germany

The following description is based on information provided by Schulte for the latest version Global Atlas (LeBlanc et al, 2008). *This report has been revised following comments received from the Federal Ministry of Environment and three of the Regional competent authorities and commercial stakeholders during the first on- line consultation in August 2009*.

In 2008, about 10,000 municipal wastewater treatment plants were in operation in Germany with a total capacity of 82 M pe. 250 of the biggest plants (with design capacities of more than 100,000 pe) treat about 50% of the wastewater, while a further 7,000 small sewage works (with design capacities less than 5,000 pe) contribute less than 10% of treatment capacity. About 94% of the wastewater volume is treated to a high standard that comprises biological treatment with nutrient removal. It is reported that 20% of effluents were from industrial origin. At the end of 2005, there were 4,2002 agglomerations ≥ 2000 pe with a generated load of 114,691,778 pe; 98.7% was collected and treated at least by secondary treatment and 97.2% by more stringent treatment .

The latest figures published by the Commission (CEC, 2006) showed that, in 2003, about 2.1 million tonnes of sewage sludge (dry matter) were produced in Germany and that 33% was recycled to agriculture. More recent figures from the German Association for Water, Wastewater and Waste (DWA) (BMU 2009, personal communication), show that total sludge production was 2.06 M tds in 2007, with; 29% recycled to agriculture; 18% in landscaping; 50% being thermally treated and 3.5% via other recycling methods. The reported sludge production rate is about 80 g ds pe per day for raw sludge and 55 gds pe per day after digestion.

No change in sewage production is expected in the future due to the existing high connection rate to the sewerage system and thus to wastewater treatment, and the expected decrease in population, modernisation of industrial production processes and the development of new techniques reducing the amount of sludge produced.

In Germany, sludge quality has improved dramatically over the last 20 years.

Over the past few years, thermal processes have become more significant for sludge management, at the expense of landfilling and recycling to land (agriculture and landscaping). This was primarily due to the following developments:

3. Disposal of sludge to landfill is no longer possible in Germany, as materials with a total organic content (TOC) of more then 3% have been banned from landfill since 2005; and
4. The political debate during the past few years about sludge recycling to land in Germany caused a lot of uncertainty. The debate focused mainly on organic contaminants which are not yet regulated, such as phthalates, pharmaceuticals or perfluorinated compounds. These discussions proposed not only the introduction of more stringent requirements such as lower maximum permissible values for heavy metals and limits for additional organic compounds and stricter hygienic quality, but also a complete ban on sludge recycling. In consequence, some operators of sewage treatment plants felt that sludge recycling to agriculture might not

be a reliable disposal option in Germany and therefore viewed thermal treatment as a more sustainable choice.

The German Sludge Ordinance of 15 April 1992 specifies stringent requirements in terms of quality limit values, restrictions on types of crops and land areas. Some federal states (Bavaria, Baden-Wurttemberg, North Rhine-Westphalia) do not support the application of sewage sludge to agriculture based on the precautionary principle. This has led to a sharp decrease in quantities of sewage sludge recycled to agriculture. For example in Baden Wurtenberg, between 2001 and 2008, the proportion of sludge recycled to agriculture fell from 20 % to 2% while the proportion of sludge incinerated increased from 31% to 87%.

Even though the use of sewage sludge has been strictly regulated by the 1992 Federal Ordinance in terms of limit values for heavy metals and some organic compounds, many experts considered that the maximum permissible values were too high. In November 2007, the Federal Environment Ministry published a new draft sludge ordinance. The draft ordinance proposes a significant reduction in existing limit values for heavy metals and limit values for additional organic substances.

The proportions of sludge going to the different disposal outlets for sewage sludge in Germany are presented in the table below.

Year	Total sludge production ($x10^3$ tds/y)	Agriculture (%)	Land-scaping (%)	Thermal treatment (%)			Landfill (%)	Inter-mediate storage (%)	Other /unspecified (%)
				Mono-incineration	Incineration in cement or power plants	MSW incineration			
1995	2,249	42		28					30
2000	2,297	37		34			3		20
2003	2,172	32	25	20	14	3	3	3	
2005	2,106	31		38			2		29
2007	2,056	29	18	22	25	1.5	>1	3.5	

Since 2003, there has been a voluntary quality system – VDLUFA-QLA - in Germany (Budewig, 2008) which introduced additional requirements regarding input, products (i.e. more stringent limit values) and utilisation of sewage sludge. About 8% of sewage sludge produced in Germany is currently certified by QLA.

Our baseline estimates for 2010 and 2020 assume that municipal sewage sludge production will remain at around 2 million tds per annum. For our baseline scenario, for 2010 and 2020, we assume the proportion of sludge recycled to agriculture may decrease slightly to around 25 to 30%, the proportion being used for landscaping will remain stable at around 25% and the proportion treated thermally will increase to about 50%.

Greece

The following description is based on information provided in a presentation from Karamanos et al (2004) on implementation of the UWWT Directive.

In 2004, it was estimated that 95% of households were connected to the sewerage system and that about 60% of the permanent population was served by 350 municipal wastewater treatment plants. The remaining population is in small villages and remote areas for which individual sanitation technologies should be used. According to the Commission, there are around 100 agglomerations above 2,000 pe in Greece with a total generated load of about 10 M pe.

Following the implementation of the UWWT Directive, large-scale sewage treatment plants have been constructed in recent years. However, as of 2009, Greece has not yet fully complied with the UWWT Directive requirements. About 56% of generated load from agglomerations discharging into sensitive areas was compliant, while about 90% of generated load from agglomerations discharging into normal areas was compliant

In Greece, sludge production dramatically increased from 52,000 tds in 1995 to 83,400 tds in 2004, 116,800 tds in 2005 and about 126,000 tds in 2006 (CEC 2006 and CEC 2009, personal communication). There are currently only small trials of recycling of sludge to agriculture (less than 100 tds per annum) and the majority of sludge produced is sent to landfill. This is in agreement with figures provided from a recent Eureau survey (2008), which reported that sludge production amounted to about 126,000 tds; the majority being disposed of to landfill with only minor trials of sludge recycling to agriculture (100 tds).

Year	**Sludge production (tds per annum)**	**Agriculture (%)**	**Landfill (%)**	**Others (%)**
1995	51,624	0	95	5
2000	66,335	0	95	5
2005	116,808	<1	95	5
2006	125,977	<1	95	5

For our baseline scenario, we have assumed that by 2010, Greece will be complying with the UWWT Directive and that sludge production will have more than doubled to amount to 260,000 tds (25 kg * 95% of 11.1 M inhabitants). By 2010, recycling to agriculture will remain low (5%) and landfilling will remain the main outlet at 95%. By 2020, sludge production will remain at around 260,000 tds but landfilling will have decreased to 55-60%,replaced by thermal treatment (35-40%) while agriculture will remain low at about 5%.

Hungary

The following description is based on information provided by Garai for the latest version Global Atlas (LeBlanc *et al*, 2008) and from a presentation by Toth (2008). *This report has been revised following comments received from the Hungarian Ministry of Environment during the first on- line consultation in August 2009.*

Hungary joined the EU in May 2004. It has a population of around 10 million and a total area of 93,000 km^2. Budapest has a population of 1.85 million with 96% connected to sewer but only 49% are served by the 2 existing wastewater treatment plants and thus untreated sewage is discharged into the Danube. A new plant (Central) has been commissioned and should be operational in 2010. In the rest of the country the situation is worse with only an estimated 68% of population connected to sewer and less than 1/3 of 3000 settlements having adequate wastewater treatment. At the end of 2005, there were 404 agglomerations ≥ 2000 pe with a generated load of 9,643,155 pe; 80% was collected and treated by secondary treatment and 20% relied on individual treatment systems.

The priority is to tackle sewerage problems from industry and 10 large cities. There are smaller investments for settlements of less than 15,000 people and by 2015, it is planned that all agglomerations of more than 2,000 pe will have a modern sewage treatment system.

The most commonly applied wastewater treatment technology is activated sludge. Sewage sludge is usually dewatered by filter belt press or centrifuge to a typical dry solids content of 18-20%. At the largest treatment plant in Hungary (North-Budapest Wastewater Treatment Plant), membrane presses are operated and sludge dry solids content is between 36-38%. A small proportion is dried.

At the larger plants, sludge is usually treated by mesophilic anaerobic digestion. At some plants, electricity is produced by biogas engines. Composting of sludge is reported to be on the increase (Ministry of Environment, 2009, personal communication).

Agricultural recycling is controlled by two regulations: the first covers compost products and the second one is for use of sewage sludge in agriculture. The bans imposed on sewage sludge recycled to land by the Government Decree 50/2001 (IV.3) are listed below:

- Protected areas (i.e. Natura 2000)
- Meadow or pasture
- Along the banks of surface waters or agricultural areas subject to flooding
- Drinking water protection zones
- Karst areas or in areas with limestone, dolomite, lime- and dolomite marl formations found 10 m below surface
- Forests
- Organic farms

Longer waiting periods are set in the Hungarian legislation with no application allowed in the growing year and in the previous year on lands used for growing of vegetables and fruits in contact with the soil.

There are no incinerators for sewage sludge in Hungary. The capacity of hazardous waste incinerators is not sufficient to receive a significant amount of sewage sludge, and the cost of processing is too high. Some cement factories are authorised for sludge incineration and trials have been performed, but it is not used on a regular basis (Garai, 2008).

From 1 July 2009, the proportion of biodegradable MSW going to landfill has to be reduced to 50% of total quantities produced in 1995 and to 35% from 1 July 2016. This will have an impact on the proportion of sewage sludge going to landfill.

While the quantities produced as reported to the Commission for 2004-2006 (CEC 2009) increased from 120,741tds to 128,400 tds, respectively the proportion recycled to agriculture decreased from 30 to 24%, respectively. According to the Ministry of Environment (2009, personal communication), the current sludge production rate is 25.8 kg/pe/year. According to a 2008 Eureau survey, the total sludge production in 2007 was about 119,000 tds/year. Sewage sludge was predominantly sent to landfill (72,000 tds, 61%) or recycled to agriculture (47,000 tds, 39%). Figures reported by Toth (2008) for 2005 also differ significantly from the ones reported in the Eureau and Commission surveys; quantities produced amounted to 105,000 tds; quantities recycled to land including recycling to agriculture and land reclamation directly and after composting amounted to 70,000 tds (67%) while quantities sent to landfill were only about 25,000 tds (24%) and about 10,000 tds to other/unknown outlets (9%).

Sludge quantities as reported to the Commission (CEC 2009):

Year	Sludge production (tds per annum)	Agriculture (tds)
2004	120,741	36,105 (30%)
2005	125,143	42,329 (34%)
2006	128,379	32,813 (24%)

The current and future estimates for sludge disposal outlets are presented below (Ministry of Environment 2009, personal communication):

Outlets	2006-2007 (%)	2020 (%)
Agriculture	65	59.3
Landfill	24	5.5
Others (biogas, incineration, renewable energy)	10	35.2

According to Toth (2008), total sludge production will rise to 175,000 tds by 2010 and reach a plateau of 200,00 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 135,000 tds (77%) and then decrease to about 115,000 tds (58%) by 2020. Quantities sent to landfill will steadily decrease to 20,000 tds in 2010 reducing further to 10,000 tds by 2020. Quantities sent for incineration will increase from 2010 until 2020 to reach about 60,000 tds per annum. The quantities sent to other/unknown will not change.

According to Garai (2008), the government aims is to decrease landfilling and increase the proportion of sludge being recycled to agriculture. By 2015, the proportion of landfilling is expected decrease to 33%.

According to the Ministry of Environment (2009, personal communication), Toths's estimate of 77% for the proportion of sludge recycled to agriculture for 2010 is probably too high, but the 58% expected for 2020 is realistic. The future proportion of sludge recycled to agriculture is expected to increase mainly using composted sludge.

For our baseline scenario, we have used figures presented by Toth (2008). We have assumed that by 2010 sludge production will amount to 175,000 tds reaching 200,000 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 70 % and then decrease to about 60% by 2020. This will include a proportion of composted sludge. Quantities sent to landfill will steadily decrease to 20% in 2010 and 10% by 2020 while quantities sent for incineration will dramatically increase from 5% in 2010 to 30% by 2020.

The nutrient content of sewage sludge used in agriculture between 2004 and 2007 (MoE, 2009, personal communication) is reported below:

Year	N (kg/tds)	P2O5 (kg/tds)
2004	34.2	18.2
2005	30.4	24/7
2006	30.4	31.3
2007	26.2	30.4

Ireland

Information has been extracted from an EPA reports on urban wastewater discharges in Ireland (EPA 2005, 2007 and 2009) as Ireland has not submitted recent reports to the Commission on sewage sludge.

In Ireland, in 2007, there were 482 agglomerations with populations greater than 500 pe, which collectively represent a total of 5,835,495 pe (EPA 2009). This includes 313 agglomerations ≤ 2000 pe which represent 5.6% of total load; 113 agglomerations from 2,000 to 10,000 pe representing 9.3% of total load; 19 agglomerations from 10-15,000 pe representing 4.1% total load, 35 agglomerations from 15-150,000 pe representing 26.3% of total load and 2 ≥ 150,000 pe which collectively represented 55% of the waste water discharges for 2007 .

There have been delays in providing the required treatment plants at a number of locations throughout the country. Although there have been large investment between 2000 and 2007 and improvements have been achieved since the previous reporting period, in 2006/2007, full compliance with the UWWT Directive is not expected to be achieved by 2010.

It is reported that, in 2007, 4% of wastewater received no treatment compared with 11% in 2005; 5% of wastewater received preliminary; 1% only primary treatment; 77% of wastewater received secondary treatment compared with 70% in 2005; and 15% of wastewater received nutrient removal in addition to secondary treatment compared with 12% in 2005. Out of the 158 agglomerations requiring secondary treatment or more by December 2005, a total of 28 did not have the required level of treatment in place. By 2010, this number should have been cut by 50% and by 2020, full compliance will have been achieved.

Sludge quantities produced by treatment plants with population equivalent greater than 500 pe have significantly increased over the last 10 years from 34,500 tds in 1997 to 86,400 in 2007 (see table below - EPA 2005, 2007 and 2009). The largest quantities (20,600tds) originate from Dublin. These figures slightly differ from those reported to the Commission (1997: 38,290 tds (11%); 2000:35,039 tds (40%); 2003: 42,147 tds (63%)).

The proportion of sludge recycled to land has also increased dramatically from 10% in 1997 but has decreased since the last report to 70% in 2007 compared with 76% in 2004/2005 (CEC 2006, EPA 2009) while proportion being disposed of to landfill have decreased to 11% went to landfill. Twenty five percent went to other outlets as composted and in forestry (EPA 2009).

Year	**Sludge production (tds per annum)**	**Agriculture (%)**	**Incineration (%)**	**Landfill (%)**	**Sea (%)**	**Other (%)**
1997	34,484	9.8	0	43	42	0
1999	35,595	23	0	45	33	0
2001	33,559	45	0	54	0	1
2003	42,298	63	0	35	0	2
2004	61,923					
2005	59,827	76	0	17	0	7
2006	77,648	77	0	11	0	12
2007	86,411	70	0	5	0	25

References: EPA 2005,2007 and 2009

We have estimated that by 2010, sludge quantities will have continued to increase and will reach up to twice the current amount with full implementation of the UWWT Directive, to around 135,000 tds. It will remain at that level until 2020. By 2010, we have assumed that proportions recycled to agriculture and disposed of to landfills and other outlets would be at the similar level as in 2005 – i.e. 75%, 15% and 10%, respectively and that by 2020, while agriculture would still be the major outlet at about 65-70%, incineration would steadily increase to replace landfilling.

Italy

The following description is based on information provided by Spinoza and Canzian for the latest version Global Atlas (LeBlanc *et al*, 2008).). *No changes to this report were made following comments received from two commercial organisations during the first on- line consultation in August 2009.*

According to the Italian National Institute of Statistics (ISTAT, 2006), the total population equivalent (urban + industrial) in Italy is estimated to be around 175 million pe, of which the urban fraction is as much as 102 million pe (55.9% resident population, 14.9% tourists, 16.6% commercial sites, 12.6% crafts and small enterprises). At the end of 2005, there were 2,436 agglomerations ≥2000 pe with a generated load of 70,578,677 pe. Some 299 towns and cities (>15,000 pe) have been listed as not yet being in compliant with EU standards.

Based on an average annual production of dry solids per capita (after aerobic or anaerobic digestion) of 30 kg ds/annum/pe, the total sludge production in Italy can be estimated at around 5.25 million tds/annum, of which about 3 million tds/annum is linked to the urban population. This is a three-fold increase compared with the current sludge production when all the population would be served by sewerage and subsequent appropriate treatment.

Sludge management in Italy varies widely as far as local disposal or reuse options are concerned due to different geographical, geological, technical, economic and social contexts. Some Italian Regions have revised the regional legislation on sludge utilisation in agriculture. For example, the Region Emilia-Romagna, in Northern Italy, published a new Regional Decree 2773 on 30 December 2004, modified and completed by Decree 285 on 14 February 2005.

Monitoring of sludge recycled in agriculture in the Region of Emilia-Romagna showed a consistent occurrence of toluene and hydrocarbons so a research programme to define limits values for the above components was started in April 2007. Preliminary theoretical evaluations indicated possible safety limits of 500 mg/kg-ds for toluene and 10,000 mg/kg-ds for hydrocarbons.

In 2004, it was estimated that annual production of sewage sludge was about 4.3 Mt, corresponding to about 1 Mt of dry solids at a solids concentration of 25%, with an increase of about 10% with respect to years 2001-2003 (ONR, 2006). This is in line with the figures reported to the Commission which are presented in the table below.

Year	Sludge production (t DS per annum)	Agriculture	
		(t DS per annum)	%
1995	609,256	157,512	26
2000	850,504	217,424	26
2004	970,235	195,161	20
2005	1,074644	215,742	20
2006	1,070,080	189,555	18

According to ONR (2006), disposal of sludge to landfill accounts for only 24% of the total quantity of sludge produced, and agricultural recycling including co-composting and land reclamation, has increased to 69%. About 2% of sewage sludge is incinerated and 5% kept in temporary storage basins.

Sewage sludge is usually thickened and digested before being recycled to agriculture or sent to landfill. Sludge post-treatments, such as pasteurisation and thermal drying, are seldom practiced. Increasingly, combined composting is performed by treating sewage sludge with other organic fractions, for example municipal solid wastes, food wastes, wood chips from broken pallets, cuttings from gardening and forest maintenance, and other similar materials.

When the quality of the compost is poor, mainly due to heavy metals exceeding the limits for unrestricted use, the resulting material can be used in land reclamation or as landfill cover. In 2005, wastes treated in composting plants amounted to about 3 million tons, with an increase of 125% from 1999. Plant inflow consisted of 70% of organic fraction derived from separate collection and green wastes, 16% of sludge (+7% with respect to 2004) and 15% of other organic wastes, mainly from the food industry. In some cases, sewage sludge is added in small amounts (up to 5%) to lime and clay in thermal processes to produce inert materials, such as expanded clay for construction.

Incineration or co-incineration with municipal solid waste is the most common thermal sludge disposal route in Italy. Sludge pyrolysis with gasification is currently under evaluation by a few water service companies.

Sludge composition is reported to be highly variable in Italy because almost all treatment plants serve urban areas where industrial activities contribute to the organic pollution load. Furthermore, many medium and large sized plants are located in industrial districts, such as (i) the wool district (Biella, Piedmont), (ii) the silk district (Como, Lombardy), (iii) other textile finishing district (Prato, Tuscany), (iv) tannery districts in Veneto and Tuscany, (v) metal surface finishing districts in Piedmont and Lombardy, and other minor districts.

It is expected that, at least in Northern Italy, where co-management with municipal solid wastes due to the integration of public services (energy, waste and water), could become a real possibility for the future, anaerobic co-digestion of sludge and wet fractions deriving from separate collection of municipal solid wastes would increase. This is still a limited practice in Italy but some examples of this type are listed below:

- Treviso: 3,500 t/annum of solid waste wet fraction and 30,000 t/annum of sewage sludge are co-digested.
- Cagliari: 40,000 t/annum of solid waste wet fraction and 15,000 t/annum of sewage sludge,
- Camposampiero: 12,000 t/annum and 12,000 t/annum, plus 25,000 t/annum from zootechnical wastewaters,
- Bassano: 16,000 t/annum of MSW and 3,000 t/annum of SS,
- Viareggio: 5,000 t/annum of MSW and 50,000 t/annum of SS.

The co-incineration of sewage sludge and solid wastes in incineration plants appears feasible if a drying step for sludge is introduced. Some trials are being carried out in Sesto San Giovanni, near Milan, involving co-operation with two public companies and results are encouraging.

For our baseline scenario, we have assumed that by 2010, Italy will have complied with the UWWT Directive, that sludge production will have reached its maximum at about 1.5 M tds and will remain at that level for the next 10 years. By 2010, recycling to agriculture will remain at around 20-25% but will increase by 2020 to about 25-30%. A large proportion will also be recycled to land reclamation projects (20-30%). Most of the sludge recycled to land will first be co-composted. Thermal treatment (including co-incineration) will increase to 20 % in 2010 and 30% by 2020. A large proportion will still be landfilled in 2010 (25%) but quantities will continue to decrease down to 5% by 2020.

Latvia

Information is mainly extracted from a report produced by GHK (2006). *Following on-line consultation in August 2009, the Ministry of Environment agreed with information given in the summary report below.*

Latvia is a small Baltic state with an area of 65,000 km^2 and 2.5M inhabitants. Agricultural land occupies 39% and forestry 44% of Latvia's territory. In the last decade, with the dismantling of collective farms, the area devoted to farming decreased dramatically -farms are now predominantly small. Latvia joined the European Union in May 2004 but Latvia had started a programme of improving wastewater treatment in 1995.

Regulation 362 regulates the use of sewage sludge and compost on land. Limits of heavy metals in sludge used in agriculture are more stringent than the limits set in the EC Directive.

At the end of 2005, there were 84 agglomerations ≥ 2000 pe with a generated load of 1,893,999 pe. The whole territory of Latvia has been classified as a sensitive area under the UWWT Directive. In 2005, it was reported that 71% of the population was connected to the sewer system (almost all connected to a treatment plant). The availability of a centralised wastewater infrastructure varies from town to town. In towns with a population above 10,000 it typically reaches 70-85% of the population while in towns with a population below 10,000 it can be as low as 30% of the population.

In 2007, there were 924 biological, 6 chemical and 306 mechanical wastewater treatment plants. Out of 71 agglomerations that have a wastewater treatment plant, only 7 were complying with the UWWT Directive standards whilst 64 had a treatment plant which was not fully compliant.

Numerous wastewater projects have been planned for implementation during 2006– 2015. By the end of 2008, Latvia should have finished improvements to wastewater collection in the largest cities above 100,000 pe. Investment will continue until 2015 to construct about 60 new treatment plants with a total capacity of 1.9 M pe and upgrade existing non-compliant treatment plants with a capacity of 1.17 M pe.

Most wastewater treatment plants do not have adequate sludge treatment. The most common final disposal routes for sewage sludge are agriculture and compost.

Wastewater volumes have more than halved between 1990 and 2000, as have the quantities of sewage sludge. It was estimated that about 20,000 tds were produced in 2000, about 29% was recycled to agriculture, 38% stored, 26% used for other uses and 7% composted. No incineration was reported (EIL, 2002). Sludge production continued to decrease between 2004 and 2006 from 36,000 tds in 2004, to 28,900 tds in 2005 and down to 24,000 tds in 2005 (CEC, 2009, personal communication). Quantities recycled to agriculture have fluctuated from 7,700 tds (31%) in 2004, 6,500 tds (22%) in 2005 and nearly 9,000 tds (39%) in 2006. It was mentioned that the high level of heavy metals sometimes restrict the recycling of sludge to agriculture.

Year	Sludge production (t DS per annum)	Agriculture	
		(t DS per annum)	%
2004	36,164	7,684	21
2005	28,877	6,545	23
2006	23,942	8,936	37

For our baseline scenario, we have assumed that by 2010, Latvia will not have finished installing new treatment capacity and thus sludge quantities will not have increased substantially compared with those in 2006. However by 2020, compliance with the UWWT Directive will have been achieved and sludge quantities will have more than doubled to 55,000 tds. In 2010, we consider that recycling to agriculture will remain at around 30 %, landfilling at 40% and 30% to other unspecified outlets. By 2020, whilst agriculture remains at around 30%, landfilling will have decreased to 20% and incineration will have increased by 5% to 10%. It was reported by the Ministry of Environment (2009, personal communication) during the consultation that the incineration of sewage sludge will not be one of the main priorities in the near future.

Lithuania

The following description is based on information provided from a presentation by Ciudariene in 2007 and Cepelè in 2008. *This report has been revised following comments received from the Ministry of Environment during the first on- line consultation in August 2009*.

Lithuania has a population of 3.4 million inhabitants – its territory is divided into 10 counties and 61 municipalities with regional differences in economic development and treatment connection rates. It joined the Union in May 2004. Lithuania designated the whole territory as a sensitive area under the UWWT Directive. It had until 31 December 2007 to provide collection of wastewater and more stringent treatment for agglomerations of more 10,000 pe (i.e. 38 agglomerations) and until 31 December 2009 to fully comply with the requirements of the UWWT Directive (collection and secondary treatment for all agglomerations between 2,000 and 10,000 pe, i.e. 57 agglomerations). It is reported that there are about 75 agglomerations with more than 2,000 pe generating a total load of 2,445,100 pe; 93.3% was collected while 6.7% was reported to be treated by individual treatment systems. 82% was treated by secondary treatment and 61% by more stringent treatment.

In 2006, 60% of the population was connected to a centralised wastewater treatment plant and at least 32% of wastewater received at least secondary treatment. Sewerage systems and wastewater treatment plants are reported to be in need of upgrade and further investments have been identified for the period 2007 - 2013. The latest Commission report on the implementation of the UWWT Directive (UBA 2009), states that in 2005/06, 93% of the generated load of all agglomerations >2,000 pe was reported to be collected with 82% of the total generated load treated by secondary treatment and 61% undergoing more stringent treatment.

Between 2004 and 2006, sludge production increased from 55,350 tds to 76,450 tds per annum (see table below- MoE, 2009, personal communication). The main outlet for sewage sludge is reported to be long-term storage. Quantities recycled to agriculture have however increased during that time.

Year	Total sludge production (tds/y)	Agriculture		Other land		Landfill		Storage	
		(tds)	%	(tds)	%	(tds)	%	(tds)	%
2004	60,579	15,919	29	2,230	4	3,920	7	33,280	60
2005	65,680	16,243	25	2,226	3	3,839	6	43,371	66
2006	71,252	24,716	32	7,454	11	8,598	11	35,682	47

Due to a lack of digestion capacity, most sludge is currently only dewatered. There is however a national plan for biowaste (also covering sewage sludge) which aims to prioritise biogas production and preservation of nutrients (composting). It is planned to set up 10 regional sludge treatment centres between 2007 and 2013, to include digestion, drying and composting plants. There are 3 existing centralised plants for anaerobic digestion of sewage sludge, and an additional 7 plants planned. There is currently one private composting plant for sewage sludge. Nine more composting plants for sewage sludge are planned to be built between 2007 and 2013 using EU funding. There are currently no municipal waste incineration plants.

For our baseline scenario, we have assumed that Lithuania would have reached compliance with the UWWT Directive by 2010, that sludge production will have reached its maximum by then and amount to 80,000 tds with no further change to 2020. In 2010, recycling to land may increase to 30% as landfilling is restricted and incineration capacity will not yet be available. By 2020, landfilling will have decreased further to 30%, agricultural recycling increased to 50-60% and incineration and other thermal treatments increasing to 10-20% of produced sludge solids.

Luxembourg

Limited information was available. The following description is based on information provided from a Interreg project by Kneip *et al* published in 2007 and other reports published by the Luxembourg Administration in 2005 (AEV 2005) and the Commission (CEC 2006).

According to the latest figures from the Commission (UBA 2009), at the end of 2005, there were, in Luxembourg, 42 agglomerations ≥ 2000 pe with a generated load of 1,035,350 pe and a collection rate of 97.8%. Ninety four % of the generated load was treated by secondary treatment and up to 80% to a more stringent level. Luxembourg has wastewater treatment capacities for approximately 950,000 pe;

80% of this treatment provided by 10 biological wastewater treatment plants with capacities ≥10,000 pe. Half of these treatment plants do not comply with the EU standards with regard to organic discharges and 6 out of 10 do not comply with the emission limits for nutrients.

The limited information submitted to the Commission by Luxembourg on sludge quantities and disposal is summarised in table below. According to official figures, from 29 out of 34 treatment plants ≥ 2,000 pe equivalent to 594,444 pe, sludge production amounted to 8,037 tds in 2004 which is equivalent to 13.5 kg MS per pe; 44% were limed; 11% composted; 6% treated by aerobic thermophilic digestion and 39% were not treated or treatment was not specified. Sludge production was reported to amount to 8,200 tds in 2005 (AEV 2005). In 2008, works started on a solar drying unit.

Forty percent (3,229 tds) were recycled to agriculture (98.8% in Luxembourg and 1.2% in Germany); 36% (2,925 tds) composted (73% in Luxembourg; 27% in Germany); 18% (1,433tds) incinerated (93.5% in Germany, 6.5% in NL) and 6% (450tds) other outlets (AEV 2004 and Kneip *et al* 2007). In 2005, 46% (3,780 tds) were recycled to agriculture ; 32% (3,510 tds) were composted (28% in Luxembourg and 15% in Germany) and 11% (900 tds) were incinerated in Germany (AEV 2005).

Sludge quantities produced in 2007 were reported to amount to 9,300 tds (Eureau survey 2008) and to be mainly recycled to agriculture (95%). The remaining sludge was sent to incineration.

Year	**Sludge production (t DS per annum)**	**Agriculture**	
		(t DS per annum)	**%**
1999	7000	5600	80
2003	7770	3300	43

For our baseline, by 2010, we have assumed that there will be no change in the collection rate but that compliance with the UWWT Directive will have been reached for all the sewage and sludge quantities will have risen by 7% to their maximum of 10,000 tds. The majority (90-95%) will still be recycled to agriculture including about 35-40% after composting, 5-10% will be thermally treated and 5% disposed of to other outlets (potentially recycled to land other than agriculture). In 2020, the proportion of sludge recycled to agriculture will have decreased but will still be significant at around 80% (mainly after composting). The proportion of sludge which is thermally treated, either by incineration or co-incineration in cement plants will increase to at least 20% after a study found it to be the best environmentally option (CRTE).

Malta

No information is available, but it is believed that until 2004 there was only a very small amount of sludge produced as there was limited wastewater treatment (17% of generated load). At the end of 2005, there were 6 agglomerations ≥ 2000 pe with a generated load of 584,000 pe. Under the UWWT Directive, by 31 March 2007 all untreated wastewater (25 M m^3 per year) should have been collected and treated to the relevant standards. Since 2006, 3 new wastewater treatment plants have been built or are under construction with the construction for the final one having started in January 2009.

For our baseline, by 2010, we have assumed that all urban wastewater will be collected and treated to the relevant standards and sludge production will have risen to 10,000 tds (25 kg * 400,000 pe). By 2010, agriculture will not be an important outlet and all sludge will be sent to landfills. By 2020, a small proportion may be recycled to agriculture (up to 10%) while the rest is still landfilled.

Netherlands

The following description is based on information provided by Kreunen for the latest version Global Atlas (LeBlanc *et al*, 2008).

The Netherlands has already achieved high compliance with the UWWT Directive. At the end of 2005, there were 340 agglomerations ≥ 2000 pe with a generated load of 16,162,030 pe, 100% was collected and 98.1% was treated by more stringent treatment. Quantities of sewage sludge are not expected to increase over the next 15 years. There are 26 Water Boards providing wastewater services in the Netherlands.

Recycling of sewage sludge in agriculture has been banned in the Netherlands since 1996 as a result of increasingly stringent standards for the application of sludge to land in the late 1980's.

The use of sewage sludge on land is regulated under 'Besluit kwaliteit en gebruik overige organische meststoffen (BOOM) van 30 Januari 1998' [Decree on the quality and use of other organic fertilisers (BOOM) of 30 January 1998].The regulations specify strict limit values for PTEs in soils and restrictions on use. For example, it is forbidden to use sewage sludge on grassland whilst it is being grazed. This ban also applies to land on which forage crops are cultivated, sludge cannot be applied less than three weeks before harvesting. For land which is used for fruit and vegetable plantations, with the exception of fruit trees, the ban applies during the growing period. Finally, it is forbidden to use wastewater sludge on land intended for the cultivation of fruit and vegetables which are in direct contact with the soil and are consumed raw, less than 10 months before harvesting, and during harvesting.

Sludge quantities as reported to the Commission (CEC 2006) are presented below:

Year	Total sludge production (tds/y)	Agriculture	
		(tds)	%
2001	536,000	27	0
2002	571,000	38	0
2003	550,000	34	0
2004	60,579	15,919	29
2005	65,680	16,243	25
2006	71,252	24,716	32

A private company - GMB Sludge Processing Company has two composting plants which process about 15% of the total (dewatered) sewage sludge produced by municipal wastewater treatment plants in the Netherlands, which amounts to approximately 1.5 million tons per year (with a total plant capacity of 1,370,000 PE). Since 2004, this granular product has been used as a biofuel in power stations, both in Germany and the Netherlands. The granules are used by the power stations either as an additive or as a stand-alone biofuel. Of the remainder, approximately 58% is incinerated and 27% thermally dried. The product resulting from these techniques (composting, incineration and thermal drying) still requires further (final) processing.

There is no support in the Netherlands for the application of sewage sludge into or onto the soil, or in agriculture. In addition, the animal manure surplus means that the farming sector is more likely to demand the exclusion of sewage sludge. For our baseline scenario, we have assumed no changes over the next 15 years.

Norway

The following description is based on information provided by Blytt for the latest version Global Atlas (LeBlanc et al, 2008). *This report has been updated following comments received from one commercial stakeholders during the on-line consultation of August 2009.*

Norway has a long coastline and is dominated by forests and mountains. Arable land covers only 3% and is mostly located near bigger cities and at the bottom of valleys. Norway has 4.5 million inhabitants. During the 1970's and 1980's, there was an increase in the number of wastewater treatment plants, especially in the parts of the country with discharges to inland waters and narrow fjords. There are currently about 1,400 treatment plants, most of which are very small.

The sludge from smaller plants is usually transported to larger treatment plants. In total, 62 treatment plants have registered their treated sludge to be regarded as a fertilizer product. Sludge is primarily treated with lime (42%), anaerobically digested (20%) treated by advanced anaerobic digestion (20%) or dried (4%).

The total quantities of sludge produced in 2006 and the main disposal outlets are presented as tds in the table below:

Year	Total production	Total utilization	Agricultural	Green areas	Mixed soil products	Top layer on landfill	Land filled	Other
2006	86,030	86,484	56,055	10,198	13,178	2,934	2,957	1,162

More than 90 % of Norwegian sludge is used as a soil improvement product on land. One-third goes to parks, sports fields, roadsides, and the top cover of landfills, and two-thirds goes to arable land within the agricultural sector. There is no incineration of sewage sludge and nearly no landfilling.

In order to achieve this high rate of land application, stringent standards have been set for the content of heavy metals and pathogens, and control of odour nuisance has been given a high priority. Norwegian regulations concerning sludge are stricter than those for most of the countries in Europe.

Since the late 1990s', political support to recycle organic waste has increased, along with requirements to remove organic waste from landfills, in order to reduce emissions of methane and leachates. Applying sludge on arable land is considered by the Norwegian authorities to be the socio-economically acceptable and cost-effective way to utilise sludge. This implies that farmers are willing to accept the use of sludge. The sewage sludge market is very sensitive to negative reports as farmers acceptance is influenced by many factors including opinions of retailers and consumers. Authorities and wastewater treatment plants work continuously on communicating these benefits, and the low levels of risk.

In the mid-1970's, a reform in the agricultural sector changed the agricultural land use in the populated regions around Oslo and Trondheim from dairy farms with grassland to the production of cereals (barley, wheat, rye and oats) and oil seeds. Single-crop farming depletes organic material in the soil. As there is very little animal manure available, there is a need for organic fertiliser like sewage sludge. Changes in the farm structure and land use are contributing factors to use of sludge on agricultural land. Sludge is not used in forests in Norway.

Several municipalities started to collect separate kitchen waste for making compost. The ministries found it necessary to harmonize the parallel regulations for different types of recycled organic waste. In 2003 a new joint regulation *"Regulation on Fertilizers Materials of Organic Origin",* prepared by the Ministry of Agriculture and Food in co-operation with the Ministry of Environment and Ministry of Health was published. This covered all organic materials spread on land that were derived from materials such as farm waste, food processing waste, organic household wastes, garden waste and sludge. It was also believed that to promote and standardise waste such as sludge, higher treatment and quality control standards had to be implemented.

The 2003 regulation sets the following major requirements for organically derived fertilizers in general, with a few special requirements for sludge:

- All producers have to implement a quality assurance system.
- Quality criteria of the products include standards for heavy metal content, pathogens, weeds and impurities, in addition to a more general requirement of product stability (linked to odour emissions). There is a requirement for taking reasonable actions to limit and prevent contamination with organic micro-pollutants that may cause harm to health or the environment.
- Requirements on product registration and labelling before placement on the market.
- Special crop restrictions for sludge, including a prohibition on growing vegetables, potatoes, fruit and berries for three years, and on spreading sludge on grassland.
- Requirements for storage facilities before use. Sludge cannot be spread on frozen soil so must not be applied later than November and not before 15 February. Sludge has to be mixed into the soil (ploughed) within 18 hours of application.
- Beside the limit values for heavy metals, the hygienic requirements are: no *Salmonella sp*. in 50 grams, no viable helminth ova. and less than 2,500 fecal coliforms per gram dry solids.

All farmers must are required to make a plan for all fertilizers including sludge to be spread on his fields, and to notify the municipality at least three weeks before sludge is locally stored or spread. The wastewater treatment plant or the sludge transport company often assists the farmer with this notification. A farmer cannot apply sludge more frequently than every 10 years on the same field, but that will depend on to the sludge quantity and amount used.

There is no change expected to the rate of sludge recycling to agriculture. However, there may be some restrictions in regions which have high P levels in soil to comply with the WFD requirements.

Markets for sludge within the landscaping sector are increasing. New markets for green energy may enhance cultivation for energy crops. This may increase sludge application on these types of arable land. There are ongoing experiments and pilot trials making synthetic diesel from sludge and organic waste. It is becoming more common to co-digest sludge and food waste in order to increase the production of biogas (methane). This will lead to a sludge quality with a lower metal, but higher nutrient content.

Poland

The following description is based on information provided from a presentation by Twardowska in 2006 and a paper by Przewrocki et al 2004.

At the end of 2005, there were 886 agglomerations ≥ 2000 pe with a generated load of 41,598,316 pe. In 2001, 51.5% of the population were connected to a sewage treatment plant. No recent update to this information has been supplied to the Commission.

Sludge production has steadily increased from 340,040 tds in 1998, 397,216 tds in 2001, 476,000 tds in 2004, 495,675 tds in 2005 and 523,674 tds in 2006 (CEC 2006 and 2009). Compared with the 2001 figure, a doubling of sludge quantities is expected by 2015 along with an amelioration of the quality of the sludge due to the reduction of industrial pollutants discharged into sewers. Almost all sludge produced is stabilised by anaerobic digestion or by a natural drying method,

The recycling of sewage sludge to agriculture increased from 8% in 1998 to 14% in 2000, then reduced to 12% in 2001 and up again to 17% in 2006 (44,819 tds in 2004, 42,558 tds in 2005 and 44,284 tds in 2006). Between 2000 and 2001 the amount of composted sludge increased from 25,528 tds to 27,591 tds (7%), while recycling to agriculture dropped slightly from 50,628 tds (14%) to 49,302 tds (12%). Industrial use (not specified) of sewage sludge increased from 19,815 tds (5%) in 1998 to 28,274 tds (7%) in 2000 and then fell to 24,220 tds in 2001 (6%). Quantities of sewage sludge sent to landfill have dropped from 191,600 tds in 1998 (56%) to 151, 618 t ds in 2000 and rose again to 198,630 tds in 2001 (50%). Quantities incinerated dropped between 1998 and 2001 from 14,389 tds (4%) to 6,937 tds (<2%).

According to a 2008 Eureau survey, sludge production in 2005 amounted to 790,900 tds; 147,000 tds (18%) was sent to landfill; 80,600 tds (10%) recycled to agriculture; 4,500 tds was incinerated and 558,700 was sent to other outlets (not specified).

The estimates for sludge management routes prepared by the Ministry of the Environment are presented below:

- The proportion of municipal sewage sludge disposed of to landfill will rise to 45% in 2010 but will decrease to 39% in 2015.
- The proportion of sewage sludge incinerated should rise from 1.6% in 2001 to 5% in 2010 and 8% in 2015. This will depend on new investments in incineration plants.
- Composting is the preferred method of sewage sludge treatment. It is estimated that 20% of sewage sludge could be composted; however, this requires the construction of sufficient composting plants.
- Another route will be recycling to agriculture. The introduction of more effective and stringent regulations will limit the increased use of sewage sludge in agriculture. In 2015, it is predicted that about 26% of sewage sludge will be recycled via this route. Sewage sludge use as fertilizers will reach 46%, including composted sludge.

Portugal

The following description is based on information provided by Duarte for the latest version Global Atlas (LeBlanc et al, 2008). *This has been revised following comments received from the Environment Agency and a commercial stakeholder during the first on-line consultation in August 2009.*

Regulations on the recycling of sewage sludge to agriculture have recently been amended by Decree-Law No 118/2006 of 21 June 2006, repealing Decree-Law No 446/91 of 22 November 1991, Portaria [Order in Council] No 176/2006 of 3 October 1996 and Portaria No 177/96 of 3 October 1996.

The principal changes to be found in Decree-Law No 118/2006 of 21 June 2006 are the adoption of more stringent rules as regards analyses, definitions, information to be provided, specific bans on the use of sludge in some situations (e.g. in organic farming) and the extension to all soils of the licensing system for the use of sludge. There are also additional provisions such as a compulsory application of sludge within two days of delivery.

Another recent regulation, Decree-Law No 173/2008, approves recycling to agriculture as the Best Available Techniques (BAT). According to the official sources, these two regulations should contribute to an increase in quantities recycled to agriculture, while the industry commented that the new regulatory regime makes it complicated and difficult to obtain the necessary authorization for sewage sludge recycling and as a result, there are some serious problems in the recycling process in Portugal.

There is a strategic plan (2007-2016) for diverting biodegrable waste from landfill through anaerobic digestion, composting, Mechanical Biological Treatment (MBT) and incineration with energy recovery. Two thermal treatment centres are planned to be operational by 2013 for combined sewage sludge and refuse derived fuel (RDF).

In Portugal, there are wide regional differences in sludge production and management as the number of inhabitants, development of wastewater treatment varies greatly along with soil and climatic conditions.

Since the implementation of the UWWT Directive, there have been major upgrades of existing wastewater treatment plants and construction of new ones, leading to an increase in sludge production. At the end of 2005, there were 404 agglomerations ≥ 2000 pe with a generated load of 11,255,420 pe; 95.2% was collected; 71% was treated by secondary treatment and 24% by more stringent treatment.

65% of the population was served by a treatment plant, most having secondary treatment (43%); 24% also providing tertiary treatment. The Southern regions (Algarve Alentejo and Lisboa e Vale do Tejo) had about 76% of the population served by a treatment plant and the Northern regions (Centro and Norte) about 58%. The objective as set up in the strategic plan for water supply and wastewater (2007-2013) is to connect 90% of total population to public sewer networks and treatment plants.

Industrial discharges to these treatment plants account for 50% of the load in the Southern, and up to 70% of the load in the Northern regions where industry is more important. The total generated load was estimated to be about 10,650,000 pe.

The available information on sludge production was reported to be scarce and dispersed. Based on field studies carried out in two different Portuguese regions: Algarve (2005) and Center Alentejo (2006), the amount of sludge produced has been estimated and is reported in the table below:

Region	**pe**	**Daily sludge production ratio (g DM/pe.day)**	**Sludge production (tds/year)**
Norte	3,500,300	80	102,209
Centro	2,404,800	50	43,888
Lisboa e Vale do Tejo	3,441,600	50	62,809
Alentejo	802,500	70	20,504
Algarve	499,500	40	7,293
TOTAL	**10,648,700**	**60**	**236,703**

The range assumed for the sludge production (40 – 80 g DM/pe.day) depends on the sludge treatment process, the upper limit is for non-digested sludge with lime addition and the lower limit is for digested sludge without lime addition.

It is estimated (AdP, 2009, personal communication) that the rate of sludge production is currently about 22 to 23 kg/pe/year. As compliance with the UWWT Directive is not yet complete, it is possible that the rate will rise, in the next decade. However, it is expected that the future volume of industrial discharges will decrease. It has been estimated that by 2015, Portugal will produce around 750.000 tds of sludge. Based on the hypothesis of 25 kg DS per capita and 90% connection – the total urban sludge production in Portugal should amount to about 150,000 tds.

Quantities reported to the Commission (CEC 2006 and 2009) are presented below:

Year	**Sludge production**	**Quantities recycled to land**	
	tds	**Tds**	**%**
1995	145,855	44,000	30
1996	177,100	53,130	30
1997	214,200	64,260	30
1998	121,138	41,413	34
1999	374,147	66,547	18
2000	238,680	37,176	16
2001	209,014	69,853	33
2002	408,710	189,758	46

Year	Sludge production	Quantities recycled to land	
	tds	Tds	%
2003	ND	ND	-
2004	63,758 [a)]	216,784 [c)]	-
2005	401,017 [b)]	225,301 [d)]	56
2006	ND	ND	-

Notes:

a) this amount does not seem correct but it is as reported by the official authorities to the Commission: 6,966 tds of urban sludge and 56,792 tds of industrial sludge
b) including 26,096 tds of urban sludge (6.5% of total) and 374,921 tds of industrial sludge
c) including 31 tds of urban sludge and 216,753 tds of industrial sludge
d) including 30 tds of urban sludge and 225,331 of industrial sludge

Until recent years, the most common disposal outlet for sewage sludge was landfill. However, this disposal option is becoming more restricted as regulations limit disposal of organic matter and the cost of landfilling is increasing.

It is reported that public opinion is against incineration and protest actions have taken place every time plans for waste incineration plants have been presented. There are also reported public concerns about the recycling of sewage sludge to agriculture. However, it is believed that the agricultural use of sludge could play a major role in the future in Portugal, especially in the Central and Southern regions of the country where soils are deficient in organic matter.

Increasing numbers of operators have started to transport and apply sludge on agricultural and forestry land. The main agricultural crop receiving sludge in Portugal is maize, followed by vineyards and orchards. Some sporadic applications occur in forage areas and in forestry after forest fires.

At the same time, other industries and activities such as agro-industries have products, such as municipal solid waste (MSW), manure and slurry from intensive livestock production also rely on agricultural land for the disposal of their waste and are thus competing with sewage sludge for the available land. This is especially the case in the Northern and Central regions which are more highly populated, thus the regions treatment plants produce more sludge and also more intensive livestock production occurs and thus production of manure and slurry competes for available agricultural land.

In 2010, Portugal will have thermal drying systems that could produce approximately 10.000 tonnes of dry pellets a year. The implementation of solar drying will allow the use of sludge in the cement industry which could receive up to 30.000 tonnes/year of dried sludge.

In 2013 Portugal will have two incineration plants operational, which will treat, together with RDF, almost 350,000 tds/year of sludge, corresponding to approximately 50% of the total estimated future sludge production.

The main outlet for the other 50% will be recycling on agricultural land, and eventually co-incineration in cement factories.

For our baseline scenario, we have assumed that by 2010, compliance with UWWT Directive will not be achieved but that sludge production would have risen slightly to about 420,000 tds and that recycling to agriculture will be about 50%. The remaining sludge will be thermally treated (30%) and landfilled (20%) depending on treatment capacity. Full compliance with the UWWT Directive will have been achieved by 2020 and sludge production will reach 750,000 tds; 50% will be incinerated and 45% will be recycled to agriculture and 5% sent to other outlets such as cement factories.

Romania

The report is based on information submitted to the Commission for the latest sludge survey and from a paper from Crac (2005). *This report has been revised following comments received from the Ministry of Environment during the first on- line consultation in August 2009*.

Romania joined the EU in January 2007 and has been granted an extended period, up to 2019, to comply with the UWWT Directive. At the end of 2005, there were 2605 agglomerations ≥ 2000 pe including 22 large agglomerations (>150,000 pe) generating a total load of 26,418,555 pe (including 9.5 M pe for large agglomerations which will have treatment plants with tertiary treatment). It is reported that at that time 47.3% of generated load was collected; 28% was treated by secondary treatment and 1.3% by more stringent treatment.

Directive 86/278/EEC was transposed in Romanian legislation by Ministerial Order no. 49/2004. Sludge quantities are reported below. Sludge production seems to have decreased between 2004 and 2006 (CEC, 2009 personal communication).

Year	**Total production (tds/y)**
2001	171,086
2004	164,969
2005	134,322
2006	137,146

There is currently no recycling of sludge to agriculture, the majority of sludge is sent to landfills. In 2005-2006, 97% of sewage sludge was stored and 3% was disposed of through other methods (not specified) (MoE, 2009, personal communication). It is reported that recycling to agriculture has been considered as an option for future management together with co-incineration in cement plants (Crac, 2005).

For our baseline scenario, the following points were taken into account: decline of population; existence of 22 big cities generating large quantities of sludge; moderate development of agriculture between 2010 and 2020; and the expansion of vulnerable areas up to 55% of agricultural land. We have assumed that by 2010 the situation will have not changed compared with 2006 and that full compliance will be achieved by 2020.

By 2020, sludge quantities will have risen dramatically to 520,000 tds (25 kg/ds/inh *21 M inhabitants). By 2020, it is expected (MoE, 2009, personal communication) that about 20% of sludge will be recycled to agriculture; 30% will be stored, 10% incinerated and the remaining 40% will be disposed of by other methods (30% for energy recovery and 10% recycled to other land (mines reclamation projects or forestry).

Slovakia

The following description is based on information provided by Sumná for the latest version Global Atlas (LeBlanc *et al*, 2008).

At the end of 2005, there were 356 agglomerations ≥ 2000 pe with a generated load of 5,054,900 pe; 75.5% was collected and 12.1% relied on individual treatment systems; 65% received secondary treatment and 18% underwent more stringent treatment. Following the implementation of the UWWT Directive, it is estimated that sludge production will increase by 20-40%. During the period 2004-2006, about 55,000 tds of sludge was generated per annum.

Sewage sludge production (tds per annum) and disposal outlets in the years 2004 – 2006 (CEC 2009) are presented in table below.

Year	Total	Incineration	Agriculture (1)	Landfill (2)	Forestry	Other
2004	53,114	0	41,116	10,581	0	1,417
2005	56,360	0	34,784	17,236	0	4,340
2006	54,780	0	33,630	15,375	0	5,775

Notes:
1) While sludge was directly applied to agricultural land in 2004 and 2005, by 2006 large quantities were diverted for the production of compost.
2) Landfill also includes quantities of sludge that were temporarily stored.

About 90% of monitored sewage sludge production in Slovakia meets the limit values for PTEs as a result of pollution reduction programmes for industrial discharges to public sewers that have been implemented.

Recycling of sewage sludge to agriculture is the preferred option, not only because it was the cheapest option but because it was recognised as being the best environmental option for sustainable development. Direct application of sludge onto agricultural land is regulated according to the Act on Sewage Sludge Application into Agricultural Land. This determines the conditions for sewage sludge application onto agricultural and forest land without affecting soil properties, plants, water, or the health of humans and animals. The Act authorises, under specific conditions, applications to arable land and permanent grassland and forestry (only soil in forest nurseries, in plantations with Christmas trees, fast-growing wood plants, energetic and intensive growths). It does not deal with the application to non-agricultural land or use of sludge in land reclamation.

Application of compost, soil, fertilizers or growing media is regulated by the Act on Fertilizers. In this case, the sludge 'product' is subject to certification and assessment that technical documentation is in line with related technical standards and legal regulations.

There is currently no incineration capacity suitable for sludge incineration. However, the national waste management plan for 2005-2010 plans to increase the capacity and to promote energy recovery from waste. The capacity for waste co-incineration in two cement plants exists in the Slovak Republic (others do not comply with the conditions of the Act on Air Protection), but currently it is reserved for the handling of industrial waste and co-incineration of animal waste. However with the decreasing production of animal waste, sludge could be considered as an alternative in the future in these facilities.

Disposal of sludge to landfill is the least favoured option for sludge management by the Slovak Government. However, due to lack of incineration capacity, it is the only alternative option for sludge disposal. It is expected that the proportion of organic waste disposed at landfills will be limited in line with the requirements of the EC Landfill Directive.

The aim of the Waste Management Programme of the Slovak Republic is to decrease the amount of landfilled waste to 13% of the total amount of waste being generated by 2010.The measures planned to achieve this are, decreasing the amount of sewage sludge disposed of to landfill, and increasing the cost of landfill disposal for all materials.

For our baseline, we have estimated sludge quantities to amount to 135,000 tds by 2020. The proportion of sludge recycling to agriculture as compost will be 50% or more, landfilling will decrease to 5% or less depending on thermal treatment capacity which could treat up to 40% of sewage sludge.

Slovenia

The following description is based on information provided by CEC, 2006; Grilc and Zupancic for the latest version Global Atlas (LeBlanc *et al*, 2008), a presentation given by Mayr and Zugman in 2005 and by Medved in 2006 and a paper from Vukadin and Podakar (from Environmental Agency) in 2007. *This report has been revised following comments received from the Ministry of Environment during the first on- line consultation in August 2009*.

Slovenia was a part of former Yugoslavia until 1991 and in May 2004 it became a member of the EU. Wastewater treatment capacity has increased steadily since 2000 when Slovenia entered the process of accession to the EU.

By the end of 2005, there were 156 agglomerations ≥ 2000 pe with a generated load of 1,531,749 pe; 73.2% was collected; 50% at least treated by secondary treatment and 19% by more stringent treatment. In 2007, there were 223 municipal wastewater treatment plants in operation with a total capacity of 2 Mpe; 10 % with a treatment capacity larger than 10,000 pe and 5 plants with a capacity larger than 100,000 pe. In 2007, about 60 % of the population was connected to a centralised treatment plant while 40% relied on cesspools. About 41% (i.e. 72.2 M m^3) of total generated load was treated by secondary treatment and 19% (i.e. 31.2 Mm^3) by more stringent treatment. The current level of connection to sewers and treatment is still low but full compliance with the UWWT Directive should be achieved by 2017.

The recycling of sewage sludge to land is regulated by the Decree 62/08. The available arable land in Slovenia is limited to 36% as 60% of the country is covered with forests and woods. Application of sewage sludge in forestry is prohibited. There is a ban on landfilling of untreated waste (including sewage sludge) due to stricter waste acceptance criteria being in force from 15 July 2009.

Current sludge production ratio in Slovenia is about 10 kg DS per capita (Mo E, 2009). Sewage sludge quantities reported by Crilc and Zupancic (2008) indicate an increase from 15,000 tds in 2002 to 47,000 tds in 2006. The official quantities reported by the Slovenian Environmental Agency (SEA 2007, CEC, 2009, MoE, 2009, personal communication) are much lower and were estimated to amount to only 7,000 tds in 2002 and about 19,500 tds in 2006 (see tables below). These figures differ slightly from figures submitted to the EC for the period 2001-2006.

Figures from the Environmental Agency of the Republic of Slovenia (MoE 2009, personal communication) are reported below:

Year	Sludge production	Quantities recycled to agriculture		Landfill		Composting		Incineration		Other	
	(tds)	(tds)	%	(tds)	%	(tds)	%	(tds)	%	(tds)	%
2000	8,800	300	3	7,500	85	1,000	11	-	-	-	
2001	8,200	500	6	6,800	83	900	11	-	-	-	
2002	7,000	1,100	16	5,000	71	900	13	-	-	-	
2003	8,800	500	6	7,000	80	0	0	-	-	1,400	16
2004	12,900	100	>	9,000	70	0	0	-	-	3,700	29
2005	16,900	100	>	9,500	56	100	>	-	-	7,200	43
2006	20,100	0	0	9,200	46	0	0	5,200*	26	5,600	28
2007	21,139	18	>	8,871	42	3,526	17	5,099	24	5,600	26

* there is no incineration plant in Slovenia – sludge is exported for incineration

Figures reported by the Commission (CEC 2006 and CEC 2009, personal communication) are presented below:

Year	Sludge production (tds)	Quantities recycled to agriculture (tds)
2001	8,200	500 (6%)
2002	7,000	1,100 (16%)
2003	9,400	800 (9%)
2004	9,687	125 (<1%)
2005	13,580	71 (<1%)
2006	19,435	27 (<1%)

Both sets of figures show that quantities of sewage sludge have increased steadily, more than doubling since 2003. The rate of increase will level off in the next few years as the construction of the largest plants is completed.

Filter presses and belt filters are mainly used at small plants, whereas continuous centrifuges are used at large plants. Anaerobic digestion of sludge is relatively rare (10 plants only), mainly at larger plants, where biogas production contributes to the reduction of treatment costs. Some plants use combined input; that is, fresh sewage sludge and separately collected biodegradable municipal waste, food waste, and other similar materials.

Crilc and Zupancic (2008) reported that, in 2006, some wastewater companies disposed of around 14% of their sludge on-site (internally). The main 'internal' outlets for dried sewage sludge was land application and recycling after composting on the premises of treatment plants or of their operators (mainly non-arable land). In addition, small amounts of sludge were temporary stored, before the most appropriate (or cheap) method could be found. The largest proportion of sludge (47%) was exported abroad in granulated dry form for incineration. The reason for this is the absence of proper incineration facilities in the country and increasingly stringent landfill requirements. The existing industrial thermal processes have not yet obtained permits to co-incinerate dried sludge as an alternative fuel. Co-incineration in cement kilns is however not considered to be particularly attractive in Slovenia due to its relatively low calorific value (about 11-12 MJ/kg at 90% DM.). The export of sludge for incineration abroad should however, only be a temporary solution as new thermal treatment facilities for wastes and sludge are currently under construction. Landfill disposal of dried sludge was reported to amount to 30% in 2006.

Figures from the Environment Agency of the Republic of Slovenia (MoE 2009, personal communication), show that agricultural recycling has became almost inexistent due to the high content of PTEs in sludge, especially zinc, copper, chromium and lead. However, it is expected that this outlet could be a viable future option with the expected improvement of sludge quality. It has been estimated that 27% out of 440 ha of arable land could be suitable for sludge application. However, locally, the Nitrates Directive requirements could significantly restrict its application.

Composting of sewage sludge seems to be favoured by the official authorities, and quantities have increased again from 0% in previous years to 17% in 2007. It is usually composted in combination with biodegradable municipal waste and other structural materials (bark, corn stalks). Compost is used in non-agricultural applications such as for recultivation of landfill sites, land reclamation of degraded areas, public parks maintenance and other similar locations.

Landfill disposal of dried sludge has been the most traditional disposal method and, was still the preferred route for sludge disposal in 2007 (42%), with about 25% exported for incineration as there is no thermal treatment plant in Slovenia.

From 2008, sludge disposal to landfill will decrease due to stricter waste acceptance criteria for landfills, such as the requirement for a total organic carbon content of less 18% DM and a calorific value less than 6 MJ/kg. In particular, the required TOC/DOC limit values are difficult to reach by conventional digestion/composting stabilization processes.

Figures from Grilc and Zupancic (2008) are presented below:

Disposal Methods	**Internally**		**Externally**	
	Quantities (tonnes DS/y)	**%**	**Quantities (tonnes DS/y)**	**%**
Temporary storage	321	<1	589	1
Recycling/Composting	2,831	6	4,030	8.5
Land use	3,288	7	0	0
Landfill disposal			13,967	30
Export (to incineration)			21,916	47
Other disposal types			123	2
Total	**6,440**		**40,625**	**47,065**

For our baseline, the situation in 2010 will remain the same as in 2007, with quantities of sludge expected to increase by 2020 to 50,000 tds. Between 2010 and 2020, the proportion of sludge being recycled to land will increase as sludge quality improves but will stay relatively low at around 15%. Disposal to landfill will also decrease to 5-10 % whilst thermal treatment will remain the preferred option.

Spain

At the end of 2005, there were 2381 agglomerations ≥2000 pe with a generated load of 71,739,629 pe. With the implementation of UWWT Directive, sewage sludge production will continue to increase. Sludge quantities reported to the Commission (CEC 2006 and CEC 2009, personal communication) are presented below:

Year	**Sludge production (tds)**	**Quantities recycled to agriculture (tds)**
1997	685,669	314,329 (46%)
1998	716,145	353,986 (49%)
1999	784,882	413,738 (53%)
2000	853,482	454251 (53%)
2001	892,238	606118 (68%)
2002	987,221	658453 (67%)
2003	1,012,157	669554 (66%)
2004	1,005316	662,009 (66%)
2005	986,086	628,553 (64%)
2006	1,064,972	687,037 (64%)

Spain has problem of soil erosion and desertification, and so the recycling of sewage sludge to agricultural land is the preferred option, as indicated in the National Sewage Sludge Plan of WWTP 2001-2006: "As long sewage sludge complies with legal requirements, including those which might be established in the future (...) it is considered that the most sustainable option is the recycling of nutrients and organic matter by agricultural land application" (art. 1.3.).

This plan estimated that by the end of 2005 the production of treatment plant sludge in Aunsalucia would reach 1,250,000 tons of wet material per year, while in Galicia, it would reach 90,000 tonnes dry matter/year. It was assumed that 40% would go to agricultural use and soil conservation, (excluding composting), 25% for composting, 20% to incineration with energy recovery, and 15% to landfill.

Recycling of sewage sludge to agriculture is regulated under the Royal Decree 1310/1990 of 29 October 1990 and its application Order of 26 October 1993. In addition, two other national regulations impact on sewage sludge recycling; Royal Decree 824/2005, of 8 July, on fertilizer products, which governs the use of sewage sludge and other bio-solids in the elaboration of organic fertilizers and their commercialization, and the Royal Decree 261/1996, on the protection of the waters produced from the nitrates from agricultural sources.

Sweden

The following description is based on information provided by Hultman et al (1999).

Sweden has a population of about 9.2 million people. The proportion of people living in urban, rural or in sparsely populated areas is about 85%, 5% and 15%, respectively. At the end of 2005, there were 339 agglomerations ≥ 2000 pe with a generated load of 7,889,073 pe; 100% of load was collected and 100% load was subject to more stringent treatment. There are approximately 2,000 municipal wastewater treatment plants and 95% of the population live in towns and agglomerations with more than 200 inhabitants and are served by plants with tertiary treatment. Full compliance with the UWWT Directive is already achieved.

Sweden has strengthened its regulations concerning limiting values of metal concentrations in sludge. In addition there are also limit values for organic substances (nonyl-phenol, toluene, total PAH and total PCB).

There are legal restrictions on disposal to landfill and, since 2005, organic wastes including sludge from wastewater treatment plants have effectively been banned from landfill disposal. In addition, since 1 January 2000, a landfill tax has to be paid when sludge is disposed of to landfill.

Centrifuges are the most commonly used dewatering equipment followed by belt presses. Other conditioning methods are used such as the KREPRO process which uses sludge conditioning by use of acids and heat. There is a growing interest to use natural and biological dewatering methods, for example, by use of reed beds.

All large treatment plants use anaerobic digestion, while the other methods are used at small and medium-sized plants. There are also some examples of thermal drying.

Co-treatment of sewage sludge with solid wastes has been investigated at different scales, for example:

- Sludge incineration together with municipal solid wastes
- Anaerobic digestion of sludge together with other organic materials
- Large-scale composting of sludge together with other organic materials.

Sludge production has been relatively stable for the last 10 years at around 210,000 tds per annum (CEC 2006 and 2009) while quantities recycled to agriculture have fluctuated due to debate over the safety of the outlet but it seems to have reached a stable level at around 10 -15 %.

At the end of the 1980s, sludge disposal outlets in Sweden were agriculture (35%), landfill (50%), land reclamation (15%) and others (5%). Ten years later (1998) agricultural use had declined to 25% and disposal to landfill had increased to 46%. In 2006, the agricultural and landfill outlets had further reduced to 15%, and 4%, respectively while other outlets (land reclamation, green spaces, co combustion, etc) were reported to have reached 81% (Eureau, 2008).

Estimated sludge production and recycling to agriculture (CEC 2006):

Year	Sludge production (tds)	Quantities recycled to agriculture (tds)
1995	230,000	67,800 (29%)
2000	220,000	35,000 (16%)
2003	220,000	19,000 (9%)
2004	210,000	20,000 (9%)
2005	210,000	25,000 (12%)
2006	210,000	30,000 (14%)

The main reason for the decrease in sludge recycling to agriculture was that, in 1990, the Federation of Swedish Farmers (LRF) recommended that its members should not use sludge. A national consultation group was formed between LRF, the Swedish Water and Waste Water Works Association (VAV) and the Swedish Environmental Protection Agency (SEPA) which reached agreements concerning agricultural use. However, at the beginning of 2000, LRF argued that agricultural spreading should be suspended because of the presence of brominated flame retardants in sludge and their possible negative effects on soils and organisms.

In the early 2000's, VAV ordered a product certification system from the Swedish Testing and Research Institute (SP). The food industry requires that sludge be quality assured through a certification system. However this offers no guarantee that the sludge will be accepted for use in agriculture. A quality assurance system (ReVAQ) has been designed together by the concerned parties, water companies, farmers, nature conservation and the food industry but the future of agricultural use of sludge is still uncertain. Future use of sludges in agriculture may, however, decrease due to concerns of the food industries and the public.

Landfilling had increased due to recommendations to avoid sludge in agriculture, but has now decreased to below 5% by 2005 due the legal restrictions on organic wastes going to land, the introduction of a landfill tax and the difficulties in finding new land areas or getting permits for the disposal.

Incineration is a well established method for solid waste treatment but not for sewage sludge. Co-incineration with solid wastes may be an alternative to mono-incineration although it seems that most existing incineration plants for solid wastes do not have excess capacity to also burn sludge. Therefore, attention has been directed towards co-incineration with biofuels (wood, peat etc), coal power plants or plants producing building materials at high temperatures (cement, brick etc). The use of incineration of sludge in Sweden will be influenced by the potential introduction of a tax on incineration and the potential requirement that phosphorus must be recovered either before or after incineration.

Other land uses of sewage sludge represent 10-15% of sludge production in Sweden. Sludge based products and soil conditioners can be used on reclaimed land, parks, golf courses, green areas etc (there are about 400,000 hectares of green areas in Sweden). Sludge can also be used as landfill cover material. Sludge used in forestry has received some attention from forest companies. Sludge can be spread dried, in pellet form, on mineral soil to compensate for nitrogen losses due to soil acidification and intensive forestry.

Increased interest has been devoted to extraction of products from sludge. Two commercial systems are mainly under consideration in Sweden, namely the KREPRO and Cambi processes. The Cambi and KREPRO processes aim to see the dissolved substances as resources, either through improved methane production in the digester (Cambi) or by reuse of precipitation chemicals, production of a fertilizer (ferric phosphate), and separate removal of heavy metals in a small stream (KREPRO).

For the baseline study, sludge quantities are expected to increase slightly mainly due to population growth. By 2010, sludge quantities will remain at 210,000 - 220,000 tds increasing to 250,000 tds by 2020. Over the next 10 years, the proportion of sludge recycled to agriculture will stay at 15% - 20% while recycling to other land uses is expected to be around 70-75%, disposal to landfill will reduce to 1% and 5%-10% will go for co-combustion.

United Kingdom

The following description is based on information provided by Matthews for the latest version Global Atlas (LeBlanc et al, 2008). *This report has been revised following comments received from the Ministry of Environment and commercial stakeholders during the first on- line consultation in August 2009.*

At the end of 2005, there were 1638 agglomerations ≥ 2000 pe with a generated load of 64,218,933 pe. About 96% of the UK population is connected to sewers leading to sewage treatment works (DEFRA, 2002). Most of the remainder are served by small private treatment works, cesspits or septic tanks.

Sludge quantities in the UK have increased steadily over the last 11 years (see table below) from 1.1 M tds in 1995 to 1.5 M tds in 2006 (CEC, 2006 and 2009, personal communication). This includes about 1.3 M tds in England and Wales; 140,000 tds in Scotland and 35, 000 tds in Northern Ireland.

In Scotland it is estimated that there will be a 17% increase in the amount of sewage sludge produced over the next 20 years as improvements to sewage treatment are implemented as required under the EC Directive. In Northern Ireland, by 2010, total sludge production is estimated to be equivalent to 52,000 tds.

Before 1998, about a quarter of UK sewage sludge was either dumped at sea or discharged to surface waters but this practice was banned in 1998 under the UWWT Directive. The most common option in the UK for sludge disposal is now recycling to agricultural land, at around 70% in 2006 (CEC 2006 and 2009). This is followed by incineration with subsequent disposal of ash to landfill. Landfill, which was always the less preferable option, is now used less due to increasing restrictions following the 1999 Landfill Directive, lack of site availability and costs. Liquid sludge can no longer be disposed of into landfill sites. There are however regional differences between England and Wales, Scotland and Northern Ireland.

In Scotland, in 2005, 51,000 tds (36%) was incinerated and 29% was recycled to agriculture; 23% was recycled to other land and 11% was landfilled.

In Northern Ireland, up until the end of December 1998, about half of the sludge was spread on agricultural land and most of the remainder (approx 15,000 tds) was disposed of at sea to a licensed area outside Belfast Lough. A small proportion, some 2,000 tds, was taken to landfill. In 2004, incineration was the preferred option treating about 22,000 tds (65%) whilst the remainder was disposed of to other outlets (not specified).

Sludge recycling to land is encouraged in the UK as a contribution to the environment by recycling valuable nutrients and organic matter. It is recognised by the Government as the BPEO in most circumstances. Requirements are defined in the 1989 Sludge Regulations (Use in Agriculture) as amended (implementing the EC Sewage Sludge Directive) and the associated non-statutory Code of Practice, and have been made more stringent by the voluntary agreement – the Safe Sludge Matrix - between the British Retail Consortium, Water UK (which represents the UK Water Utilities), and ADAS (the Agricultural Development and Advisory Service), with the support of the Environment Agency. The UK Government announced its intention to revise the regulations to provide further safeguards against the transfer of pathogens from sewage sludge to the food chain and could make current voluntary requirements statutory. Regulations have not yet been amended partly because the voluntary agreement is being respected.

Year	**CEC 2006, 2009**	**DEFRA 2009**			
	Sludge production (x10^3 tds)	**UK sludge**	**England and Wales (x10^3 tds)**	**Scotland (x10^3 tds)**	**Northern Ireland (x10^3 tds)**
1995	1,120	1,124	993	93	34
1998	1,045	1,058	936	97	25
2001	1,187		1,137	-	-
2002	1,303	1,390	1,249	113	28
2003	1,360	1,422	1,280	113	29
2004	1,445	1,368	1,221	113	34
2005	1,511	1,509	1,369	140	ND
2006	1,545	ND	ND	ND	ND

ND – no data

Outlets for sewage sludge in the UK (CEC, 2006 and 2009 ad DEFRA, 2009)

Year	**Quantities recycled to agriculture**		**Incineration**		**Landfill**		**Sea**		**Power generation**		**Land reclamation**		**Other**	
	(x10^3 tds)	**%**	**(x10^3 tds)**	**%**	**(x10^3 tds)**		**(x10^3 tds)**	**%**	**(x10^3 tds)**	**%**	**(x10^3 tds)**	**%**	**(x10^3 tds)**	**%**
1995	550	49	82	7	115		254	22	-		-		125	11
1998	504	48	185	17	115		150	14	-		-		105	9
2002	761	58	232	17	65		0		52	4	84	6	196	14
2003	824	61	227	16	38		0		50	4	106	7	177	12
2004	878	62	265	19	15		0		0	0	150	11	60	4
2005	1,056	70	NI		NI		0						NI	
2006	1,050	68	NI		NI		0						NI	

Untreated sludge is no longer applied in agriculture. The extent of dewatering and stabilisation varies from site to site. A variety of treatment methods are used depending on the local treatment facilities. There is no set treatment requirement and many factors are taken into account to meet the required treated sludge quality.

A common method of treating sludge at present is anaerobic digestion to standards that meet the terms of the Matrix. After a period of doubt in the 1990's about the future of anaerobic digestion, the process now has a secure place in sludge strategies, and the design and operation of plants has developed significantly. The process has been extended to higher levels of efficacy and effectiveness to meet the terms of the Matrix by the use of additional stages. These can also have the advantage of improving product quality (that is, releasing ammonia, improving consistency, and reducing smell), producing gas and reducing volume. When digestion is used, the value of the energy created from the methane in the sludge gas is becoming increasingly important. Most sludges are dewatered using centrifuges or belt presses. There continues to be an interest in other thermal processes, such as pyrolysis and gasification, but these are not currently available.

The application rate onto agricultural land depends on the crops, which can be a cereal, but on a local basis could be maize, rape, or sugar beet, (uses for growing potatoes and other root vegetable have become much less frequent in recent years). A typical application rate would be 6-8 dry tonnes/ha/year.

In the past, small quantities of sludge have been supplied to the domestic and horticultural market. The practice has not been widely encouraged for the domestic market due to the difficulties of effecting realistic controls over application and the disproportionate costs. One opportunity to supply a product would be as compost, which incorporated sludge with other materials. Investigation of this continues but, so far, products including a straw-based compost have not proved to be an attractive or cost effective product. If such products are supplied, there is a move towards the much tighter standards produced by the British Standards Institution, such as PAS 100, for composts, and details can be found on the Sustainable Organic Resources Partnership web site – www.sorp.org).

Only a small amount of sludge is used in forestry and this will probably not increase in the future. Untreated sludge is no longer used for any part of the forestry cycle.

Sludge has also been applied on energy crops such as willow and poplar or miscanthus in short rotation plantations. The harvested wood can be used for a number of purposes, including use as a fuel source. The use of untreated sludge is permitted for these crops.

It is unlikely that the use of sludge on conservation and on recreational land would ever constitute more than a small fraction of the disposal of sludge. This market might be bigger than that at present if sludges were composted or dried and pelletised. The soil criteria for agricultural land apply, and it is likely that only fully treated sludge would be used, particularly on recreational land.

There is some use of sludge for land reclamation (i.e. capping landfill sites and creation of woodland on brownfield sites) However, these tend to be opportunistic and will probably never constitute a significant outlet for sludge.

For our baseline scenario, the two main options will continue to be recycling to agricultural land and thermal treatment. The issues of energy consumption/production and carbon footprint will become important in assessing the sustainability of operations.

The UK is in the process of reviewing sludge use legislation. The UK Government has proposed the incorporation of the Safe Sludge Matrix into Regulations and could incorporate further changes to reflect any developments of knowledge and attitudes. If implemented, the Regulations would make many of the restrictions explicitly mandatory, rather than placed in a Code context. However as yet there are no firm indications as to when the law will be changed. Nevertheless the Companies are incorporating the principles in their operations. There is a clear awareness of the issues of risk management and accredited quality assurance programmes and many schemes have been registered under ISO 14000 or 9000.

Some of the changes to the Regulations would be:

- Use of untreated sludge would be banned
- Treatment will be in accordance with definitions of conventional treatment and
- enhanced treatment
    - Conventional treatment is 99% (2 log) reduction of *E. Coli* and an MAC of 100,000 per gram DS
    - Enhanced treatment is 99.9999% (6 log) reduction of *E. Coli* and an MAC of 1000 per gram DS and an absence of *Salmonellae* sp
- Ban the use of conventional sludge on grassland unless it is incorporated
- Restrict access for harvesting or grazing for conventional sludge to 12-month intervals for field vegetables and 30 months for vegetables eaten raw
- Max limit for lead lowered to 200 mg/kgDS
- Max limit for zinc in soils pH 5.5-7.0 would be 200 mg/kgDS and for pH values above 7 with a calcium carbonate content more than 5% would be 300 mg/kgDS.

For our baseline, sludge production is not expected to increase over the next 10 years from the 2006 level of 1.6 million tds. Recycling to agricultural land will also stay at a similar high level at around 65-70% over the next 10 years; incineration may increase to 20-25%; land reclamation will increase to 15-20% and landfill will remain low at about 1%.

Table 20 **Estimates of annual sewage sludge production and percentages to disposal routes, 1995 – 2005 (Using data in this report)**

Country	1995					2000					2005				
	total sludge	agriculture	incineration	landfill	other	total sludge	agriculture	incineration	landfill	other	total sludge	agriculture	incineration	landfill	other
	tds/a	%	%	%	%	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	20,000			100		20,000			100		33,700	40	0	60	
Cyprus	4,000			100		4,000			100		6,542	52		48	
Czech Republic	146,000	24		50	26	210,000	45		30	25	220,700	10	10	10	60
Estonia b)	15,000					15,000					26,800	10			
Hungary	30,000					30,000					125,143	34	1	25	40
Latvia	20,000					20,000	37		38	33	28,877	23	0	40	37
Lithuania	48,000			90	10	48,000	10		90	10	65,680	25	0	6	69
Malta	0					0									
Poland	340,040	8	4	56	32	397,216	12	2	50	36	495,675	8	1	18	70
Romania						171,086	0		100		134,322	0		97	3
Slovakia											56,360	62	0	30	8
Slovenia						8800	3	0	85	12	16,900	<1	0	56	43
Austria a)	390,000	12	5	11	72	401,867	10	10	11	60	238,100	17	43	5	35
Belgium	87,636	32	34	32	2	98,936	13	76	14		125,756	17	67	4	12
Denmark	166,584	67	25		8	155,621	60	43	2		140,021	59	40		
Finland	141,000	33			66	160,000	12			88	147,000	3			97
France	750,000	66	15	20		855,000	65	15	20		1,021,472	62	21	13	4
Germany	2,248,647	42	28		30	2,297,460	37	34	3	20	2,059,351	31	38	2	29
Greece	51,624	0		95	5	66,335	0		95	5	116,806	0		95	5
Ireland	34,484	10	0	43	42	33,559	45	0	54	1	59,827	76	0	17	7
Italy	609,256	26	5	30	40	850,504	26	5	30	40	1,074,644	20	7	31	42
Luxembourg	7,000	80			15	7,000	80			15	8,200	40	18	0	42
Netherlands	550,000	0	100			550,000	0	100			550,000	0	100		
Portugal	145,855	30	0	70		238,680	16	0	84		401,017	56	0	44	
Spain	685,669	46		54		853,482	53		47		986,086	64		46	
Sweden	230,000	29		50	20	220,000	16		44	40	210,000	12	2	4	82
United Kingdom	1,120,000	49	7	10	33	1,066,176	55	21	5	16	1,510,869	70	19	1	10
EU12 % of total EU	8	1	0	4	2	11	2	0	6	2	12	2	0	4	5
EU15 % of total EU	92	36	19	15	22	89	33	22	16	16	88	37	22	13	18
EU27 % of total EU	100	37	19	19	24	100	35	22	22	19	100	39	22	17	23

Notes:

a) In Austria, quantities reported to the Commission for 1995 and 2000 included sludge from municipal treatment plants (60%) and industrial treatment plants (40%) (mainly from cellulose and paper industry)
b) No data provided for Estonia – quantities produced have been estimated

Table 21 Estimates of annual sewage sludge production, and percentages to disposal routes, 2010 - 2020 (from data in this report)

Country	2010					2020				
	total sludge	agriculture	incineration	landfill	other	total sludge	agriculture	incineration	Landfill	other
	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	47,000	50		30	20	151,000	60	10	10	20
Cyprus	10,800	50		40	10	17,620	50	10	30	10
Czech Republic	260,000	55	25	10	25	260,000	75	20	5	5
Estonia	33,000	15			85	33,000	15			85
Hungary	175,000	75	5	10	5	200,000	60	30	5	5
Latvia	30,000	30		40	30	50,000	30	10	20	30
Lithuania	80,000	30	0	5	65	80,000	55	15	5	25
Malta	10,000			100		10,000	10		90	
Poland	520,000	40	5	45	10	950,000	25	10	20	45
Romania	165,000	0	5	95		520,000	20	10	30	40
Slovakia	55,000	50	5	5	10	135,000	50	40	5	5
Slovenia	25,000	5	25	40	30	50,000	15	70	10	5
Austria	273,000	15	40	>1	45	280,000	5	85	>1	10
Belgium	170,000	10	90			170,000	10	90		
Denmark	140,000	50	45			140,000	50	45		
Finland	155,000	5			95	155,000	5	5		90
France	1,300,000	65	15	5	15	1,400,000	75	15	5	5
Germany	2,000,000	30	50	0	20	2,000,000	25	50	0	25
Greece	260,000	5		95		260,000	5	40	55	
Ireland	135,000	75		15	10	135,000	70	10	5	10
Italy	1,500,000	25	20	25	30	1,500,000	35	30	5	30
Luxembourg	10,000	90	5		5	10,000	80	20		
Netherland	560,000	0	100			560,000	0	100		
Portugal	420,000	50	30	20		750,000	50	40	5	5
Spain	1,280,000	65	10	20		1,280,000	70	25	5	
Sweden	250,000	15	5	1	75	250,000	15	5	1	75
United Kingdom	1,640,000	70	20	1	10	1,640,000	65	25	1	10
EU12 % of total EU	12	5	1	4	2	19	7	3	3	6
EU15 % of total EU	88	37	26	9	15	81	36	30	3	12
EU27 % of total EU	100	42	27	14	17	100	43	33	6	18

15 Annex 3 – Respondent comments summarised

The summary table has been prepared as a link between this report and the individual respondents comments. These summaries of each respondents comments must only be used as a guide to the original comment. The original comments must be regarded as the authoritative source.

Name	Type	Country	Respondent comments summary
Officials			
Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (Austrian Ministry of Environment)	MS	Austria	Forecast figures for Austria realistic Extend scope of directive to cover all land uses Review limit value to current state of the art Limit values for OCs are necessary Quality assurance system is necessary Allow more stringent local limits Not enough covering of alternative for poor quality sludge (P recovery) Favour mono-incineration in order to enable P recovery Check more recent data submitted to COM. Justification of stricter national limit missing Wider group of stakeholder to consult REACH impact on quality of sludge not expected Check info on MBT outlet Check number of states banning recycling and criteria for landfilling
Danish Ministry of Environment-Environmental Protection Agency	MS-A	Denmark	Check connection rate figure 90%, 10% with individual treatment or septic tanks Strict limit in place including for 4 OCs New studies to be included on triclosan (summary in English) and musks (not yet published) Include Kyoto protocol effect Figures for disposal outlets submitted for 2002 - only estimates for more recent years – no figures for future production but some comments such as a reduction of tax on incineration of waste (incl sewage sludge) and potential future increase of sludge going to incineration instead of being recycled. Recycling to land is promoted in DK as P properties of sludge important in DK and help to reduce CO2 emissions by acting as carbon sinks in relation to Kyoto protocol commitment Strict limit values is reported to have lead to an improving of quality fo SS Some public concerns about leaking of unknown harmful substances to groundwater
Romanian Ministry of Environment	MS	Romania	Need to update information: 22 cities for WWTW & correction to collection rate of 54% (by end of 2005) and number /load of big STWs. Only limited agriculture expected, some difficulties with nutrient status including Danube and NVZ. Proposes change to our predict usage in 2020 – 20% ag, 10%

Name	Type	Country	Respondent comments summary
			incin, 30% storage and 40% other – but also refers to EU money to do AD on 30% destined to storage. Need to clarify if storage means landfill
Slovenian Ministry of Environment and spatial planning/Department for prevention of environmental pollution	MS	Slovenia	Update tables on sludge production and management (need checking as total outlets >100%), but 2020 prediction agreed. No figure for industrial sludge. About 60% popn connected, but expect to meet WWTP reqs including nutrient removal by 2015 most country. Ban on landfilling after July 2009. No incineration capacity so 25% sludge exported for incineration. Expect to reduce these quantities but poor quality sludge (high level of PTEs) and more stringent local decrees on PTEs eliminate sludge from agriculture. Consider possibility of other future recycling as quality improve and non-agricultural uses – renovation, but not forests (ban) (64% of country) as only 36% arable land. Should have consistent formal risk management methods through EU. Sludge has greater benefits than nutrient content only – soil conditioning, and climate change benefits
UK Department of Environment, Food and Rural Affairs/water quality	MS	UK	Confidence in reports. Provisional comments at this stage. Not UK government view. UK Environment Agency input needed. Recycling option vital for many MS. Flexibility to be retained for domestic guidelines. Any changes to standards for pathogens, untreated sludge and metal limits to be harmonised across MS. Difficult and inappropriate to standardise risk management procedures across all MS. More emphasis on C release re future management of sludge (incineration).
Portuguese Environment Agency	MS-A	Portugal	Partial comments (awaiting additional comments) Short email: Recently published regulations which introduced a faster licensing procedure and recognise agriculture recycling as BAT should encourage and increase recycling to land. In addition strategic plan for solid waste (2007-2011) aims at diverting biodegradable waste from landfill through anaerobic digestion, composting, MBT and incineration. Plan to reach 90% of sewer connection by 2013
Ministry of the Environment of the Republic of Latvia/Environmental Protection Department	MS	Latvia	Very brief response. Agree with summary report and situation as described except for limit values for PTEs in sewage sludge as reported in Table 6 (rep 1). Baseline scenario overall realistic Few corrections for country report. Date of accession 2004 and not 2007; Incineration is not one of the main priority in the near future and unsure about future forecast for 2020- however no other figures proposed.
Lithuanian Ministry of Environment	MS	Lithuania	Brief responses only on the country report. No responses to questions. Few figures to correct about number of UWWT plants and number of composting and digestion plants. Disposal include landfill **AND** mainly storage. Update figures on sludge production and outlets (2007). No changes to future estimates and outlets.
Hungarian Ministry of Environment	MS	Hungary	Complimentary about reports (very detailed and thorough studies). Not all 28 questions have been answered (need more time) but

Name	Type	Country	Respondent comments summary
			willing to collaborate further to this process. Importance of protection of soil and groundwater. Agreed with actual sludge production and usage figures given although the reported sludge production rate is 25.8 kg/pe/y compared with 13 kg/cap/y (need checking). Update future outlets: proportion for recycling (77% excessive but 58% realistic). Estimates provided. Additional land available. Composting and anaerobic digestion is increasing. Landfilling is decreasing. Data on nutrient sludge quality is provided. The Hungarian regulations for sludge recycling to land are given. A formal common risk management approach throughout the EU may not be feasible or preferred because of different agro-ecological situations between the MS. Important to have a ban in forestry (as already the case in Hungary). Ban in organic farming. Statutory longer waiting periods (i.e. 1 year for vegetable crops and fruits).
French authorities (secretaire general des affaires européennes- sgae)	MS	France	Update tables 1,2,3,4 and 6, 7 and 8 in summary report 1- have submitted even more recent data for 2006, 2007 and 2008 (only partial). Anaerobic and aerobic digestion are less widespread than implied in the report Latest development – computerised reporting, national risk funds, review assessing implementation of new tracability measures for the last 10 years Additional references to be potentially included. Quantities produced increasing and Recycling to agriculture is on the increase
German Ministry of Environment	MS	Germany	Excellent survey, overall agreement, description for Germany still actual. Some small improved data. Cu and Zn not necessary to have limit, Cu used by farmers. Most German Fed states keen on sludge recycling – Bav & Baden special cases – has proposed additional sentences to this effect. Sludge should be WASTE. Replace figures in table 3 (rep 1) with data provided on disposal routes for 2007 Data in other tables 5 and 6: still valid. Table 8: update last row - others Expect no changes in sludge quantities in future at about 2.06 Mio t ds per y incl. 20% industrial sludge (55 g/pe*d/y fr 82 Mio p.). Agree with 25% for future recycling to agriculture. Expect to increase demand for sludge esp. with improved quality and QA. Sludge regulations the most important factors. No comment on OCs other than studies sent to BZ (need to be included). Note in estimate that 90% sludge undergoes AD.
Bavarian Ministry of Environment and Health	MS-R	Germany	Comments not included in tables: Economic figures too old – figures for 2006 available in 2006 study (see ref). Also do not take into account recent development such as solar drying and decentralised disposal and incineration plants. Investigations on OC in Bavaria showed that a large number of

Name	Type	Country	Respondent comments summary
			OCs are found Insufficient information on nanoparticles and pharmaceuticals. Underestimation of dioxin and dioxins-like compounds such as PCBs; synergetic effects of these compounds Precautionary approach not included. Check reference list and hyperlinks REACH and WFD positive impacts are not confirmed: i.e. risk due to perfluorinated surfactants, dioxins and PCBs Antibiotic resistance genes not adequately considered The advantages of using of solar energy or other non-usable waste heat to dry sludge (negative CO2 balance and net energy gain) not covered in report see LCA study by IFEU in 2001. Strong public opposition in Bavaria to recycling
North Rhine Westphalia - Ministry of Environment and Conservation, Agriculture and Consumer Protection	MS-R	Germany	Submitted 2 reports on organic contaminants (not thoroughly reviewed – not yet included) Risks to soil organisms and animal and human food supplies should be considered not only human health Stricter limits and new limits for organics should be included
Baden-Württemberg Ministry of Environment	MS-R	Germany	Recycling to agriculture in BW has decreased from 20% in 2001 down to 2% in 2008 for precautionary environmental and health protection. Incineration increased from 31 to 87%. Main points for issue are OCs – sewage sludge is the only route of entry to soils (no background level). Soil protection has to follow precautionary principle! Study is not thorough enough! Some suggestions: Need a chapter defining criteria for assessment of contaminants in soils! Additional review of literature on OCs (see studies listed on CIRCA) Need a chapter on leaching of contaminants to groundwater, soils organisms, etc. REACH will not be sufficient to control OCs Cost data need updating Solar drying is missing Incineration and co-incineration: recycling! Recommended to integrate an evaluation of European regional strategies
Belgium			
Brussels Region – IBGE-BIM (Brussels Institute for Environment)	MS-R	Belgium	Update sludge production figures and disposal routes for 2006 instead of 2002. no existing study on future trends so no comments – study currently being done. Update legislation table (LV for soil and application rates) No comment on risk and opportunities report
Walloon Region Ministry of Agriculture, natural resources and	MS-R	Belgium	Need a glossary/list of abbreviations to define ‘sewage sludge’(incl. industrial sludge?) and clarify ‘disposal i.e. storage and treatment’; too UK orientated. Additional references to be potentially included especially to

Name	Type	Country	Respondent comments summary
Environment –Soil and waste department – soil protection direction (DGANRE-DSD-DPS)			update country annex (not always relevant: i.e. one on waterworks sludge!) Existing local practice additional controls on OCs; Update figures for sludge production with latest figure available for 2007 (but could use 2006 for comparison with other MS). Sludge production: industrial sludge not included – this could explain low sludge/pe; No figures available for total production of municipal +industrial sludge only quantities recycled to land available. Future trends based on 25 kg/cap as well as linear increase between 2005 and 2020 unrealistic for Wallonia.- two estimates provided - update future sludge production Data provided on implementation of UWWT plants Update data provided on sludge quality for 2006. Update figures on disposal routes for 2007. Landfilling prohibited since 2007. Expect increase in agricultural use; No limits values for OC but OCs are monitored against defined thresholds for sludge recycled to land. Main issues with PAH and prohibition to recycled sludge if landfill leachates have been treated in STW. No limits for pathogens but monitored Better definition of analytical methods. Expect competition with other organic wastes. Prohibits sludge to vegetables (by industry agreement). Improving sludge quality. Additional regulations to consider/amend: a) Soil Framework Directive/measures taken for soil organic improvement and nitrate pollution may compete b) Animal by-product regulation 1774/2002? (could apply to industrial sludge going for composting) c) Renewable energy directive – impact uncertain d) Waste directive: can also be negative Information on costs provided
Flemish Region-OVAM (Flemish waste agency)	MS-R	BE	Does not support to recycling to land (stricter limit values and ban for untreated sludge and uneconomical for treated sludge since 2006), no landfilling but rather biogas or other energetic valorisation: 88% is incinerated (2006)! Review new ref. progress report 2005-2006 Update figures of sludge production and production rate for 2006 (101913tds i.e. 16.7 kg/inh) Future sludge production is overestimated as 100% connection in rural areas unrealistic: update figure 110,500 tds form 2010 and 2020. Increased capacity for digestion and incineration across Europe encourage by green energy financial support
Ministry of Environment/Waste Management department	MS	CZ	No fundamental comments. Some corrections: Table 1 – update sludge quantities with 2007 figures Correct date of accession 2004
Ministry of Agriculture, Natural	MS	CY	Brief responses for first 3 questions All sources mentioned

Name	Type	Country	Respondent comments summary
Resources and Environment/			Check limit for Cr in soil Update future sludge production (official figures provided) No comments on future risks
Commercial organisations			
Water UK	NF	UK	Very extensive response and detailed comments on both reports including specific questions and additional references (38 pages!). Complimentary comments (good basis for review and baseline reflect most current knowledge). A few improvements suggested: 0. Whilst a re-examination of the directive is appropriate, the commission need to send a clear message of support towards recycling to land (BPEO) and that the current directive has demonstrably protected human health and the environment 1.References missing (see list provided) (tbc) 2.Conflicting population projections! 3. Forecasted sludge quantities underestimated as Landfill Directive and WFD (and in particular EQS directive) will lead to increased sludge production (proposed a change baseline timing from 2010 to 2015 to fit with first cycle of WFD). 4.Update figures in tables 3,4 and 5 through consultation 5. no scientific evidence justifying the need for LV on OCs, simplify controls on PTEs and limit to 2 or 3 main limiting elements (Zn, Cu) and pathogens controls to include different levels of quality according to treatment and end use. Untreated sludge banned. Waiting period to eliminate pathogens for treated sludge unnecessary 6. Corrections to legal sections (see responses for details) . Correct nitrates directive discussion page 13 7. update tables 5 and 6 (check) 8. Cost data provided- check figures (dispute statement on limed cake being the cheapest) and need to update 2002 figures 9. Other comments which could be considered to update reports (see response for details: especially on agronomic values and risks from OC including antibiotics and risks from pathogens 10..Update Table 4 sludge production and rate and check disposal outlets figures for 2007: inc 17%, ldf: 1%, other thermal 0% 11. further restrictions: advanced treated sludge: no restrictions and conventional treated sludge: 10 weeks waiting period; expand uses to include restoration and forestry. But unnecessary to move towards enhanced treatment for general agricultural application! 12. risk management: need to be flexible ! 13. increasing co-digestion and co-composting 14. list of treatment should also include pre-treatment such as prepasteurisation 15. revision of directive should permit and recognise the development of sludge materials that meet end-of-waste criteria, also land recycling of materials arising from co-digestion processes with sludge 16. odour nuisance is the single most important factor that raises public hostility

Name	Type	Country	Respondent comments summary
			17. green house gases: major concerns over the data sources as no references mentioned. 18. what about the impacts of biowaste directive?
EFAR (European Federation of Recycling in Agriculture)	EF	France	Complimentary comments (good synthesis of the current knowledge) 1. too much focus on land recycling and not enough on other outlets 2. imbalance between benefits (1 pg) and risks (10 pgs) 3. should also include industrial sludge 9at least food and paper also in baseline scenario) 4. other land application not afforded a more positive judgment 5. to sum total quantities recycled to land: should add composting to the agriculture: 5,162 M tds (50%) 6. European waste catalogue should be mentioned in legislation 7. CH policy should not be mentioned as not EU member- need to discuss relevance of limit values on total HM conc in solid as only limited fraction available Need to include other fertiliser (manure, compost , mineral). pH also varies on same plant during the year (!). Any new limit of PTE ins soil should look at cost and benefits taking into account existing data on HM conc in EU soils- could provide data 8. need to update costs data (2002!) 9. need to mention for FR a health review committee in place since 1997 and the fact that there has been no reported cases of animal disease following sludge application 10. check comments for Austria 11. nitrates directive - check 12. need to present main assumptions to establish green house gas emissions 13. additional ref on public perception 14. see suggestions for additional reporting information and additional monitoring 15. check table 13 unit for pH 16. costs: global costs no need to split them up 17. need clarify impact for landfill, incineration and waste directives 18. sludge incineration is **NOT** a source of renewable energy – see Austria study 19. justify future additional crops restrictions and other outlets 20. need to dispose of data on sludge quality per country AND per size of WWTP or at least taking into account DS production 21. competition with inorganic fertiliser – adapted to EU context 22. check cost data in euros and not dollars!
InSinkErator (manufacturer of food waste disposers)	IS	USA/UK	Support the addition of food waste to sewage sludge via sewer system Support a common regulatory regimes for sludge and biowaste and the resulting digestate Long justification about the merit and advantages of this technique.

Name	Type	Country	Respondent comments summary
Aguas de Portugal	IS	Portugal	Some of the data for Portugal is missing or out of date; some new figs. are given. More emphasis needed on high tech processes which urban areas will have to move to, and also energy recovery. Q 1-28 are answered in order.
DAKOFA (Danish Waste Management)	NF	Denmark	Additional references: tbc See comments on C- sequestration and P shortage: drivers Update future outlets: 25% inc may be too high- however reduction of tax on incineration could have a positive effect Apparent reduction in sludge quantities due to different methods for reporting (content of DS) Public opinion is the most uncertain factor)end of waste criteria may be one solution to increase acceptance High quality and sufficient management systems
FP2E (Professional Federation of Water Companies)	NF	France	Additional references – see comments Forecast for France unrealistic LCA support (i.e. JRC work) Support voluntary quality assurance schemes and constant approach for sludge and other biowaste Clarify definition of sludge and outlets Lack of discussions on analysis methods Update figures for FR sludge production and disposal with 2007 official figures Some data on treatment Concerns about a widespread use of prohibition clause from food industry Odour! End of waste status for compost – important issue in FR as 15% of recycled sludge are composted. Impact of future IPPC (i.e. waste treatment BREF!) See interesting figure on ratio sludge production/proportion of necessary arable land Price of mineral fertiliser has a positive impact Support co-treatment but current existing barriers exist
EUREAU (European federation of national associations of drinking water suppliers and waste water services)	EF	EU	Complimentary comments: comprehensive review of existing knowledge; good basis for review. Some suggestions: 1. strengthened reporting requirements under the directive to have annual update 2. collect more recent data for tables 1,2,and 3 via consultation process 3. additional notes for legislation sections (see comments for details) 4. need to take into account biogas production and its contribution to renewable energy in economics section 4 5. justify statement about pyrolysis costs versus incineration and also in section 10 6. disagree with changes proposed to Zn soil limits- need to justify further changes proposed to Zn, Cd in solid and Pb in

Name	Type	Country	Respondent comments summary
			sludge 7. need to considered RED proposals and declared source for table 10 8. include policy owners and merchant and supply chain contractors as principal stakeholder 9. treated production rate with caution 10. EQS directive, WFD, UWWT and Landfill Directive will lead to increasing sludge production 11. Although ongoing revision of IPPC Directive could lead to increased treatment and process control costs for sludge recycling as recovery activity 12. For MS that have a higher target to increase renewable energy generation - Renewable energy directive will lead to increased biogas generation from sewage sludge and the resultant digestate used as fertiliser subject to county policy preferences 13. nitrates directive may reduce landbank if further designation are made. WFD may lead to reduced localised sludge application rarest due to high soil P from artificial P. 14. evolvable could open up organic farming land bank 15. support for treated sludge used in forestry (see ref in SE and FI examples) 16. support a voluntary and flexible risk management 17. increasing prices of inorganic fertiliser seems to have a positive effects on demand for quantities of sludge recycled to land 18. co-treatment is important issue
Incopa (European coagulants producers)	EF	EU	Report 1 - Too UK focus Report 2 – very good report More exhaustive list of abbreviations Add missing references, substantiating some figures Check legislation (Lahti Energies case) Additional technologies (i.e. oxidation processes) Availability of nutrients: check/ref. Future trends: stabilised volumes of municipal sewage sludge more co-anaerobic digestion . reduced proportion of industrial sources input Increased sterilisation/pasteurisation/pathogen kills P issues Check info for SE and Kemicond
Ecosol (European producers of Linear Alkylbenzene)	EF	EU	Brief comment mainly focusing on LAS Check spelling for full name in reports 1 and 2
FederUtility (representative of local public utility companies)	EF	Italy	Brief comments – not all questions answered Legislation in Emilia Romagna limit drastically recycling to agriculture as well as legislation in Veneto regions – check but I think this is already mentioned Expect increased difficulties for recycling to agriculture and large increase in cost of the other outlets (3-5 times in the last 5 years)

Name	Type	Country	Respondent comments summary
			Nitrates directive will have a negative impact. Do not have information for the whole of Italy (only 7 water companies!!!!)
EWA (European Water Association)	EF	EU	Preliminary response to be read in parallel with individual members responses (i.e. CIWEM, ASTEE and DWA) Based on EWA Pembroke workshop of April 2008 (paper provided on QLA) and EWA response to Biowaste green paper in Feb 2009. Need to extend the scope of this analyst to over all biowaste under a biowaste directive Should be a full review of COST 68/681 programme Need to include other routes such as landscaping and forestry. Need to distinguish mono and co - incineration Need more discussions on climate change (incl soil conditioning properties reducing moisture loss) Importance of soil conditioning and P fertiliser properties as Phosphare reserves diminish could simplify controls of PTEs as conc have declined and propose statutory monitoring for Zn and Cu and possibly Cd and monitoring of other elements for quality assurance purposes such as Ni, Pb, Cr and Hg development of pathogen controls (ban of untreated sludge and 2 levels of treatment for different end uses review QAS for Germany and Sweden update Commission reports on OC published in 2001 sewage sludge product should be granted an eco-label
FIWA (Finnish Water and Waste Water Works Association)	NF	Finland	All references covered and baseline projections realistic. Agreed with figures on sludge production and outlets. Currently mainly landscaping - large amount used as landfill cover. As many ldfs will be closed and new incineration plants will be built – this outlet will decrease. No figures for future but comments supporting report summary: i.e. – mainly landscaping, maybe use in forestry (as 70% land is covered by forests (20.3 M ha) – this is currently being studied but not yet used) or increasing proportion in agriculture and incineration may become more popular. One problem scenario is that treated sludge is defined as product and falls under REACH: could be too expensive! Control at source! Co-treatment- should be encouraged - need a clear legislation covering such issues Some additional information on Finnish situation: majority of sludge is composted (need to correct 73% of waste water treatment plants reported that sludge is treated in open pile or windrow composts and 21% reported that sludge is composted in composting plants, screened and mixed with other materials (sand and pear) and marketed as a growing medium or solid improver for landscaping- this outlet needs to be better recognised. New decree in 2004 on upgrade sewer connection and sewage treatment for rural areas by 2014 including improve individual treatment and 90% of sludge transported to municipal treatment plants so increase sludge production.

Name	Type	Country	Respondent comments summary
			63% connected population will have N removal treatment and 100% P removal. P is usually limiting factor when sludge applied to agriculture: 40% of P in sludge is considered to be available. In some cases N is the limiting factor. In some cases Cd is the limiting factor (as limit value :1.5 g Cd/ha/y over 4 years or 6 g Cd/ha total). Famers association is against sludge use in agriculture. Large amount of manure in some areas. Current proportion recycled to agriculture 3% compared with 10-17% a few years ago.
Copa-Cogeca (European Farmers and Agri-cooperatives)	EF	EU	Good and comprehensive overview of current situation Not revising the directive is not a sensible option Need to extend the scope of directive to cover all land uses Quality assurance schemes are vital to guarantee a process of checking quality Should have harmonised list of compounds also for other pollutants and pathogens Need to extend discussion on competition with other biowaste
Part of COPA-COGECA response: Austrian Chamber of Agriculture	NF	AT	Extend the scope to cover other land uses Possibility to keep more stringent national limit values Need to discuss a mandatory quality assurance system
BDE (Federation of German Waste Management Industries)	NF	Germany	Way to improve public confidence through mandatory quality assurances and quality management systems – urgently needed to be part of a revised EC directive No significant changes expected in Germany until 2020 No impact from IPPC! Fertiliser regulation was revised in 2008 with new restrictions imposed since 2009 and further requirements by 2017. This could lead to a shift towards thermal treatment. Revised sludge regulation in DE will probably distinguish between 3 types of soils limiting the use of sewage sludge Main PTEs: Pb and Cd. Future potential reduction in some PTEs but Cu and Zn may increase Conc of N and P have increased since 1995 and will continue to increase. Importance of P fertiliser value could cover 20-30% of total P need in agriculture.
DWA (German Association of Water)	NF	Germany	Rep 1 – good basis for the review Need to include landscaping and to sub-divise incineration into mono- and co- Update data for DE on sludge outlets for 2007
EuLA (European Lime Association)	EF	EU	Brief comments on risks due to pathogens Need to list possible treatment processes for the reduction of pathogens in order to obtain public acceptance Need to include in annex 1 and section 2.4.2 established processes as well as new processes
Alan Srl	IS	Italy	Partial and vague comments (only for Lombardy) and not always substantiated with figures – not included. Unrealistic baseline scenario Figures for Lomardy only: 120,000-130,000 tds/y recycled to land

Name	Type	Country	Respondent comments summary
			including 80-85% of municipal sewage sludge. Private companies have agreement with farmers Storage capacity must be 1/3 of total amount spread in a year and treatment capacity for 100% Main treatment is lime. One plant use ammonia and others mix with green waste but don't produce compost (?!) Production of compost in NOT main process to recycle sludge Some STW produce dried sludge (expecting more comments)
VEAS (Vestfjorden Avløpsselskap – Oslo water company)	IS	Norway	Correct summary report on Norway No change expected Suggest a change to allow sludge derived products to receive eco-label P is an issue and price for fertiliser has a positive effect on demand for sludge No justification for OCs No co-treatment foreseen
Other			
CEN (European Committee for Standardization)	Other	EU	No comments on questions Additional references (tbc) and Update of table 14 – list of CEN sludge analysis
CIWEM (Chartered Institution of Water and Environmental Management)	NGO	UK	Support recycling to land as a safe and effective fertiliser and soil conditioner Refer to EWA workshop Support a consistent framework of controls for all residuals applied to any land No documentary evidence of any adverse effects on public health when treatment and use have conformed to existing legislation and known small risks Take climate change impacts! Risks should be borne by producers and not landowner so farmer should be indemnify for an extended period against the possibility of adverse effects until the risk could be considered nul Extend scope of study to cover all biowaste under a biowaste directive and all soil requirement (lack of soil framework!) No barrier to eco-label for suitably treated sludge Sewage sludge = sewage biowaste=wastewater biosolids Clostridia- not a sensible indicator Aerosol measurement – see reference Greenhouse gases (check table 10) (to be reviewed by experts) Pyrolysis- not a strong future prospect Assumption in report 2 – quite reasonable Future increased sludge production at around 28 kg/pe/yr with tertiary treatment or chemical nutrient removal Recovery of fertilisers from dewatering liquids becoming more practicable ! Proposed amendments:

Name	Type	Country	Respondent comments summary
			1. Odour – should be a legal requirement 2. revise pathogen reduction requirements similar to Safe Sludge matrix and require treatment based on HACCP. No OC limit values! Separate regulatory regimes for biowaste inhibiting co-treatment Future trends: increased recycling with increasing anaerobic digestion Nitrates directive may lead to co-composting with green waste P fertiliser value : important issue and price of fertilisers has an positive impact on demand for sludge

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Profile of the Agricultural Livestock Production Industry

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EPA/310-R-99-001.	Profile of Local Government Operations	202-564-2310

* Spanish translations available.

** This document revises compliance, enforcement, and toxic release inventory data for all profiles published in 1995.

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LIST OF EXHIBITS

LIST OF ACRONYMS

ACM	Asbestos-Containing Material
AFS	AIRS Facility Subsystem (CAA database)
AFO	Animal Feeding Operation
ANSI	American National Standards Institute
APO	Administrative Penalty Order
AU	Animal Unit
BIF	Boiler and Industrial Furnace
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CAFO	Concentrated Animal Feeding Operation
CCAP	Climate Change Action Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	CERCLA Information System (CERCLA database)
CESQG	Conditionally Exempt Small Quantity Generator
CFC	Chlorofluorocarbon
CFO	Conservation Farm Option
CFR	Code of Federal Regulations
CNMP	Comprehensive Nutrient Management Plans
COD	Chemical Oxygen Demand
CPA	Conservation Priority Areas
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWAP	Clean Water Action Plan
CZARA	Coastal Zone Act Reauthorization Amendments
DOT	United States Department of Transportation
DUN	Dun and Bradstreet
EBI	Environmental Benefits Index
EMS	Environmental Management Standards
EPA	United States Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EQIP	Environmental Quality Incentives Program
ESPP	Endangered Species Protection Program
FDA	United States Food and Drug Administration
FFDCA	Federal Food, Drug, and Cosmetic Act
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS	Facility Indexing System
FQPA	Food Quality Protection Act
FSA	Farm Services Agency

LIST OF ACRONYMS (CONTINUED)

FWS	Fish and Wildlife Service
FY	Fiscal Year
HAP	Hazardous Air Pollutant (CAA)
HSWA	Hazardous and Solid Waste Amendments
HUD	United States Department of Housing and Urban Development
IDEA	Integrated Data for Enforcement Analysis
IPM	Integrated Pest Management
ISO	International Organization for Standardization
LDR	Land Disposal Restrictions (RCRA)
LEPC	Local Emergency Planning Committee
LQG	Large Quantity Generator
MACT	Maximum Achievable Control Technology (CAA)
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standards (CAA)
NAICS	North American Industrial Classification System
NASS	National Agricultural Statistics Service
NCBD	National Compliance Database, Office of Prevention, Pesticides and Toxic Substances
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
NICE	National Industrial Competitiveness Through Energy, Environment and Economics
NOA	Notice of Arrival
NOAA	National Oceanic and Atmospheric Agency
NPDES	National Pollutant Discharge Elimination System (CWA)
NPL	National Priorities List
NPS	Nonpoint Source Management Program
NRC	National Response Center
NRCS	Natural Resources Conservation Service
NSPS	New Source Performance Standards (CAA)
OECA	Office of Enforcement and Compliance Assurance
OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyl
PCS	Permit Compliance System
PESP	Pesticide Environmental Stewardship Program
PMN	Premanufacture Notice
POTW	Publicly Owned Treatment Works
PWS	Public Water System
RCRA	Resource Conservation and Recovery Act

LIST OF ACRONYMS (CONTINUED)

RCRIS	RCRA Information System (RCRA database)
RLEP	Ruminant Livestock Efficiency Program
RMP	Risk Management Plan
RQ	Reportable Quantity
RUP	Restricted Use Pesticides
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEP	Supplemental Environmental Project
SERC	State Emergency Response Commission
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SPCC	Spill Prevention, Control, and Countermeasure
SQG	Small Quantity Generator
TMDL	Total Maximum Daily Load
TRI	Toxic Release Inventory
TRIS	Toxic Release Inventory System
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, and Disposal
TSS	Total Suspended Solids
UIC	Underground Injection Control (SDWA)
USDA	U.S. Department of Agriculture
UST	Underground Storage Tank (RCRA)
WHIP	Wildlife Habitat Incentives Program
WPS	Worker Protection Standards
WRP	Wetlands Reserve Program

I. Introduction to the Sector Notebook Project

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water and land pollution (such as economic sector, and community-based approaches) are becoming an important supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water and land) affect each other, and that environmental strategies must actively identify and address these interrelationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies addressing all media for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition by the EPA Office of Compliance of the need to develop the industrial “sector-based” approach led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several interrelated topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community and the public.

For any given industry, each topic listed above alone could be the subject of a lengthy volume. However, to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be explored further based upon the references listed at the end of this profile. As a check on the information included, each notebook went through an external document review process. The Office of

Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be sent via the web page.

Adapting Notebooks to Particular Needs

The scope of the industry sector described in this notebook approximates the relative national occurrence of facility types within the sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers also may want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume. If you are interested in assisting the development of new notebooks, please contact the Office of Compliance at 202-564-2310.

II. INTRODUCTION TO THE AGRICULTURAL LIVESTOCK PRODUCTION INDUSTRY

This section provides background information on the agricultural livestock production industry. It presents the types of facilities described within this document and defines them in terms of their North American Industrial Classification System (NAICS) codes.

Establishments that produce livestock are classified in ***NAICS code 112 (Animal Production)***. Data for the notebook, specifically in this chapter, were obtained from the U.S. Department of Agriculture (USDA) and the 1997 Agriculture Census (Ag Census). All data are the most recent publicly available data for the source cited.

> The Office of Management and Budget (OMB) has replaced the Standard Industrial Classification (SIC) system, which was used to track the flow of goods and services within the economy, with the NAICS. The NAICS, which is based on similar production processes to the SIC system, is being implemented by OMB.

It should be noted that the data on the number of livestock establishments presented in the following sections do not represent the number of animal feeding operations (AFOs) or concentrated animal feeding operations (CAFOs) in the U.S. The data simply represent numbers of livestock establishments only. Additional information on AFOs and CAFOs is presented in Section II.C.

Establishments primarily engaged in livestock production are classified in subgroups up to six digits in length, based on the total value of sales of agricultural products. An establishment would be placed in the group that represents 50 percent or more of its total sales. For example, if 51 percent of the total sales of an establishment are from sales of beef cattle, that establishment would first be classified under NAICS code 1121 (Cattle Ranching and Farming), then 11211 (Beef cattle ranching and farming, including feedlots), and finally under 112111 (Beef cattle ranching and farming).

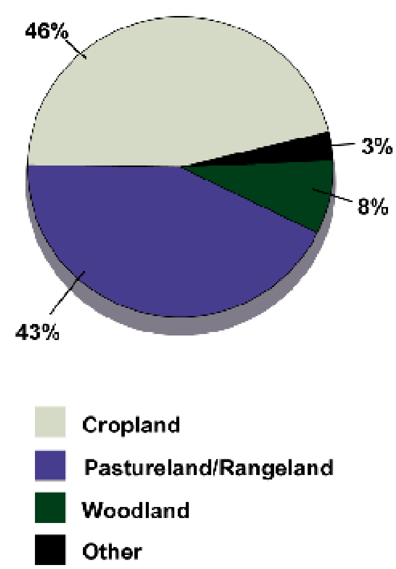
II.A. General Overview of Agricultural Establishments

This section presents a general overview of all agricultural establishments to provide the reader with background information regarding the number and organization of such establishments and production data. The USDA's National Agricultural Statistics Service (NASS) defines an *agricultural establishment* (farm) based on production. It defines an agricultural establishment as a place which produced or sold, or normally would have produced or sold, $1,000 or more of agricultural products during the year. Agricultural products include all products grown by establishments under NAICS codes 111 - Crop Production and 112 - Animal Production.

According to the 1997 Ag Census, there were more than 1.9 million farms (i.e., agricultural establishments) in the United States. Of these, approximately 53 percent (1,009,487 farms) were classified as NAICS code 112 - Animal Production. The other 47 percent (902,372 farms) were classified as NAICS code 111 - Crop Production. These 1.9 million agricultural establishments represent nearly 932 million acres of land, with the average agricultural establishment consisting of 487 acres. (Note: 1 acre is approximately the size of a football field.) Both of these numbers--932 million acres and 487 acres--are smaller than those for 1992, which were 946 million acres and 491 acres, respectively.

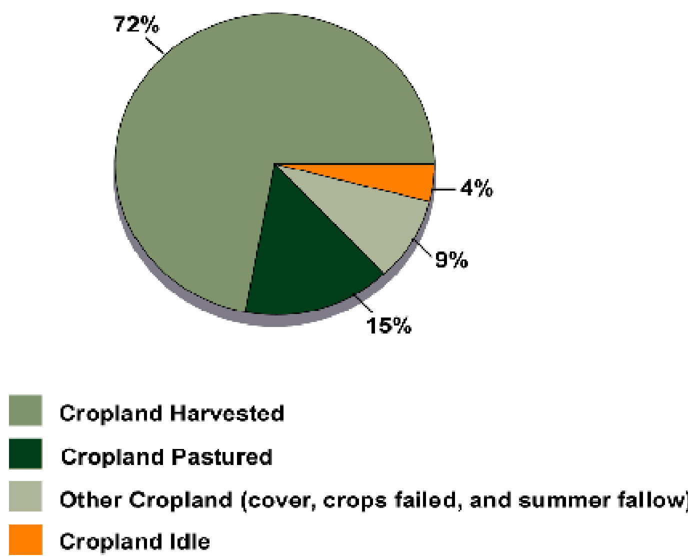
As shown in Exhibit 1, of the 932 million acres of agricultural land, the overwhelming majority (89%) consists of cropland and pastureland/rangeland.

Exhibit 1. Agricultural Land Use in the U.S. (1997 Ag Census)



As presented in Exhibit 2, the 1997 Ag Census describes cropland as:

Exhibit 2. Types of Cropland (1997 Ag Census)



- *Harvested cropland* -- Includes all acreage from which crops are harvested, such as: (1) corn, wheat, barley, oats, sorghum, soybeans, cotton, and tobacco; (2) wild or tame harvested hay, silage, and green chop; and (3) vegetables. It also includes land in orchards and vineyards; all acres in greenhouses, nurseries, Christmas trees, and sod; and any other acreage from which a crop is harvested even if the crop is considered a partial failure and the yield is very low.

- *Cropland used only for pasture or grazing* -- Includes land pastured or grazed which could be used for crops without any additional improvement, and land in planted crops that is pastured or grazed before reaching maturity.

- *Cropland used for cover crops* -- Includes land used only to grow cover crops for controlling erosion or to be plowed under for improving the soil.

- *Cropland on which all crops failed* -- Includes: (1) all land from which a crop failed (except fruit or nuts in an orchard, grove, or vineyard being maintained for production) and no other crop is harvested and which is not pastured or grazed, and (2) acreage not harvested due to low prices or labor shortages.

- *Cultivated summer fallow* -- Includes cropland left unseeded for harvest, and cultivated or treated with herbicides to control weeds and conserve moisture.

- *Idle cropland* -- Includes any other acreage which could be used for crops without any additional improvement and which is not included in one of the above categories of cropland.

The 1997 Ag Census describes pastureland and rangeland as land, other than cropland or woodland pasture, that is normally used for pasture or grazing. This land, sometimes called "meadow" or "prairie," may be composed of bunchgrass, shortgrass, buffalo grass, bluestem, bluegrass, switchgrass, desert shrubs, sagebrush, mesquite, greasewood, mountain browse, salt brush, cactus, juniper, and pinion. It also can be predominantly covered with brush or browse.

As presented in Exhibit 3, approximately 82 percent of agricultural establishments in 1997 consisted of fewer than 500 acres; only 4 percent consisted of 2,000 or more acres.

According to the 1997 Ag Census, all agricultural establishments combined to produce approximately $197 billion worth of agricultural products.

Exhibit 3. Acreage of Agricultural Establishments in the U.S. (1997 Ag Census)

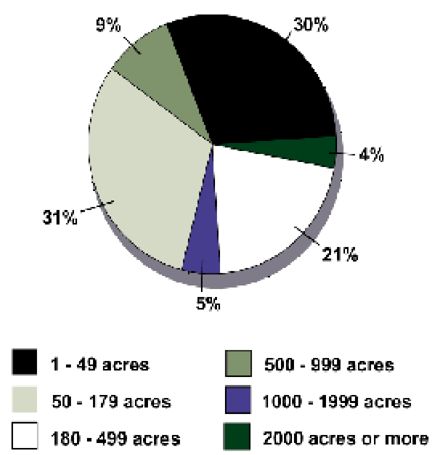
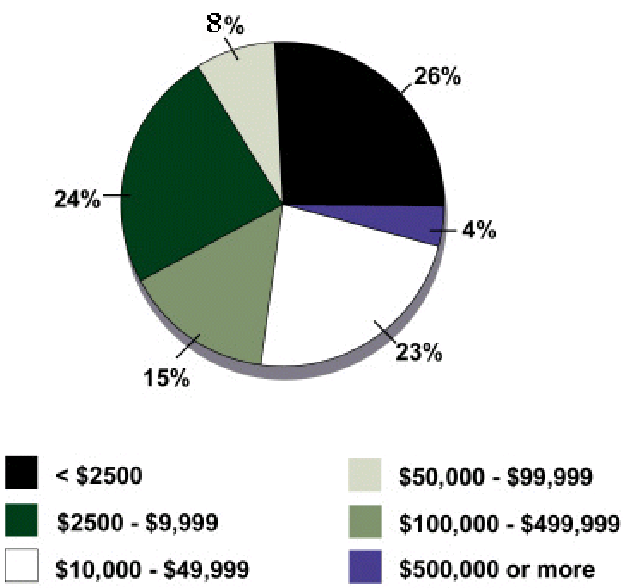


Exhibit 4. Agricultural Establishments by Value of Sales (1997 Ag Census)



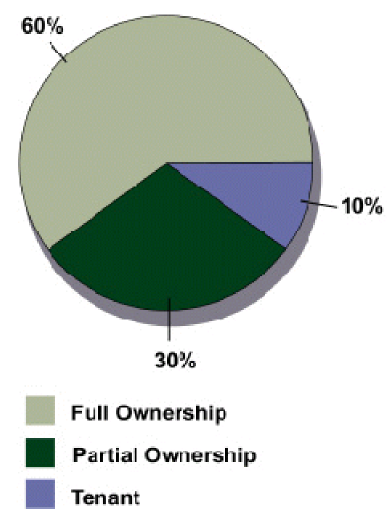
The market value of the agricultural products sold was split almost evenly between crop production, including nursery and greenhouse crops (49.6%) and livestock production (50.4%).

As shown in Exhibit 4, approximately 73 percent of all agricultural establishments produced less than $50,000 worth of agricultural products.

In addition to tracking the number of agricultural establishments and the value of products sold, the Ag Census tracks and identifies other characteristics of agricultural establishments, such as ownership and organization. Exhibit 5 presents a breakdown of the ownership status of agricultural establishments in the U.S. The Ag Census basically identifies the ownership status of agricultural establishments by one of three categories:

- Full ownership, in which full owners operate only the land they own.
- Partial ownership, in which partial owners operate land they own and also land they rent from others.
- Tenant/rental arrangement, in which tenants operate only land they rent from others or work on shares for others.

Exhibit 5. Ownership Status of Agricultural Establishments in the U.S.
(1997 Ag Census)



The Census further classifies agricultural establishment ownership by the person or entity who owns the establishment. There are four distinct types of organization: (1) individual or family (sole proprietorship), (2) partnership, including family partnership, (3) corporation, including family corporation, and (4) other, including cooperatives, estate or trust, and institutional. Approximately 86 percent of all establishments are owned and operated by individuals or families. Partnerships account for another 9 percent of the establishments and corporations own just more than 4 percent of the establishments. Fewer than 1 percent of all farms are owned by other organizations (1997 Ag Census).

II.B. Characterization of the Livestock Production Industry

This section provides data and information on the livestock production industry. For the purposes of this profile, livestock production includes the six categories of livestock presented in Exhibit 6. It should be noted that this profile does not include the processing of agricultural livestock products (e.g., meat processing plants, milk processing, etc.), and only discusses livestock production to the point of sending the livestock to the processing point (e.g., beyond the feedlot).

This notebook follows the structure provided by the 1997 Ag Census, which classifies all of these livestock production operations within NAICS code 112.

Exhibit 6. 1997 NAICS Descriptions for Animal Production (NAICS 112)

Type of Establishment	NAICS Code	SIC Code	
Cattle ranching and farming, dairy farming	1121	0211, 0212, 0241	Establishments primarily engaged in raising cattle, milking dairy cattle, or feeding cattle for fattening.
Hog and pig farming	1122	0213	Establishments primarily engaged in raising hogs and pigs. These establishments may include farming activities, such as breeding, farrowing, and the raising of weaning pigs, feeder pigs, or market size hogs.
Poultry and egg production	1123	0251, 0252, 0253, 0254, 0259	Establishments primarily engaged in breeding, hatching, and raising poultry for meat or egg production.
Sheep and goat farming	1124	0214	Establishments primarily engaged in raising sheep, lambs, and goats, or feeding lambs for fattening.
Animal aquaculture	1125	0273, 0279, 0919, 0921	Establishments primarily engaged in the farm raising of finfish, shellfish, or any other kind of animal aquaculture. These establishments use some form of intervention in the rearing process to enhance production, such as holding in captivity, regular stocking, feeding, and protecting from predators.
Other animal production	1129	0271, 0272, 0279	Establishments primarily engaged in raising animals and insects for sale or product production (except those listed above), including bees, horses and other equines, rabbits and other fur-bearing animals and associated products (e.g., honey). Also includes those establishments for which no one animal or animal family represents one-half of production.

According to the 1997 Ag Census, there were 1,009,487 establishments producing the six categories of livestock referenced above (see Exhibit 7). Of the 1,009,487 livestock producing establishments, approximately 78 percent were classified as cattle ranching and farming.

All livestock producing establishments combined covered nearly 530 million acres of land.
Based on the number of establishments and total acreage for each NAICS code, Exhibit 8 presents the average size of each type of establishment.

Exhibit 7. Number of Livestock-Producing Establishments by NAICS Code
(1997 Ag Census)

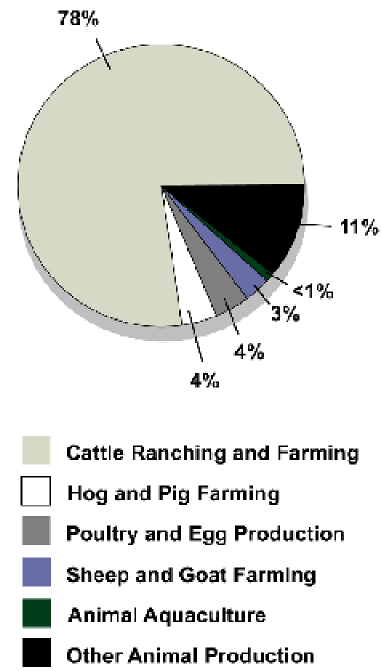
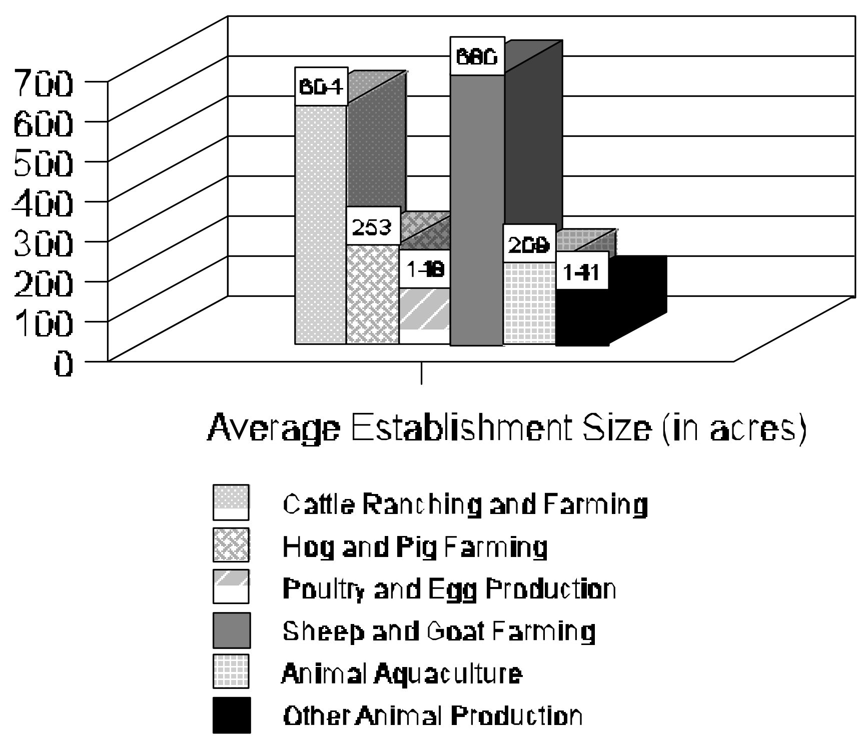


Exhibit 8. Average Establishment Size (1997 Ag Census)



The six types of livestock producing establishments defined above accounted for approximately $99 billion worth of products sold in 1997. Exhibit 9 presents the distribution of total sales among the six types of establishments compared to the total number of establishments. EPA's *Preliminary Data Summary Feedlots Point Source Category Study* released in January 1999 contains additional detailed information for beef cattle, dairy, pork, sheep, and poultry operations.

Exhibit 9. Percentage of Establishments & Sales by Type (1997 Ag Census)

Type of Livestock Establishment	Percent of Establishments	Percent of Sales
Cattle Ranching and Farming	78	60
Hog and Pig Farming	4	14
Poultry and Egg Production	4	23
Sheep and Goat Farming	3	<1
Animal Aquaculture	<1	<1
Other Animal Production	11	2

II.B.1. Cattle Ranching and Farming

Cattle ranching and farming establishments (NAICS code 1121) comprise the overwhelming majority of all establishments categorized under NAICS code 112 by accounting for 77.9 percent of all livestock establishments. In the U.S. in 1997, there were 785,672 cattle ranching and farming establishments. Of these, approximately 89 percent (699,650 establishments) were categorized as beef cattle establishments, including feedlots. The remaining 11 percent (86,022 establishments) were categorized as dairy cattle and milk production facilities. In 1997, the average beef cattle establishment was nearly 635 acres in size. Establishments raising dairy cattle and producing milk averaged approximately 356 acres.

Cattle ranching and farming establishments accounted for approximately $60 billion of sales in 1997. Of that $60 billion, beef cattle establishments had sales of approximately $38 billion (approximately 65 percent of sales), while dairy cattle and milk production accounted for the remaining $21 billion. Exhibit 10 compares the percentage sales of each subcategory to the percentage of establishments.

Exhibit 10. Percentage of Establishments & Sales in the Cattle Ranching and Farming Industry (1997 Ag Census)

Type of Establishment	Percent of Establishments	Percent of Sales
Beef cattle ranch and farming, including feedlots	89	65
Dairy cattle and milk production	11	35

II.B.2. Hog and Pig Farming

Hog and pig farming (NAICS code 1122) comprised approximately 4.6 percent (46,353 establishments) of all the livestock producing establishments in the U.S. in 1997. These establishments accounted for nearly $14 billion in total sales, or approximately 14 percent of total livestock producing establishment sales in 1997.

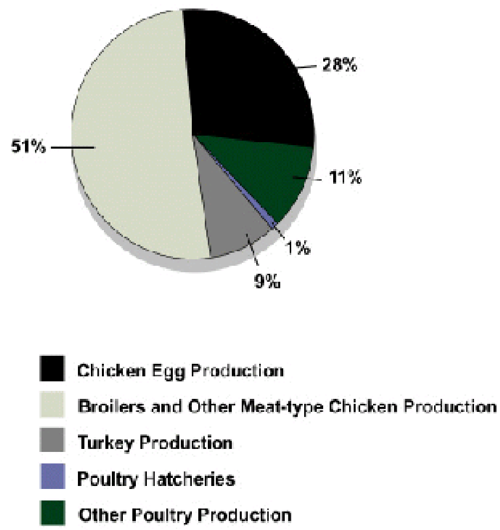
II.B.3. Poultry and Egg Production

Poultry and egg production is classified in NAICS code 1123. In 1997, this category included 36,944 establishments, or approximately 4 percent of all livestock producing establishments in the U.S. Poultry and egg production is divided into 5 subclassifications:

- Chicken egg production (NAICS code 11231)
- Broilers and other meat-type chicken production (NAICS code 11232)
- Turkey production (NAICS code 11233)
- Poultry hatcheries (NAICS code 11234)
- Other poultry production, including ducks, emus, geese, ostrich, pheasant, quail, and ratite (NAICS code 11239)

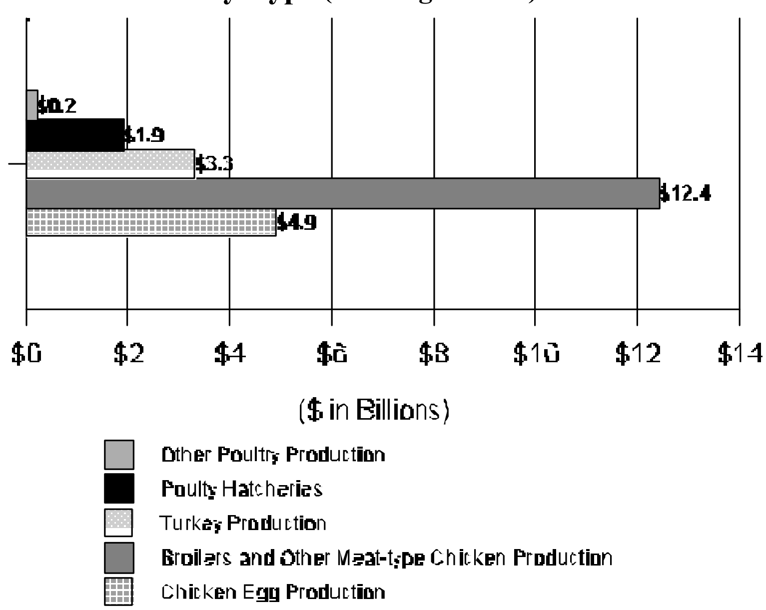
Exhibit 11 provides a breakdown of the 5 subclassifications by number of establishments. Each of these establishments averages approximately 150 acres in size.

Exhibit 11. Percent of Poultry and Egg Production Establishments by Type
(1997 Ag Census)



In 1997, the poultry and egg production industry combined for nearly $23 billion in sales, which accounted for 23 percent of total livestock sales in the U.S. Sales of broilers and other meat-type chicken accounted for 54 percent of those sales (approximately $12.4 billion). Exhibit 12 presents the total sales of each of the subclassifications of the poultry and egg production industry.

Exhibit 12. Total Sales of Poultry and Egg Production Establishments by Type (1997 Ag Census)



The poultry industry has increased its use of contractual agreements because of the high number of producers relative to the number of available buyers willing to handle raw farm products. The use of contracts has been noted to affect the organizational structure of the poultry industry raising questions about ownership responsibility as well as environmental concerns. This is particularly true when animals are produced under contracts where the contractor (processor or integrator) dictates the terms of the contract and controls the amount produced and the production practices used, but the contractee (grower) retains responsibility for increased animal waste management and disease control often without adequate compensation to meet these additional costs. In a 1993 study, USDA showed that almost 90 percent of the value of all poultry production is produced under contract, which has played a key role in the influence of integrators on the poultry sector.

II.B.4. Sheep and Goat Farming

Sheep and goat farming (NAICS code 1124) comprised 3 percent of all livestock establishments in the U.S. in 1997 and accounted for nearly 4 percent of the total acreage of livestock establishments. Of the 29,938 sheep and goat establishments, 21,084 (approximately 70 percent) are sheep farms; the remaining 8,854 are goat farms. The average sheep farm is approximately 830 acres in size. Goat farms average approximately 320 acres.

In 1997, sheep and goat farms combined for $625 million in total sales, which is less than 1 percent of total livestock producing establishment sales and the least amount of the six primary NAICS codes. Sheep accounted for $568 million in sales (approximately 91 percent) and goat sales accounted for the remaining $57 million.

II.B.5. Animal Aquaculture

Animal aquaculture (NAICS code 1125) is the smallest of the livestock producing establishments in terms of number of establishments, with only 3,079 active establishments in 1997. This accounted for fewer than 1 percent of all livestock producing establishments in the U.S. It also accounted for less than 1 percent ($800 million) of the 1997 total sales of livestock producing establishments. NAICS subdivides animal aquaculture establishments as follows:

- Finfish farming and fish hatcheries (NAICS code 112511), which is raising finfish (e.g., catfish, trout, goldfish, tropical fish, salmon, and minnows) and/or hatching fish of any kind.

- Shellfish farming (NAICS code 112512), which is raising crayfish, shrimp, oysters, clams, and/or mollusks.

- Other animal aquaculture (NAICS code 112519), which is raising animals other than finfish and shellfish, including alligators, frogs, and/or turtles.

While data for each of the specific NAICS subclassifications were not available through the 1997 Ag Census, USDA's NASS has identified at least 955 catfish producing operations. These operations are located primarily in four states--Alabama, Arkansas, Louisiana, and Mississippi. Similarly, the USDA has identified 451 trout operations located in 16 states, but primarily in North Carolina, Wisconsin, and Michigan. These trout operations had total sales in 1998 of $78.9 million. Both the number of operations and the value of total sales are down from the 1997 totals of 465 and $79.8 million, respectively.

II.B.6. Other Animal Production

Production of other animals (NAICS code 1129) occurred at 107,051 establishments in 1997, which is approximately 11 percent of all livestock producing establishments in the U.S. These establishments produce a variety of other animals including:

- Apiculture [bee farming (i.e., raising bees)] (NAICS code 11291)

- Horse and other equine production, including burros, donkeys, mules, and ponies (NAICS code 11292)

- Fur-bearing animal and rabbit production, including chinchillas, foxes, and mink (NAICS code 11293)

- All other animal production, including aviaries, bison/buffalo, cats/dogs, llamas, snakes, and worms (NAICS code 11299)

These four subclassifications accounted for just more than 2 percent of the total sales of livestock producing establishments in 1997. Exhibit 13 provides a breakdown of the 4 subclassifications by percent of establishments, as well as by percent of sales.

Exhibit 13. Percent of Establishments & Sales for the Other Animal Production Industry (1997 Ag Census)

Establishment Type	Percent of Establishments	Percent of Sales
Apiculture	4	5.9
Horse and Other Equine Production	86	42.9
Fur-bearing Animal and Rabbit Production	1	4.7
All Other Animal Production	9	46.5

II.C. Animal Feeding Operations

Many livestock establishments within NAICS code 112 are defined by EPA as either animal feeding operations (AFOs) or concentrated animal feeding operations (CAFOs). The primary factor classifying a livestock operation as an AFO or CAFO is the confinement of animals in a relatively small area devoid of sustaining vegetation. According to the USDA/EPA Unified National Strategy for AFOs, "AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small area of land." This factor separates AFOs (and CAFOs) from the pasture and range operations. The number of animals, among other factors, separates the AFOs from the CAFOs.

EPA is currently collecting and analyzing data on livestock production facilities to determine the number of facilities which meet the definition of AFO or CAFO. This will allow the Agency to better understand the universe of the regulated community, assist compliance, and as necessary, take enforcement action. EPA is currently developing AFO guidance documents and revised regulations that address permitting, performance standards, and other issues. The following sections provide information on the regulatory definitions of both AFOs and CAFOs.

Animal Feeding Operations

What is an AFO?
The term animal feeding operation or AFO is defined in EPA regulations [40 CFR 122.23(b)(1)] as:

- A lot or facility where animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period; AND

- Where crops, vegetation, forage growth, or post-harvest residues are not sustained over any portion of the lot or facility in the normal growing season.

According to EPA[1], the first part of this regulatory definition of an AFO states that animals must be kept on the lot or facility for a minimum of 45 days. If an animal is at a facility for any portion of a day, it is considered to be at the facility for a full day. However, this does not mean that the same animals must remain on the lot for 45 days; only that some animals are fed or maintained on the lot or facility 45 days out of any 12-month period. The 45 days do not have to be consecutive, and the 12-month period does not have to correspond to the calendar year. For example, June 1 to the following May 31 would constitute a 12-month period.

The second part of the regulatory definition of an AFO is meant to distinguish facilities that have feedlots (concentrated confinement areas) from those which have pasture and grazing land, which are generally not AFOs. Facilities that have feedlots with constructed floors, such as solid concrete or metal slots, satisfy this part of the definition. If a facility maintains animals in an area without vegetation, including dirt lots, the facility meets this part of the definition. Dirt lots with nominal vegetative growth along the edges while animals are present or during months when animals are kept elsewhere are also considered by EPA to meet the second part of the definition.

The NPDES permit regulations [40 CFR Part 122.23(b)(1)] give the permitting authority (EPA or NPDES-authorized States) considerable discretion in applying the AFO definition. EPA defines the AFO to include the confinement area and the storage and handling areas necessary to support the operation (e.g., waste storage areas). Grazing and winter feeding of animals in a confined area on pasture or range land are not normally considered to meet the AFO definition.

As indicated in the USDA/EPA Unified National Strategy for AFOs, discharges from areas where manure and wastewater are applied to the land can have a significant impact on water quality. These land application areas are outside the area of confined animals but can be implicated by their direct relationship to AFO waste. Discharges of CAFO wastes from land application areas can qualify as point source discharges in certain circumstances. Accordingly, NPDES permits for CAFOs should address land application of wastes from CAFOs.

[1] *Guidance Manual and Example NPDES Permit for Concentrated Animal Feeding Operations (Draft)*, U.S. Environmental Protection Agency, August 6, 1999.

How Do You Determine the Size of an AFO?

Once the facility meets the AFO definition, its size, based upon the total numbers of animals confined, is a fundamental factor in determining whether it is a CAFO. The animal livestock industry is diverse and includes a number of different types of animals that are kept and raised in confined situations. In order to define these various livestock sectors in relative terms, the concept of an "animal unit"[2] was established in the EPA regulations [40 CFR Part 122 Appendix B]. An animal unit (AU) varies according to animal type; one animal is not necessarily equal to one AU. Each livestock type, except poultry, is assigned a multiplication factor to facilitate determining the total number of AUs at a given facility. Multiplication factors are defined in Exhibit 14.

Exhibit 14. Multiplication Factors to Calculate Animal Units

Animal Type	Multiplication Factor
Beef Cattle (slaughter and feeder)	1.0
Mature Dairy Cattle	1.4
Swine (weighing more than 55 lbs.)	0.4
Sheep	0.1
Horses	2.0
Poultry	There are currently no animal unit conversions for poultry operations. However the regulations [40 CFR 122, Appendix B] define the total number of animals (subject to waste handling technology restrictions) for specific poultry types that make these operations subject to the regulation.

These factors also are used when determining the total number of animal units at a facility with multiple animal types. Multiplication factors are applied to the total for each type of animal to determine the AU for that animal type. The AUs for each are then totaled for the facility total. A hypothetical AFO with multiple animal types and the calculation to determine the total number of animals confined at the facility is presented below (see box).

[2] EPA and USDA both use the concept of "animal unit," however it is important to recognize that with respect to swine and poultry, there are Agency differences in the application of this concept.

Example: Animal Unit Determination for an AFO with Multiple Animal Types

Situation: An AFO is being evaluated to determine if it meets the animal unit criteria for being defined as a CAFO and subject to NPDES permitting. The facility confines 200 horses, 300 sheep, and 500 beef cattle.

Animal Unit Calculation:	200 Horses x 2.0 =	400 AUs
	300 Sheep x 0.1=	30 AUs
	500 Beef Cattle x 1.0 =	500 AUs
	Total	930 AUs

Under the regulations, two or more AFOs under common ownership are considered one operation if they adjoin each other or use a common waste disposal system [40 CFR 122.23(b)(2)]. For example, facilities have a common waste disposal system if the wastes are commingled (e.g., stored in the same pond or lagoon or land applied on commonly owned fields) prior to use or disposal. The collective number of animal units of the adjoining facilities is used in determining the size of the AFO. Many poultry feeding operations adjoin each other and often meet the definition of one facility.

Concentrated Animal Feeding Operations

AFOs are CAFOs if they meet the regulatory definition [40 CFR 122, Appendix B] or have been designated on a case-by-case basis [40 CFR 122.23 (c)] by the NPDES-authorized permitting authority.

AFOs are Defined as CAFOs if:

- More than 1,000 AUs are confined at the facility [40 CFR 122, Appendix B (a)]; ***or***
- From 301 to 1,000 AUs are confined at the facility and:
  - Pollutants are discharged into waters of the U.S. through a man-made ditch, flushing system, or other similar man-made device; or
  - Pollutants are discharged directly into waters of the U.S. that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals.

AFOs <u>Defined</u> as CAFOs
According to the NPDES regulations, a specific definition must be used when determining whether an AFO is a CAFO. The definition is broken down according to the number of animals confined at the facility (see box). AFOs with more than 1,000 AUs are CAFOs. AFOs with 301 to 1,000

AUs are defined as CAFOs only if, in addition to the number of animals confined, they also meet one of the specific criteria addressing the method of discharge (see text box).

AFOs with fewer than 300 AUs are not defined as CAFOs under the current regulations but may be designated as a CAFO.

- ***AFOs With More Than 1,000 AUs are CAFOs***. Under existing regulations, virtually all AFOs with more than 1,000 AUs are CAFOs and should apply for an NPDES permit. For individual animal types, the regulations state the number of animals required for the facility to be defined as a CAFO. These numbers are presented in Exhibit 15. If the number of AUs for any one animal type at a facility exceeds the corresponding number, or if the cumulative number of animal types exceeds 1,000 AUs, the facility is defined as a CAFO.

Exhibit 15. Threshold Number of Animals (by Animal Type) to Meet the Definition of a CAFO with More Than 1,000 AUs

Animal Type	Number of Animals Units
Beef cattle	1,000 slaughter or feeder cattle
Dairy cattle	700 mature dairy cattle (whether milked or dry)
Swine	2,500 swine (over 25 kilos - approximately 55 lbs.)
Sheep	10,000 sheep or lambs
Horses	500 horses
Chickens	100,000 laying hens or broilers when the facility (if continuous flow watering system); 30,000 laying hens or broilers (if liquid manure system)
Turkeys	55,000 turkeys
Ducks	5,000 ducks

Source: 40 CFR Part 122, Appendix B (a)

- **AFOs With 301 to 1,000 AUs *May Be* CAFOs.** AFOs with 301 to 1,000 AUs are defined as CAFOs only if, in addition to the number of animals confined, they also meet one of the specific criteria governing "method of discharge." If the number of AUs for any one animal type exceeds the specified number [40 CFR Part 122, Appendix B(b)], or if the *cumulative* number of animal types exceeds 300 AUs, **and** only one of the "method of discharge" criteria are met, the facility is defined as a CAFO.

- **AFOs with up to 300 AUs.** An AFO with up to 300 AUs may be considered a CAFO only if designated as such by the permitting authority and if it meets the discharge criteria (see below).

AFOs Designated as CAFOs

According to the NPDES permit regulations [40 CFR 122.23 (c)], the NPDES-authorized permitting authority can, on a case-by-case basis, designate any AFO as a CAFO after determining that it is a significant contributor of pollution to waters of the United States. No AFO with fewer than 300 AUs shall be designated a CAFO unless it also meets the discharge criteria outlined in 40 CFR 122.23(c).

An AFO *cannot* be designated a CAFO on a case-by-case basis until the an inspector has conducted an on-site inspection of the facility and determined that the facility is a significant contributor of pollution. The designation is based on the factors listed in 40 CFR 122.23 (c) and shown below. This determination may be based on visual observations as well as water quality monitoring. Exhibit 16 shows example case-by-case designation factors and the inspection focus related to each factor.

Exhibit 16. Example Factors for Case-by-Case CAFO Designation

Designation Factor	Inspection Focus
Size of the operation and amount of waste reaching waters of the United States	• Number of animals • Type of feedlot surface • Feedlot design capacity • Waste handling/storage system design capacity
Location of the operation relative to waters of the United States	• Location of water bodies • Location of flood plain • Proximity to surface waters • Depth to groundwater, direct hydrologic connection to surface water
Means of conveyance of animal waste and process waste waters into waters of the United States	• Identify existing or potential man-made (includes natural and artificial materials) structures that may convey waste • Direct contact between animals and surface water
Slope, vegetation, rainfall and other factors affecting the likelihood or frequency of discharge	• Slope of feedlot and surrounding land • Type of feedlot (concrete, soil, etc.) • Climate (e.g., arid or wet) • Type and condition of soils • Depth to groundwater • Drainage controls • Storage structures • Amount of rainfall • Volume and quantity of runoff • Buffers
Other Relevant Factors	• Waste handling and storage • Land application timing, methods, rates and areas

Following the on-site inspection, the NPDES permitting authority will prepare a brief report that: (1) identifies findings and any follow-up actions; (2) determines whether or not the facility should be designated as a CAFO; and (3) documents the reasons for that determination. Regardless of the outcome, a letter would be prepared and sent to the facility. The letter should inform the facility that it has been either: (1) designated a CAFO and required to apply for an NPDES permit; or (2) has not been designated as a CAFO at this time. In those cases where a facility has not been designated as a CAFO but the NPDES authority has identified areas of concern, these would be noted in the letter.

II.D. Geographic Distribution and Economic Trends

As described in the executive summary of the *Preliminary Data Summary: Feedlots Point Source Category Study* (December 1998), livestock production operations in the U.S. vary widely in both the mode and scale of production, with individual farms spanning small scale production facilities with few animals to large, intensive production facilities. The following are summaries of the principal producing States in 1992 by animal commodity for beef cattle, swine, dairy cattle, and poultry.

- Ranked by the number of cattle and calves sold, the top ten producing states controlled 65 percent of U.S. beef production in 1992. Texas was the largest beef producing state accounting for 16 percent of 1992 sales. Other major states included Kansas, Nebraska, Oklahoma, Colorado, Iowa, California, South Dakota, Missouri, Wisconsin, and Montana.

- The hog farming sector is concentrated among the top five producing states that together supply about 60 percent of U.S. pork production. Iowa accounted for 24 percent of 1992 hog sales. Other major hog producing states included North Carolina, Illinois, Minnesota, Indiana, and Nebraska.

- The top five dairy cattle states controlled more than 50 percent of all U.S. milk production in 1992. Wisconsin was the largest dairy producing state with 16 percent of volume milk sales. Other major milk producing states included California, New York, Pennsylvania, and Minnesota.

- Broiler and chicken meat production is controlled by 10 producing states, which supply about 80 percent of all broilers sold. Arkansas was the largest broiler producer in 1992, with 16 percent of sales. Other major states included Georgia, Alabama, North Carolina, Mississippi, Texas, Maryland, California, Delaware, and Virginia.

- The top ten producing states accounted for about 80 percent of turkey production. North Carolina was the largest turkey producing state in 1992, with about 20 percent of sales. Other top producing states included Minnesota, California, Arkansas, Virginia, Missouri, Indiana, Texas, Iowa, and Pennsylvania.

- Egg production is dominated by 10 producing states that supply almost two-thirds of the eggs sold. California was the largest egg producing state in 1992 with about 12 percent of all eggs sales. Other major producers included Indiana, Pennsylvania, Georgia, Ohio, Arkansas, Texas, North Carolina, and Alabama.

Recent trends in the U.S. livestock sector are marked by a decline in the number of farms attributable to ongoing consolidation in the livestock industry. Farms are closing – especially small farming operations – due to competitive pressures from highly specialized – often lower cost – large scale producers. This trend toward fewer and larger livestock operations represents a significant shift in the industry. Both 1992 and 1997 Agriculture Census data highlight the ongoing shift from many small, diversified farms toward fewer large-scale, year-round, intensive breeding and feeding operations.

Another industry trend has been a steady increase in animal production and sales in the U.S. This trend has occurred at the same time there has been a decrease in the number of animals on site. This trend signals continued gains in production efficiency on U.S. farms in the form of higher per-animal yields and quicker turnover of animals prior to marketing.

A detailed industry economic profile is presented in the *Feedlots Point Source Category Study* and covers major commodity sectors, industry trends in the U.S. livestock and poultry farm sectors, recent market trends, farm revenue, farm-gate prices, financial operating conditions, industry marketing chain, and industry employment generated.

Additional geographic and economic information can be found by accessing the 1997 Agriculture Census at http://www.nass.usda.gov/census/ and the National Agriculture Statistics Service at http://www.usda.gov/nass/.

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III. SUMMARY OF OPERATIONS, IMPACTS, AND POLLUTION PREVENTION OPPORTUNITIES FOR THE AGRICULTURAL LIVESTOCK PRODUCTION INDUSTRY

This section provides an overview of commonly employed operations and maintenance activities in the agricultural livestock production industry. This discussion is not exhaustive; the operations and maintenance activities discussed are intended to represent the material inputs, major pollution outputs, and associated environmental impacts from agricultural livestock production practices. General pollution prevention and waste minimization opportunities are also discussed in the context of each of the operations and maintenance activities.

The choice of practices or operations influences the material used and the resulting pollution outputs and environmental impacts. Keep in mind that environmental impacts are relative, as some kinds of pollution outputs have far greater impacts than others.

Impact of Agriculture on the Environment

> The Clean Water Act Plan of 1998 called for the development of the EPA/USDA *Unified National Strategy for Animal Feeding Operations* (AFOs) to minimize the water quality and public health impacts of AFOs.

According to the *EPA/USDA Unified National Strategy for Animal Feeding Operations* (March 9, 1999), despite progress in improving water quality, 40 percent of the Nation's waterways assessed by States do not meet goals for fishing, swimming, or both. While pollution from factories and sewage treatment plants has been dramatically reduced, the runoff from city streets, agricultural activities, including AFOs, and other sources continues to degrade the environment and puts environmental resources (i.e., surface water, drinking water) at risk. According to EPA's 1996 305(b) water quality report, the top two pollutants from agriculture were identified as sediment and nutrients, respectively. Additional agricultural pollutants, such as animal wastes, salts, and pesticides, were identified by EPA[1]. The following presents a brief discussion of the environmental impacts or effects of agricultural pollutants.

(1) ***Nutrients***. Excess nutrients in water (i.e., phosphorus and nitrogen) can result in or contribute to low levels of dissolved oxygen (anoxia),

[1] *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters,* U.S. Environmental Protection Agency, January 1993.

eutrophication, and toxic algal blooms. These conditions may be harmful to human health; may adversely affect the suitability of the water for other uses; and, in combination with other circumstances, have been associated with outbreaks of microbes such as *Pfiesteria piscicida*.

- Phosphorus. Phosphorus determines the amount of algae growth and aging that occurs in freshwater bodies. Runoff and erosion can carry some of the applied phosphorus to nearby water bodies.

- Nitrogen. In addition to eutrophication, excessive nitrogen causes other water quality problems. Dissolved ammonia at concentrations above 0.2 mg/L may be toxic to fish. Biologically important inorganic forms of nitrogen are ammonium, nitrate, and nitrite. Ammonium becomes adsorbed to the soil and is lost primarily with eroding sediment. Even if nitrogen is not in a readily available form as it leaves the field, it can be converted to an available form either during transport or after delivery to waterbodies. Nitrogen in the form of nitrate, can contaminate drinking water supplies drawn from groundwater. Nitrates above 10 ppm in drinking water are potentially dangerous, especially to newborn infants.

(2) ***Sediment.*** Sediment affects the use of water in many ways. Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, clog the filtering capacity of filter feeders, and clog and harm the gills of fish. Turbidity interferes with the feeding habits of fish. These effects combine to reduce fish and plant populations and decrease the overall productivity of waters. In addition, recreation is limited because of the decreased fish population and the water's unappealing, turbid appearance. Turbidity also reduces visibility, making swimming less safe.

(3) ***Animal Wastes***. Animal waste includes the fecal and urinary wastes of livestock and poultry; process water (such as from a milking parlor); and the feed, bedding, litter, and soil with which fecal and urinary matter and process water become intermixed. Manure and wastewater from AFOs have the potential to contribute pollutants such as nutrients (e.g., nitrogen and phosphorus), organic matter, sediments, pathogens, heavy metals, hormones, antibiotics, and ammonia to the environment. Decomposing organic matter (i.e., animal waste) can reduce oxygen levels and cause fish kills. Solids deposited in waterbodies can

accelerate eutrophication through the release of nutrients over extended periods of time.

Contamination of groundwater can be a problem if runoff results from the misapplication or over application of manure to land or if storage structures are not built to minimize seepage. Because animal feed sometimes contains heavy metals (e.g., arsenic, copper, zinc), the possibility for harmful accumulations of metals on land where manure is improperly or over applied is possible.

> ***Pathogens in manure.*** Pathogens in manure can cause diseases in humans if people come in contact with the manure. Pathogens in manure also create a food safety concern if manure is applied directly to crops at inappropriate times or if manure contaminates a product (e.g., food, milk). In addition, pathogens are responsible for some shellfish bed closures. Runoff from fields receiving manure may contain extremely high numbers of bacteria (though all of these bacteria may not be harmful) if the manure has not been properly incorporated. Pathogens, such as *Cryptosporidium*, have been linked to impairments in drinking water supplies and threats to human health.

Air pollution is also a concern in relation to animal wastes. Farms on which animals are raised often concentrate odors associated with the microbial degradation of manure and other by-products of the production of meat, milk and eggs. Odors can be a nuisance to neighbors of animal operations, and there is increasing concern about the potential health effects from emissions of odorous compounds.

(4) ***Salts***. Salts are a product of the natural weathering process of soil and geologic material. In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs. The accumulation of soluble and exchangeable salts leads to soil dispersion, structure breakdown, decreased infiltration, and possible toxicity; thus, salts often become a serious problem on irrigated land, both for continued agricultural production and for water quality considerations. High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops.

(5) ***Pesticides.*** The primary pollutants from pesticides are the active and inert ingredients, diluents, and any persistent degradation products. Pesticides and their degradation products may enter groundwater and surface water in solution, in emulsion, or bound to soils. Pesticides may, in some instances, cause impairments to the uses of surface

waters and groundwater. Both the degradation and sorption characteristics of pesticides are highly variable. Some types of pesticides are resistant to degradation and may persist and/or accumulate in aquatic ecosystems. Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species.

Within a livestock production establishment, pesticides may be applied directly to livestock or to structures (e.g., barns, housing units) to control pests, including parasites, vectors, and predators.

Pesticides are both suspected and known for causing immediate and delayed-onset health hazards for humans. If exposed to pesticides, humans may experience adverse effects, such as nausea, respiratory distress, or more severe symptoms up to and including death. Animals and birds impacted by pesticides can experience similar illnesses or develop other types of physical distress.

Pollution Prevention/Waste Minimization Opportunities in the Agricultural Livestock Production Industry

The best way to reduce pollution is to prevent it in the first place. Industries have creatively implemented pollution prevention techniques that improve operations and increase profits while minimizing environmental impacts. This can be done in many ways such as reducing material inputs, reusing byproducts, improving management practices, and employing substitute toxic chemicals.

To encourage these approaches, this section provides general descriptions of some pollution prevention advances that have been implemented within the agricultural livestock production industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for establishments interested in beginning their own pollution prevention projects. This section provides information from real activities that may be or are being implemented by this sector. When possible, information is provided that gives the context in which the technique can be effectively used. Please note that the activities described in this section do not necessarily apply to all facilities that fall within this sector. Facility-specific conditions must be carefully considered when pollution prevention options are evaluated, and the full impacts of the change must examine how each option affects air, land, and water pollutant releases.

The use of pollution prevention technologies and environmental controls can substantially reduce the volume and concentration of the contaminants released/discharged into the surrounding environment. In some cases, these pollution prevention approaches may be economically beneficial to the agricultural production industries because they decrease the amount of chemicals needed, and therefore the cost of maintaining operations.

Waste minimization generally encompasses any source reduction or recycling that results in either the reduction of total volume or the toxicity of hazardous waste. Source reduction is a reduction of waste generation at the source, usually within a process. Source reduction can include process modifications, feedstock (raw material) substitution, housekeeping and management processes, and increases in efficiency of machinery and equipment. Source reduction includes any activity that reduces the amount of waste that exits a process. Recycling refers to the use or reuse of a waste as an effective substitute for a commercial product or as an ingredient or feedstock in an industrial process.

It should be noted that as individual practices, these pollution prevention and waste minimization practices can significantly reduce the environmental impacts of agricultural operations. However, to get the full effect of the practices and maximize pollution prevention potential, an agricultural operation must consider its individual practices in the context of a system. The practices combine to form an integrated system in which each practice interacts with the others and is affected by the others. That is, outputs from one practice may be inputs into one of the other practices, in effect creating a closed-loop system that both maximizes profits and minimizes environmental impacts. By considering their establishments as systems, operators will be better able to evaluate and implement pollution prevention or waste minimization opportunities.

Operations of Livestock Production

Livestock production generally includes the following activities:

- Feed storage, loading, and unloading
- Housing
- Feeding and watering
- Managing animal waste
- Applying pesticides and pest control
- Maintaining and repairing agricultural machinery and vehicles
- Fuel use and fueling activities

The additional activities of planning and management are required for all of the above processes to occur. Exhibit 17 presents the material inputs and pollution outputs from each of these processes.

Exhibit 17. Livestock Production Activities and Potential Pollution Outputs

Activity	Potential Pollution Outputs
Feed storage, loading, and unloading	• Dust emissions • Unusable or spilled feed • Leachate from silage • Nutrient-contaminated runoff
Housing	• Animal waste • Waste bedding • Air emissions (e.g., odors, methane, ammonia) • Washwater from flushing and washdown of housing areas
Feeding	• Animal waste • Air emissions (e.g., dust, methane) • Moldy feed discard • Spilled feed • Nutrient-contaminated runoff
Watering	• Animal waste • Water contaminated with animal waste • Destruction of stream bank, riparian zone (from animals in streams)

Typically, most of the above activities include the generation of *animal waste.* Animal waste must be managed appropriately because of its potential environmental impacts.

Managing animal waste, includes collecting and transporting; storing and treating; and utilizing animal waste	• Discharges and leaching of wastewater • Manure and urine • Bedding • Air emissions (e.g., ammonia, methane, other gases, odor, dust) • Hair and/or feathers • Carcasses • Pathogens • Heavy metals • Wasted products (e.g., milk, eggs)

Exhibit 17. Livestock Production Activities and Potential Pollution Outputs

Activity	Potential Pollution Outputs
Additional activities that occur at agricultural establishments and their potential pollution outputs include:	
Pest control	S Discharges and leaching of pesticides S Chemical air emissions
Maintaining and repairing agricultural machinery and vehicles	S Used oil S Spent fluids and organic solvents S Used tires S Spent batteries S Metal machining wastes S Scrap metal
Fuel use and fueling activities	S Fuel spills or leaks

III.A. Feed Storage, Loading, and Unloading

Feed storage, loading, unloading, and transport are major activities in livestock production. Livestock feed may include hay, grain (sometimes supplemented with protein, vitamins, mineral supplements and antibiotics), and silage -- with grain and hay being the most common feeds. Livestock operations may produce all, a portion, or none of the animal feed. Purchased feed is transported to the livestock operation by truck or, at very large animal operations, by rail. Stored feed must be loaded, transported to the animals' normal feed location, and unloaded.

S Hay that has been cut and partially dried is collected from fields and compacted into small rectangular bales or rolled into large round bales. Hay may be stored in covered and enclosed buildings, in fields, and in outside storage areas where it may or may not be covered. Small rectangular hay bales may be placed in a barn by conveyor.

  Feed hay is often transported on tractor-drawn wagons to feed bunkers, feed rings, and mangers. Small rectangular hay bales may be mechanically or manually placed in bunkers and mangers. Front-end loaders are used to unload round bales and place them in the feed rings.

- Harvested grain is sometimes milled (ground) on site or more commonly sent offsite to a milling facility for grinding prior to being returned to the facility for use. Depending on the livestock species, protein, vitamins, mineral supplements, and antibiotics are often added at the time of milling or mixing. Grain is typically stored in aerated grain bins and handled with augers. High moisture corn is stored in silos. Grain, which is typically placed in feed bunkers, troughs, or feeder units, can be transported using a front-end loader, tractor front bucket, grain wagon, or manually for smaller volumes.

- Silage is usually produced onsite and may consist of chopped green corn or hay. Silage is allowed to ferment in vertical or horizontal silos or storage bunkers prior to use as feed. Silage is removed from silos and then distributed along the feed bunks.

Potential Pollution Outputs and Environmental Impacts
The primary pollution outputs include unusable feed; dust emissions from loading, unloading, and grinding activities; air emissions from transportation to and from sites; and leachate from silage. A minor pollution output is contamination of storm water from spilled feed. Dust emissions pollute the air that agricultural workers and animals breathe and can cause respiratory problems in instances of prolonged exposure. Research indicates that silage materials stored at 65 percent moisture content or higher can produce leachate.

Pollution Prevention/Waste Minimization Opportunities
One potential pollution prevention practice focuses on minimizing unusable feed and consequently maximizing the amount of feed that is consumed by the animal. One way to maximize animal consumption is by grinding the feed in either a grinder-mixer or a tub grinder. Grinding increases the ability of the animal to digest the feed. Where possible, grinders should be used with a dust collector to reduce dust emissions. Silage leachate can be reduced by allowing the material to wilt in the field for 24 hours, varying cutting and harvesting times, cutting or crimping the material, or adding moisture-absorbent material to the silage as it is stored[2].

[2] *Farm-A-Syst, Fact Sheet #9, Reducing the Risk of Groundwater Contamination by Improving Silage Storage*, University of Wisconsin, Extension/Cooperative Extension, College of Agricultural and Live Sciences.

III.B. Housing

Livestock housing may consist of feed lots, barns, stables or stalls, corrals, covered loafing areas, pens, poultry houses, and other similar structures that confine the animals in an area and manner best suited to the overall livestock production process. There are three general ways to house livestock:

(1) Enclosed housing (i.e., a roofed and walled structure)
(2) Partially enclosed (i.e., usually roofed with walls on some structure sides)
(3) Open or no structures

The type of housing used for a particular animal type/livestock production is related to animal size, feeding, animal health and biosecurity, climate, and the goal of achieving the optimum weight gain or commodity produced at the lowest cost.

- Dairy cattle. Most dairy operations provide separate housing for different animal groups based on age or milking status (lactating versus dry). Calves may be housed in barns, individual pens within a barn, open fields, and hutches. Heifers may be housed in freestall barns and bedded pack housing. Bedded pack housing is often used with an open feeding area. Dry cows (<3 months to calving) are usually housed on pasture or in freestall barns. Lactating cows are housed in freestall and other types of barns such as stanchion, corrals, structures, and open lots that provide shade[3].

- Beef cattle. Beef cattle are mainly housed in pastures and open feedlots. Calving facilities may consist of an open pasture, a shed with stalls, or an open, wind-protected pen. Bulls are either penned separately or in groups of up to 10. They may be contained in a barn or in an open pen with shade. Cattle feedlots are usually open areas that may have windbreaks and shade. Very few beef cattle are housed in freestall barns with slotted floors for manure collection.

- Sheep. Sheep are maintained primarily on open grazing land, but some are kept in open lots with shelters, facilities with slotted floors for manure collection, and in bedded pens.

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[3] *Preliminary Data Summary: Feedlots Point Source Category Study*, U.S. Environmental Protection Agency, Office of Water, Washington, DC, December 1998.

- Horses. Most horses maintained in concentrated numbers are housed in stalls within an enclosed barn. Approximately 70 percent of the horse operations that use stalls have one animal per stall. Horses may also be housed in partially enclosed housing or on pasture.

- Poultry. Poultry including turkeys and ducks are maintained in an enclosed house. Chicken broilers, roasters, and pullets, which may be caged, are usually maintained in houses on a solid floor with bedding. Breeders are usually maintained in houses with a slatted floor generally covering one-third of each side of the house along the length of the side-wall of the house. Most layers are maintained in houses inside of cages with mesh floors, and a few in houses with a litter or slat/litter floor. Turkey poults are reared in enclosed brooder houses, then generally are moved to grower houses and sometimes to range. Turkeys are normally raised on a dirt or clay floor with a bedding cover. Duck housing is normally an enclosed house that has a wire-mesh floor, a solid floor, or a combination of the two.

- Goats. Goats are housed in loose housing common areas that may contain bedded and exercise areas, individual stalls, pens, and corrals. Pregnant does are usually housed in bedded pens.

- Swine. While some swine are raised outdoors with a shelter (e.g., hoop housing), most are housed in an enclosed barn or house. Breed sows may be kept in small group pens and then during farrowing, a sow is usually placed in an individual pen. Young pigs are placed together in larger nursery pens. Finishing operations keep several pigs in the same pen.

The floors of some livestock housing for cattle, swine, and sheep, may be of slotted construction. The floors for some poultry housing may be of wire-mesh or slat construction. The slotted, wire-mesh, and slatted housing floor systems allow the manure to drop into a long-term or temporary storage/collection/transfer area.

Bedding is mostly used in the housing of dairy cattle, poultry, and horses but may be used for the housing of any of the livestock types presented above. Manure and bedding needs to be removed at regular intervals. Methods of removal vary depending on the type of housing. Manure is primarily removed from housing by scraping, scooping, and flushing (see Section III.D. Managing Animal Wastes).

Potential Pollution Outputs and Environmental Impacts

The primary pollution outputs include animal wastes, bedding, wastewater from flushing and washdown of housing areas, and air emissions (e.g., methane, ammonia, and odors). The main impacts of these outputs are soil and water contamination stemming from waste spills, improper storage, and runoff.

From an environmental standpoint, each type of livestock housing (enclosed, partially enclosed or open) has advantages and disadvantages. The move from outdoor housing to confinement housing has removed the weather factor and runoff, which is a substantial problem for outdoor housing, and provided producers the opportunity to manage manure as a resource and not a waste. However, concentrated amounts of manure can be viewed as a disadvantage. While concentrating the animals (and therefore the animal manure) may lead to easier manure management, concentrated amounts of manure have a greater potential to significantly impact the environment in the event of a spill, release, or improper management.

Wastes, including manure and fouled bedding, that are not properly transported from housing could spill and potentially contaminate storm water runoff. Open housing such as feedlots, corrals, and pens, if not scraped as necessary, may also contaminate storm water runoff. Wastes carried in storm water runoff may be discharged to surface waters causing pollution, or may be deposited in low areas and potentially leach to the groundwater.

Animals contained in pasture areas (technically not housing but used for livestock containment) can wear away soil from feeding sites, destroy streambanks at natural watering sites, and, if allowed access, defecate and urinate in surface waters. This results in increased runoff, soil erosion as well as sediments, manure, and urine in the water.

With enclosed or partially enclosed housing areas, odors and other gases (e.g., methane, ammonia, and hydrogen sulfide gases) from animal waste can be concentrated, potentially harming the health of the animals and workers. When the gases are released outside, the odor can affect the surrounding areas and create nuisance problems for neighbors.

Pollution Prevention/Waste Minimization Opportunities
While the majority of the wastes discussed above for housing cannot be prevented, both the wastes and their impacts can be reduced by implementing best management practices.

- *Minimize water use during cleaning*. By cleaning livestock (except poultry) housing on a regular and frequent basis and using minimal amounts of water during cleaning, operations may reduce the volume of wastes to be handled and used. Keeping the waste dry also facilitates its management, reduces runoff potential, and minimizes odors from decomposition.

- *Minimize runoff by cleaning open areas*. Cleaning open areas reduces the potential for the runoff of wastes to surface waters.

- *Reduce odor by preventing ammonia generation*. Ammonia is created by the rapid conversion of urinary nitrogen (urea) to ammonia by microorganisms. By applying various chemicals (e.g., urease inhibitors) on a weekly basis, the conversion of nitrogen to ammonia can be reduced, thus minimizing ammonia emissions and odors, and conserving valuable fertilizer[4].

- *Use tools to minimize odor impacts on the surrounding community.* When considering the installation of a new livestock operation or the expansion of an existing operation, facilities should consider maximizing the distance to neighboring dwellings, the existence of "reverse" setback rules, the potential for new neighbors, and the potential impact neighbors may have on limiting the expansion of the animal housing. Additional methods for reducing odors in other aspects of livestock operations are discussed below.

III.C. Animal Nutrition and Health

There are many activities and considerations when managing animal nutrition and health, including feeding, watering, and biosecurity issues. Animal nutrition is an important consideration for livestock operators for various reasons, including the health of the animals, as well as the nutrient

[4] *Use of Urease Inhibitors to Control Nitrogen Loss From Livestock Waste,* U.S. Department of Agriculture, 1997.

composition of the manure. The nutrient composition of manure (nitrogen and phosphorus) is directly related to the composition of the animal feed, feed supplements, and ability of the animal to digest the feed.

Feeding

Corn, soybean, grasses, hay, silage, and other grains are some of the common food sources for livestock. Most livestock operations adjust the composition of the animals' feed to meet the animals' current protein needs. As an example, dry cows are typically fed a lower protein diet when compared to cattle being milked or nursing calves. Likewise, swine operations often use phase feeding and separation of sexes to best meet the animals' protein needs, lower feed costs, and reduce nutrient levels of the manure. Generally, swine operations feed varying protein diets in relationship to the growth phase and/or need of the animal. As an example, operations provide higher protein feed to farrowing sows, less protein to gilts, and even less to barrows (made possible through separate confinement of sexes). Some livestock operations place swine in confinements recently used for cattle. The swine will receive a portion of its nutrient requirement by feeding on the cattle manure. This provides an overall reduction in the nutrients excreted at the livestock operation.

Feed supplements may include amino acids and enzymes. The supplement of synthetic lysine in swine feed assists in lowering the nitrogen level in the manure. The addition of this amino acid allows feeding of a lower protein diet. Normally, the phosphate in the phytic acid passes through the digestive tract of swine and poultry and is excreted. The addition of phytase, an enzyme to swine and poultry feed, will allow the animal to digest phytic acid from cereal grains and soybean meal and convert it to phosphate for use by the animal. This reduces the need for supplemental phosphorus in the diet of swine and poultry. Currently, the use of phytase is not feasible due to economic and production concerns.

The ability of the animal to digest the feed can be increased by fine grinding and pelletizing feed. Fine grinding increases the surface area of the feed and thereby increases the portion digested.

Feeding can take place in the housing facility, at a separate feeding facility or feeder unit(s), and from pastureland. Other than grazing, where the animal (e.g., sheep, horses, cattle) goes to the feed, the feed is brought to the animals and placed in a feeding device. The feeding process begins with the feed being transported, by various means, from the storage areas to feeding area or unit. The method of feeding is usually related to the type of animal and the housing structure.

- Most dairy operations feed the animals between milking events and may feed the animals from feed bunks that may be covered or uncovered. Small dairy cattle operations may feed the animals during milking and place them on pasture for grazing between milkings.

- Beef (feeder) cattle operations generally feed the animals from feed bunks that may be covered or uncovered. These operations may also use feed rings for large bales of hay.

- Horses, if maintained inside, are fed from a manger and/or other feed device.

- Housed poultry and swine are generally fed continuously from feeding devices. The two major types of feeding devices for poultry and swine are self feeders, which provide the animal with a constant supply of food, and mechanical feeders, which distribute the feed to the animals at predetermined intervals.

Watering

Watering involves the operation and maintenance of animal drinking systems or access to naturally-occurring surface waters or man-made watering structures (e.g., ponds, reservoirs). It is essential that a constant or on-demand supply of water be provided for livestock.

For those housed or in other types of confined areas, there are many different types of man-made watering devices, each of which can be modified depending on the animal using the system. Some of the most commonly used systems include the following:

- *Animal-operated pumps or drinkers*. Large livestock kept in enclosed and partially enclosed housing can use animal-operated pumps or valves (nose pumps/valves). Livestock-operated on-demand watering devices allow the animal to use its nose to actuate a valve or push a pendulum unit that dispenses water. Small livestock kept in enclosed housing generally have on-demand drinkers that are actuated by the mouth or beak of the livestock.

- *Trough systems*. Large livestock kept in enclosed and partially enclosed housing can also use trough systems. In trough systems, animals drink directly from troughs or tanks. The discharge of water to the trough/tank may be float-controlled or continuous.

Many partially enclosed, open, and pasture/grazing livestock operations perform water hauling or provide access to watering sources to meet livestock watering needs.

- *Water hauling*. Water may also be provided to animals in open pastures and grazing operations through water hauling. By using a truck with a main storage tank and an easily-moved stock tank, the watering point can be relocated as necessary throughout the operation.

- *Access to privately-owned ponds or reservoirs using restricted access ramps*. For grazed cattle and pastured dairies, natural streams and other surface waters provide a source of drinking water. Many partially enclosed, open, and pasture/grazing livestock operations allow animals access to watering sources, such as privately-owned ponds or reservoirs, via restricted access ramps. Access ramps allow the animals to use the water source while minimizing erosion of the banks. While some reservoirs are supplied by natural precipitation, many use water pumping systems. Powered by gas, solar energy, and wind, these systems transport water from the water source to the reservoir or pond.

Biosecurity

Biosecurity consists of the procedures used to prevent the spread of animal diseases from one facility to another. Animal diseases can enter a facility with new animals, on equipment, and on people. Animals, equipment, and people that have recently been at another facility may pose the greatest biosecurity risk. Biosecurity procedures include such general categories as use of protective clothing, waiting periods for new animals and visitors, and cleaning.

Biosecurity is important to livestock owners because some diseases can weaken or kill large numbers of animals at an infected facility. In some cases, the only remedy available to an operation is to sacrifice an entire group of animals in order to prevent the spread of the disease to other parts of the facility or to other facilities. In other words, a failure to conduct biosecurity procedures can cause serious financial and productivity losses for a livestock operation.

The types of biosecurity procedures necessary will depend on the type of animal at a facility, the way the diseases of concern spread to and infect animals, and vulnerability of the animals to each specific disease. For example, if a group of swine has little immunity to a serious virus, and that virus can enter the facility on the skin or clothing of visitors, a facility may need to require visitors to observe a waiting period, take a shower, and change into clean clothing provided by the facility before entering. A different group of swine may have better immunity to the virus, and such biosecurity measures would be unnecessary.

Some of the general types of biosecurity procedures include:

- Controls on the introduction of new animals to a group or facility (such as quarantine periods).
- Controls on equipment entering the farm (such as washing and disinfecting crates).
- Controls on personnel entering the farm (such as requiring service personnel to stay out of animal buildings, or providing protective clothing and footwear).
- Controls on wild or domestic animal access (such as closing holes in buildings to keep undesirable animals out).
- Sanitation in animal housing areas (such as cleaning pens).
- Identification and segregation of sick animals (including adequate removal and disposal of dead animals).

The key to developing adequate biosecurity procedures is to find accurate information about animal diseases and how to prevent them. Potential sources for specific biosecurity information and recommendations include extension services and other agricultural education organizations; veterinarians and veterinary organizations; producer and industry groups; and published information in books, magazines, and World Wide Web sources.

Potential Pollution Outputs and Environmental Impacts

Feeding. When feeding, the potential pollution outputs are soil erosion due to overgrazing, animal wastes (which are partially composed of unabsorbed feed components), spilled feed during feed unloading to feed equipment and by livestock as they feed, mechanical failures with feed equipment (e.g., inoperative cutoff switch), and dust emissions during feed transport. The pollution outputs and potential environmental impacts vary based on the type and location of feed equipment and number of animals.

- *Overgrazing* can contribute to soil losses due to severe erosion, and impoverishment can change the vegetation composition and associated organisms in rangelands.

- *Surface water and groundwater contamination from concentrated wastes*. Totally enclosed feed locations (e.g., barns, poultry houses), when compared to the same livestock types in a partially sheltered or open area, may generate a larger quantity of animal waste per acre of land due to a higher concentration of livestock in a smaller area. Totally enclosed structures are protected from rainfall and should not experience the runoff of livestock wastes and wasted feed that may occur in partially sheltered and open feed locations.

- *Surface water and groundwater contamination from runoff*. Partially sheltered feed locations (e.g., dairy operation free-stall barns and covered loafing areas) and open feed locations (e.g., feeder cattle maintained in a area that has no roofed or walled structures) have a greater pollution potential due to runoff. Areas with no vegetation may experience runoff of livestock waste and spilled feed during rainfall events.

- *Air emissions (e.g., dust).* Areas with no vegetation that are dry may produce dust pollution during the transportation of feed.

Watering. The primary pollution output from watering is excess water, which most likely becomes wastewater that is contaminated with livestock wastes (e.g., manure, urine) and feed. Surface waters and groundwater can become contaminated from wastewater runoff, and surface waters can be directly contaminated with wastes (e.g., manure, urine) from livestock that are allowed access to the water (e.g., during watering).

Properly operated man-made watering systems significantly reduce the environmental impact of livestock. However, continuous watering systems that overflow and cause runoff often cause significant environmental damage. Additionally, livestock with access to creeks, rivers and other natural water sources cause environmental damage by contaminating the water with animal waste, destroying riparian habitat, and eroding the stream banks.

Pollution Prevention/Waste Minimization Techniques
There are many pollution prevention opportunities to reduce or minimize the pollution outputs and impacts from livestock feeding and watering activities. Generation of these wastes can be prevented through management practices, preventive maintenance, appropriate feedlot location, and use of waste minimization technologies.

Feeding. Wastes generated during feeding (e.g., feed spills, unused feed) can be prevented by using troughs or mechanical feeding systems that reduce feed loss and prevent contact with watering areas, weather, and the ground.

- *Use portable and/or covered feeders*. Feeders can be constructed to be portable, eliminating the problem of manure buildup that occurs around stationary feeders. For outdoor or partially enclosed feeding operations, use of covered or protected feeders prevents the feed from being exposed to rain or wind. Examples of such feeders include mineral feeding boxes, and weathervane mineral feeders.

  - A mineral feeding box is simply a trough that is raised off the ground, enclosed on three sides, and covered by a roof.

  - A weathervane mineral feeder consists of a 55-gallon drum with a cut out opening of sufficient size for the animal to reach the feed. The drum pivots on a concrete base that is heavy enough to prevent overturning by cattle or wind. A weathervane is attached to the top of the drum so the feed opening is pushed away from the wind direction, and rain is prevented from reaching the opening.

- *Use specially designed feeders.* For hay feeding operations, using feeders that are specifically designed to accept bales minimizes hay loss and prevents potential nutrient runoff.

- *Use feeders that prevent spills and contact with the ground.* Feeding racks store hay between steel bars, thus minimizing the amount of hay that an animal can pull from the rack and spill on the ground. Totally enclosed racks where the hay is located inside a rectangular or circular enclosure may have diagonally shaped bars containing the hay inside. These bars require the animal to turn its head in order to reach through and remove its head from the hay, thus significantly reducing the amount of hay the animal can pull from the feeder and spill.

Watering. Pollution prevention techniques to prevent environmental impacts from watering include the following:

- *Prevent access to surface waters*. Livestock operations can use physical barriers (e.g., fencing) to prevent animals access to surface waters (e.g., creeks, streams, rivers). This will minimize contamination of these waters caused by animal defecating directly in the water, and runoff carrying waste reaching the water.

- *Reduce excess water use and spills of water*. Preventing overflows of watering devices and excess water use during watering can prevent water becoming mixed with wastes and potential runoff.

- *Use self-watering devices*. The on-demand, self-watering systems that are used in many types of animal operations are an effective method of reducing waste as long as they are well maintained and checked frequently.

III.D. Managing Animal Wastes

Animal wastes are produced at all stages of the livestock production process, including housing, feeding, and watering. *For the purposes of this document, the term animal waste refers to animal manure, urine, and other materials that come in contact with and/or are managed with manure and urine in a typical livestock operation*. These materials may include, but are not limited to, bedding, wastewater from flushing and washdown of housing areas, lot runoff, disinfectants and cleaners, and spilled feed.

Animal manure has been recognized for centuries as an excellent source of plant nutrients and as a soil "builder" in terms of its positive benefits to soil quality. Animal manure is an excellent source of nutrients for plants because it contains most of the elements required for plant growth. Livestock operators today are managing and using manure as an important and valuable resource. If managed and used properly, manure can provide benefits for the livestock operation, such as reduced commercial fertilizer use and increased soil quality.

Overall, the amount of animal wastes to be managed can be extensive. The challenges of animal waste management have been compounded in recent years due to the growth of animal feeding operations. These types of operations have resulted in the concentration of manure production on an ever smaller land area. The consistency and volume of animal waste to be managed at a livestock operation depends on the types of animals at the facility. Generally, dairy cattle, beef cattle, swine, and sheep produce a comparatively wet waste and broiler poultry litter is dry (22-29 percent water). Laying and breeding operations are often considered to have wet manure because of how the waste is handled. Exhibit 18 provides a comparison of the manure production for various animals.

Animal Type	Weight of Manure (lbs/day/1000 lbs of animal live weight)	
Dairy Cow, Lactating	80.0	75-90
Beef, Cow	63.0	20-80
Swine, Grower (40 - 220 lb)	63.4	70-85
Poultry, Broiler	80.0	22-29
Sheep	40.0	70
Horse	50.0	70

Source: *Preliminary Data Summary: Feedlots Point Source Category Study*, Table 11.2, U.S. Environmental Protection Agency, Office of Water, Washington, DC, December 1998.
Composting Manure and Other Organic Residues, Table III, Cooperative Extension, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, March 1997.

Types of Animal Waste Management Systems. Animal waste management systems involve the collection, transport, storage, treatment, and utilization (rather than disposal) of waste, preferably in a manner that is economically and environmentally sound. The type of system that each operation uses

Additional management activities at livestock operations include controlling or collecting runoff from outdoor lots and waste storage; directing clean water away from lots and storage areas; and disposing of livestock mortalities.

depends on the type of animal(s), manure moisture content, size of the operation, acreage and site, available manure utilization methods, and operator's personal preference. Additional information on animal waste management systems, including collection, storage, treatment, transfer, and utilization, can be found in Chapter 9: Agricultural Waste Management Systems of the *Agricultural Waste Management Field Handbook* (USDA, 1992) which can be accessed at http://www.ftw.nrcs.usda.gov/awmfh.html.

Using Best Management Practices. Livestock operators can implement structural and nonstructural best management practices (BMPs) to reduce the volume of animal wastes that must be managed.

- *Structural BMPs* for an animal waste management system may include roof gutters on buildings to collect and divert clean water; vegetated filter strips and riparian buffers to trap sediment; and surface water diversions to move clean water around the areas containing waste.

- *Non-structural (management) BMPs* for an animal waste management system may include reduced frequency and volume of washdown; implementation of a comprehensive nutrient management plan; relocation of manure stacks; and other site-specific land uses that do not involve construction or land movement.

III.D.1. Collecting & Transporting Animal Wastes

The most significant quantities of animal waste are generated at feeding, watering, and housing locations. Waste collection methods vary based on the type of housing and feeding operations, as well as manpower, available equipment, operator training, pen size, and manure moisture content. Some types of manure collection systems used in livestock productions are:

- *Slotted floor systems*. The slotted floor system allows the manure to drop through the slots to a storage tank or area located beneath the floor.

- *Scraping*. Scraping is the primary method of manure collection for open housing and a common method for partially enclosed housing and enclosed housing. Common scraping equipment includes small tractor operated scrapers, tractor-pulled pan scrapers, and automated alley scraper blades on a cable. The manure may be scraped into storage facilities, to treatment, or to utilization equipment.

- *Flushing*. Flushing is often used in enclosed and partially enclosed housing. Manual or automated hydraulic flush equipment uses water to flush the manure to collection/storage pits or lagoons.

The following describes the animal waste collection and transport systems used for different types of animals.

- Dairy cattle. Dairy cattle manure is usually collected and transported from sheds and freestall barn alleys by a manual or automated hydraulic flush in warmer climates and alley scrapers in colder climates. Manure dropped in milking parlors is commonly collected by a manual hydraulic flush. Freestall barns and alleys may also have the manure collected by scraping. Manure in open areas such as corrals is primarily collected by scraping; manure in grazed areas is not collected.

- Beef cattle. Manure is usually collected from beef cattle feedlots by scraping. The feedlot area may be unpaved, partially paved around feed and watering areas, or totally paved. Though rare, if beef cattle are kept in enclosed and partially enclosed housing, manure collection is accomplished by a slotted floor system. The manure drops through the slots to a below-floor tank that provides either short-term or long-term storage. In grazed areas, the manure is not collected.

- Sheep. Sheep are primarily maintained on pasture and the manure is not collected. Manure, from sheep kept in enclosed housing, is usually collected by a slotted floor system.

- Horses. Manure from horses housed in enclosed barn stalls, is most often collected by shoveling. The manure and bedding from stalls is often removed daily and placed in stacks.

- Poultry. Poultry manure collection is generally related to the type of operation. Poultry manure is generally dry (22-29 percent water). Broiler, roaster, pullet, turkey, and some duck houses usually raise the birds on the house floor or in cages on beds of shavings, sawdust, rice hulls, or peanut hulls. The manure is allowed to accumulate on the floor where it is mixed with the bedding.

  Many of the poultry broiler houses are only cleaned out completely once a year. Often, they only remove the top two inches or so between flocks (approximately 5-6 flocks per year in broilers houses). The litter is removed with a cruster machine or a small tractor with a front bucket. In layer and duck operations, the operator commonly collects the manure by allowing it to drop through the wire-mesh cage, house floor or slotted floor to a collection area where it is usually removed by a hydraulic flush or belt scraper to a lagoon. Manure is sometimes composted, but can also be stored in stacking sheds, roofed storage areas, outside and covered or uncovered, or occasionally in ponds until it is ready for transport to a disposal or land application area.

- Goats. Goat manure is collected by manual shoveling from small pens or stalls or scraped from larger containment enclosed, partially enclosed, and open areas.

- Swine. Manure from swine in enclosed housing is often collected by allowing it to drop through a slotted floor to a storage area, or it may be collected by a manual or automated flush system. Manure from swine maintained in partially enclosed or open housing is usually collected by scraping.

In housing where animals are confined, frequent manure collection and transport are critical to livestock health. Frequent removal of wastes reduces the naturally occurring volatilization of nitrogen as ammonia and the anaerobic digestion and the subsequent release of gases in the production buildings. This reduction of pit gases, which can be fatal, and odor improves the in-house environment and employee working conditions.

Collection and transport of wastes by flushing is facilitated by slightly sloped, paved floors, alleys, or gutters. Waste collected through slotted floors and wire-mesh cages is usually transported from the below-floor/below-cage collection area by a hydraulic (water) flush or may be scraped. The flushed manure and/or litter may be transported to a storage area or treatment lagoon. Two advantages of the flush system for collecting and transporting manure are that it is non-labor intensive and it provides a safe means to remove manure from confined spaces. The flush, which can be initiated manually or cycled by timer, dosing system, tip tank, or other means, transports the manure from the collection area. Pumping is used to transport liquid and slurry wastes from collection pits to storage or treatment lagoons. High solid wastes are often collected and transported from the housing or feeding areas using tractors with scraper blades and/or bucket loaders. Manure collected in gutters is often transported by automatic scrapers. Some disadvantages of the flush system include a huge increase in the amount of manure, manure cannot be transported very far because of the high cost versus low value, large use of water, problems with overloading when land-applied, and lagoons increasing the volatilization of nitrogen.

Potential Pollution Outputs and Environmental Impacts
For manure collection and transport, the pollution outputs can include manure, urine, litter, bedding, and water. Additional outputs include ammonia emissions from the waste, odors, hair and/or feathers, pathogens, and heavy metals.

Wastewater that may leak from storage areas or transport processes could result in surface water and groundwater contamination. While waste flushing systems aid in removing manure from underground storage basins, flush systems also generate additional manure wastewater that must be managed. Adding water also increases the risk of a manure spill or runoff reaching groundwater or surface water. Frequent collection and transport of manure and collection of surface runoff assists in reducing the nutrient losses and thereby provides greater nutrient availability during utilization. Between 40 to 60 percent of manure's nitrogen content may be lost through volatilization of ammonia NH_3 while the solid manure remains on an open lot[5]. Other nonvolatile nutrients (e.g., organic nitrogen, phosphorus) may be lost through leaching and surface runoff.

Pollution Prevention/Waste Minimization Opportunities
There are many techniques available to reduce pollution caused by animal waste collection and transport activities.

- *Reduce water used in flushing systems*. Alternative technologies, such as low-flow waste flushing systems or no-flow waste scraping systems, use less water than traditional systems, and decrease the amount of liquid that is sent to be treated in the lagoon.

- *Recycle water for flushing*. To minimize the amount of wastewater generated, some means of recycling clarified wastewater for flushing may be desirable. Separation of solids from flush water can be used to reduce the solids in the recycled flush water.

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[5] *Generally Accepted Agricultural and Management Practices for Manure Management and Utilization*, Table 5, Nitrogen Losses During Handling and Storage. Adopted by Michigan Agriculture Commission, Lansing, Michigan, June 1997.

III.D.2. Storing & Treating Animal Wastes

Waste Storage
Storage is the temporary containment of manure and wastes. Following collection, animal waste not immediately used may be stored in dry or wet form by various means and structures. Broiler and beef wastes are stored in dry forms while dairy and swine wastes are stored in wet forms.

- Manure stacks, bunkers, and stacking sheds are commonly used for dry wastes.

- Pits, tanks, ponds, and lagoons for liquid or slurry wastes.

Dry manure or litter is often placed in a covered or roofed area so that it does not come into contact with storm water. Storage may be short-term, usually a few days to a few weeks, or long-term, which is usually less than one year. The purpose of short-term storage is typically the retention of manure at the point of collection until transport to long-term storage or treatment. The purpose of long-term storage is retention of the waste until utilization is possible and/or appropriate as determined by the field condition, crop, weather, and other factors. Storage containment must be designed to hold the total volume of manure generated during the maximum length of time between applications. Additionally, federally regulated CAFO liquid storage units that accept storm water runoff must be sized to contain normal precipitation and runoff (less evaporation) for the storage period plus a 25-year, 24-hour storm event flow and still provide adequate freeboard. Waste storage is not treatment and any treatment that occurs is incidental.

Waste Treatment
Following collection and/or storage, livestock production facilities may treat animal wastes. Treatment may include (1) solids separation by gravity, mechanical, or vegetative methods, and (2) stabilization of the waste by anaerobic lagoons, aerobic lagoons, or composting.

- *Solids Separation.* Solids separation is a physical treatment process whereby a portion of the larger solids and fibers are removed from the manure and can be reused. Solids separation is often used preceding a storage or a treatment lagoon to slow the rate of solids accumulation in the basin. Solids separation may be accomplished by settling basins, mechanical separation, and vegetative filter strips.

- S Settling basin. Solids separation, in a settling basin, is achieved by discharging the wastestream to a basin where the rate of flow is low enough to cause gravity settling of the solids.

- S Mechanical solids separator. A mechanical solids separator unit may be a static screen, vibrating screen, mechanical flat belt (press), or roller press. In solids separation by static or vibrating screen, the flow is generally passed across the screen where the solids are captured and the liquid drops through. The liquid portion from the settling basin and/or mechanical separator is normally sent to storage or treatment or used to irrigate cropland. The collected solids may be used for bedding, feed, soil amendment, or compost.

- *Lagoons (Anaerobic or Aerobic)*. Lagoons can be anaerobic or aerobic (non-mechanical and mechanical), although aerobic lagoons are used less frequently. In contrast to solids separation, lagoons are biological treatment processes used to satisfy the oxygen demand (e.g., BOD, COD) and volatilize nitrogen. Lagoons can convert ammonia nitrogen to nitrate, though this is extremely rare in animal treatment systems.

  Lagoons vary in shape and size, but when properly constructed should have sufficient volume to hold the waste during the treatment period and contain normal precipitation and runoff (less evaporation) for the storage period plus a 25-year, 24-hour storm event flow and still have adequate freeboard. Lagoons should be lined either with clay, naturally occurring high clay content soils, concrete, or a synthetic liner.

  - S *Anaerobic lagoons* are commonly used to treat animal waste -- particularly swine, but also cattle and layers. Because anaerobic lagoons do not require free oxygen for treatment, they are usually six to ten feet deep. Anaerobic systems are sometimes operated with two lagoons in series allowing the first lagoon to overflow via pipe or spillway to the second lagoon.

  - S *Non-mechanical aerobic lagoons* are shallow, usually two to five feet deep and have a large surface area. This allows more sunlight to reach the algae, which in turn produce oxygen needed for treatment to occur. Non-mechanical aerobic lagoons are rarely used in livestock applications because they require large amounts of land.

- S *Mechanical aerobic lagoons* have higher construction costs due to the aeration equipment. The aeration process is expensive to operate; however, digestion occurs at a faster rate and fewer odors are produced. Due to the additional construction and operating costs, mechanical aerobic lagoons are uncommon. Mechanically aerated lagoons are sometimes used to control odors in odor-sensitive areas. Aerobic lagoons will produce more sludge than anaerobic lagoons and thus require additional solids handling.

- *Composting.* Composting is an aerobic biological process that converts organic waste into a stable organic product that can be used onsite or transported offsite for use. Composting reduces the volume of waste and kills pathogens while preserving more of the nutrients for use by crops. The composted material improves soil fertility, tilth (tilled earth), and water holding capacity. Composting is optimized by proper ratios of carbon to nitrogen and carbon to phosphorus; moisture content; temperature; pH; and time.

  In the composting process, a bulking agent (e.g., wood chips, peanut husks, animal bedding, or other materials) is mixed with the manure to provide the proper carbon ratios. Because of its high nutrient to volume ratio, composted animal waste, or compost, is a beneficial agricultural product. Compost can be spread on paddocks, cropland, and nursery stock, or used for landscaping and home gardens. Note: Many poultry and some swine operations also use composting for carcasses.

  There are four general composting methods -- static pile, aerated static, windrow, and in-vessel.

  - S Static pile method is the simplest composting operation and requires the least labor, but take the longest time to complete the process. The static pile operation is not mixed or aerated.

  - S Aerated static pile method is not mixed but usually has piping to allow air to reach the interior of the pile.

  - S Windrow method involves a long narrow pile that is regularly mixed and aerated.

- In-vessel method is an enclosed operation that allows accurate control of moisture and other parameters, while containing the odors.

Potential Pollution Outputs and Environmental Impacts

During waste storage, livestock production operations may produce stack seepage and storm water runoff which should be directed to the liquid storage ponds and lagoons.

During waste treatment, the pollution outputs and impacts include releases of ammonia and other gases to the air, contaminated runoff to surface waters, leaching resulting in groundwater contamination, and odors. For lagoons, the major pollution output is wastewater that is leached to groundwater through improperly lined lagoons; discharges to surface waters due to overfilling and breakthroughs; or improper transfer of wastes between facilities resulting in surface water contamination.

Pollution Prevention/Waste Minimization Opportunities

There are pollution prevention techniques that can be used during animal waste storage and treatment activities. These include:

- *Proper location*. The location of manure storage systems should consider proximity to water bodies, floodplains, and other environmentally sensitive areas.

- *Cover wastes*. During storage, place dry manure or litter in a covered or roofed area so that it does not come into contact with storm water. When composting, impacts can be significantly reduced by maintaining the compost operation under a roof or in an enclosed area.

- *Prevent spills by regular inspections and maintenance*. Spills and overflows can be prevented by regular inspections and preventive maintenance of lagoons; never filling lagoons beyond treatment capacity; and removing sludge as needed.

- *Use vegetative filters.* Vegetative filters are often used to prevent runoff from lagoon or settling basin liquid overflow from reaching a waterbody. As the water flows across the vegetative strip, the solids drop out of the water, thus reducing the amount of solids that can impact the environment. Vegetative filters are effective when located near the lagoon.

- *Build a reserve lagoon*. While the installation of a reserve lagoon may not be economically viable in all situations, the potential release of lagoon contents to the environment can be reduced by maintaining a spillway to a reserve lagoon. Spillways provide for limited release of overflow, which reduces the tendency for stress-related structural failure. A reserve lagoon is an integral component of a spillway system that prevents contamination of surface water and groundwater.

- *Prevent overtopping*. In preparation of rain events or to prevent exceeding lagoon capacity, livestock operations may hire a contractor to remove liquids from lagoons that are in danger of overtopping.

III.D.3. Utilizing Animal Wastes

Animal wastes (e.g., manure and urine) can be used as sources of plant nutrients. Land application is the most common, and usually most desirable, method of utilizing manure and wastewater because of the value of the nutrients and organic matter. Land application should be planned to ensure that the proper amount of nutrients are applied in a manner that does not adversely impact the environment or endanger public health.

Benefits of Land Application of Animal Wastes. The benefits of proper application include improvement of the physical, chemical, and biological properties of the soil, as well as significant economic returns from the use of manure as a plant nutrient.

Considerations for appropriate land application should include:

Nutrient Management Plans[6]. The primary purpose of nutrient management is to achieve the level of nutrients (e.g., nitrogen and phosphorus) required to grow the planned crop by balancing the nutrients that are already in the soil with those from other sources (e.g., manure, biosolids, commercial fertilizers) that will be applied. At a minimum, nutrient management can help prevent the application of nutrients at rates that will exceed the capacity of the soil and the planned crops to assimilate nutrients and prevent pollution.

- Comprehensive Nutrient Management Plans (CNMPs). As discussed in the *USDA-EPA Unified National Strategy for Animal Feeding Operations*, all animal feeding operations should develop and implement technically sound, economically feasible, and site-specific CNMPs to minimize impacts to water quality and public health. In general, a CNMP identifies actions or priorities that will be followed to meet clearly defined nutrient management goals at an agricultural operation. CNMPs should address, as necessary, manure and wastewater handling and storage, land application of manure and other nutrient sources, site management, record keeping, and feed management. CNMPs should also address other utilization options for manure where the potential for environmentally sound land application of manure is limited at the point where it is generated.

- *Timing and Methods of Application:* The timing and methods of application should minimize the loss of nutrients to groundwater or surface water and the loss of nitrogen to the atmosphere. Manure and wastewater application equipment should be calibrated to ensure that the quantity of material being applied is what is planned. Care must be taken when land-applying manure and wastewater to prevent it from

[6] On May 24, 1999, USDA-NRCS released the Policy for Nutrient Management and the revision to the conservation practice standard for Nutrient Management (Code 590). NRCS' directive and supporting technical guide establishes policy for nutrient management, sets forth guidance to NRCS personnel who provide nutrient management technical assistance, and for the revision of the NRCS nutrient management conservation practice standard. These two documents will provide the framework for all nutrient management plans developed by NRCS for the agricultural community, which will be tailored by State Conservationists within a two-year period. Of particular importance is the new policy as it relates to producers that may not have sufficient land available to spread manure at rates that utilize nitrogen and phosphorus and will, as a result, need to pursue off-farm utilization options.

entering streams, other water bodies, or environmentally sensitive areas.

Manure can be land applied as solids, slurries, and liquids. The type of application equipment used depends on the manure moisture content. Box spreaders are typically used for dry manure, flail spreaders and injection for slurries, and irrigation and injection for liquids. Manure application may be by the livestock operation personnel or a custom applicator.

- *Surface application*. Box and flail spreaders apply the manure to the soil surface as the spreader is pulled or driven across the field. If surface applied, the manure may then be incorporated into the soil. Incorporation within 24 hours greatly reduces ammonia volatilization thus retaining nitrogen.

- *Injection*. Injected manure is incorporated into the soil as the equipment is driven or pulled across the field.

- *Irrigation.* Many livestock operations with storage ponds or treatment lagoons use irrigation systems, portable irrigation equipment, or hire custom irrigators. Those establishments with field crops or silviculture often use portable irrigation systems such as traveling guns or center pivots. Operations with several different fields or large acreage on which to apply the waste typically use travelers. Small acreage establishments often use small-nozzle, moderate-pressure, permanent irrigation systems, because they provide low labor costs and more uniform distribution of lagoon liquids.

Potential Pollution Outputs and Environmental Impacts

While properly applied animal wastes provide nutrients and have little negative environmental consequence, improper management and use of animal wastes, such as overapplication, excessive spraying, or application during rain events or on frozen ground, may result in serious impacts to the environment.

The potential pollution outputs of land application include nutrient runoff and leaching, which may cause surface water and groundwater contamination, respectively. Pollutants of concern include (1) nitrates and nitrites that originate from oxidation of nitrogen contributed by the manure, and (2) phosphorus. Groundwater contamination is caused by the nitrates leaching from the crop root zone into the groundwater aquifer. The amount of contaminated runoff depends on factors such as what type of manure is used, how it is handled, type of crop being grown, stage of growth, weather conditions, method of application, and the amount of existing nutrients in the soil.

Overapplication or improper application of animal waste can also lead to aesthetic problems, including odors and vectors. It can also result in polluted runoff resulting in contamination of surface waters. The presence of ammonia, phosphates and organic matter in surface waters can result in increased biochemical oxygen demand and low levels of oxygen. This can cause the death of fish and other aquatic life forms. (Ohio State University, *Ohio Livestock Manure and Wastewater Guide*)

> Vectors are defined as organisms that carry pathogens from one host to another, such as insects or rats/mice.

Pollution Prevention/Waste Minimization Opportunities
In addition to land application, other manure use practices include:

7 Processing and recycling through ruminant feeding programs.

7 Biogas production as an energy source using anaerobic digester technologies.

7 Pyrolysis processes to produce electricity, chars (materials scorched, burned, or reduced to charcoal), and industrial petrochemicals.

7 Microbial and algae production as an animal feed source.

7 Aerobic degradation to produce composted products.

III.E. Other Management Issues

Odor Control

Odors are typically generated throughout the livestock production process. The odor from manure can vary depending on the type and consistency of the manure, how it is stored, and how and where it is applied.

Potential Pollution Outputs and Environmental Impacts
With enclosed or partially enclosed housing areas, odors and other gases (e.g., methane, ammonia, and hydrogen sulfide gases) from animal waste can be concentrated, potentially harming the health of the

animals and workers. When the gases are released outside, the odor can affect the surrounding areas and create nuisance problems for neighbors.

Pollution Prevention/Waste Minimization Techniques
There are several ways livestock facilities can reduce odors resulting from their operations and waste management practices. These include:

- *Reduce methane emissions*. One method of reducing methane emissions from livestock is to supplement the animal's diet. Scientists have found that supplementing a cow's diet with substances such as urea increases the animal's ability to digest food. With improved digestion, less fermentation takes place during digestion, and methane emissions per unit of forage have been reduced 25-75 percent. In addition, as digestion improves, productivity also improves, as dairy cows produce more milk and beef cattle fatten faster (*Information Unit on Climate Change, 1993*).

- *Follow BMPs for land application*. Odors from land application of manure can be minimized by following BMPs that are designed to maximize the nutrients available to the soil and crops. Many of these BMPs may be required by state or local ordinance. These practices include the following:

  - Spreading manure within agronomic rates.
  - When possible incorporating surface-applied manure within 24 hours.
  - Spreading early in the day as the air is warming and rising; this allows the applied waste to dry which reduces odor.
  - Avoiding spreading manure on windy days (i.e., blowing towards the neighbor).
  - Avoiding spreading manure during holidays and weekends.
  - Avoiding spreading waste near heavily traveled roads.

Managing Animal Carcasses

Dead animals should be disposed of in a way that does not adversely affect ground or surface water or create public health concerns. Composting, rendering, and other practices are common methods used to dispose of dead animals.

As with rendering plants, dead animals may be processed for use as pet food, composted, buried, or incinerated. USDA and FDA regulations prohibit the use of mortalities as feed for animals that are to be consumed by humans. *Note: State law or self-imposed industry standards may limit some of these options.* Because rendering must generally occur within 24 hours of an animal's death, it is helpful for the livestock production facility to establish rendering contacts in advance. Where this may not be possible, freezer storage could be used until such time as the rendering facility can collect the animals for processing. Some centrally located rendering facilities may provide pickup services to local livestock operations.

Animal carcass composting is another common method of handling poultry and small animal mortalities. Carcass composting typically takes more time than manure or yard waste composting, but has been shown to be an effective waste management approach. Many poultry and some swine operations use composting for carcasses. Livestock operations may use poultry compost sheds to dispose of their dead birds by mixing the dead birds with bedding and other materials.

As with manure composting, the compost process requires a carbon source to provide the proper carbon/nitrogen ratio for the necessary bacterial processes. Sawdust and straw are typically used as a carbon source due to their small particle size, ease of handling, absorbency, and high carbon content. Sawdust in excess of that required for the ideal carbon/nitrogen ratio is used in the initial stages of composting to provide adequate coverage of the carcasses. Sawdust also helps reduce odors from the composting process.

Potential Pollution Outputs and Environmental Impacts

Animal carcasses must be properly and quickly managed because they are a source of disease and can attract many vectors. Environmental impacts of carcasses depend on the management method used.

- Burial and/or pit disposal of carcasses in coarse textured soils and in areas of a high water table may contribute nutrients to groundwater.

- Animal carcasses that are disposed of above ground or insufficiently covered can cause aesthetic and potential human health impacts including odor generation and vector attraction, such as flies and mice.

- Specifically, poultry compost houses can be a potential source of pollution if not managed properly (e.g., kept at the right temperature, moisture content, etc.) because a leachate can form and leak from the compost house.

- The rendering process generates wastewater that must be managed according to the rendering facility's NPDES permit or pretreatment permit.

Pollution Prevention/Waste Utilization Techniques

There are several techniques that can be used to minimize wastes resulting from animal mortalities. As described above, rendering or composting are considered disposal methods that prevent pollution. If these are not available, burying carcasses can be another option. The impact of burying carcasses can be minimized by burying them deep below the surface of the ground, well away and downgrade from any source of drinking water, and covered with a generous supply of quicklime to reduce soil pH before fill dirt is added. If the carcasses must be disposed of onsite, it is preferable to have:

- A burial area at least 100 meters away from houses and watercourses
- The pit base at least 38 inches above the level of the watertable
- Heavy soil of low permeability and good stability
- Good access to the site for earthmoving machinery and stock transport unless the stock are to be walked in for slaughter

> The burial of dead animals is being phased out. In fact, some states prohibit the practice, except under the most extreme circumstances.

It is important to avoid sites sloping toward watercourses and areas that are likely to drain to surface water. Many states may have more strict statutes regulating the burial of dead animals. For example, Oregon requires that the animal carcasses be buried to such a depth that no part of them are nearer than four feet to the natural surface of the ground and they are covered with quicklime and at least four feet of soil.

III.F. Pest Control

Within a livestock production establishment, pesticides may be used for a variety of purposes. They may be applied directly to livestock or to structures, such as barns and housing units, to control pests (e.g., parasites, vectors). Pesticides can also be used to control predators. Vectors are defined as organisms that carry pathogens from one host to another, such as insects or rats/mice.

Livestock. Commonly, pesticides are applied directly to livestock using high-pressure and low-pressure sprayers, mist application equipment (i.e., fumigation and foggers), and dipping vats. In addition, pesticides may be added to ear tags and to gates through which animals commonly pass (i.e., gate wipes/brushes). Spraying or fogging animals, especially high-pressure spraying, allows penetration into fur and wool to control lice, mange, wool maggots, and other parasites and vectors. Portable dipping vats are used for treating external parasites, especially of sheep and swine.

Structures. Pesticides may also be applied directly to or used in and around structures, such as barns or other types of housing units. Sprayers and foggers are the most commonly used methods to apply insecticides, rodenticides, and disinfectants, although other methods may be used, such as injected termite treatments, rat/mouse traps, or other types of insect traps. Such applications are used to control flies, beetles, and manure larvicides, among others.

Predators. Some livestock operations, especially sheep and goat operations, experience problems with predators. Historically, these problems have been addressed by operators through various methods to scare away potential predators. Such methods included scarecrows or bells. Recently, another method, livestock protection collars, have been developed to help combat predators. Livestock protection collars are placed around the necks of the livestock and contain a rubber bladder filled with a pesticide. When predators, primarily coyotes, attack livestock they go for the throat, puncture the bladder on the collar, and ingest the pesticide. The livestock are unhurt, but the coyotes ultimately die from the ingested pesticide.

Potential Pollution Outputs and Environmental Impacts

The potential environmental impacts from pesticide application are runoff or leaching to surface water or groundwater, spills to surface waters, potential human and animal exposure, overtolerance levels on animals and products, and soil contamination that could leave land unproductive. These environmental impacts may all occur if pesticides are not applied in accordance with the label directions. The degree of environmental impact depends on the application method.

- The application of pesticides using spray or fogger systems is more likely to involve releases to air, which may result in human and excessive animal exposure.

- If not disposed of properly, liquids from dipping vats may contaminate both surface water and groundwater.

- If not protected with backflow prevention devices, pesticides applied through spray systems that are connected to water supplies can siphon back to the water source and potentially contaminate drinking water systems.

- In addition to runoff and leaching, spills of pesticides may also negatively impact the environment. The impacts are the same as for runoff and leaching, but may be more significant since the spilled materials will be concentrated in one specific area. Also, improperly cleaned and disposed pesticide containers may cause releases to the soil and/or surface waters.

Pesticides are both suspected and known for causing immediate and delayed-onset health hazards for humans. If exposed to pesticides, humans may experience adverse effects, such as nausea, respiratory distress, or more severe symptoms up to and including death. To help reduce this potential exposure, tolerance levels have been established for residues on agricultural products. Animals and birds impacted by pesticides can experience similar illnesses or develop other types of physical distress. Following label directions for application, protective gear, and disposal will help ensure such environmental impacts do not occur.

Pollution Prevention/Waste Minimization Opportunities

Environmental impacts from pesticides can be minimized by following the label directions and preventing or minimizing their use wherever possible. Pesticide use accounts for a substantial portion of farm production costs. By reducing their use, agricultural establishments can not only reduce production costs, but also reduce environmental impacts of their operations. Pesticide use and impact can be minimized by using general good housekeeping practices, integrated pest management, and good management practices. Examples of these are presented below.

7 **Integrated Pest Management**. Integrated pest management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment. Examples of IPM in the livestock production industry could include maintaining structures (e.g., plug holes, place stripping around doors and windows), good housekeeping in barns and other structures, rodent and insect traps, and use of predators (e.g., certain insects, snakes). IPM can involve the use of pesticides. In such cases, the IPM plan should indicate when a pesticide is needed, and its selection is based on persistence, toxicity, and leaching and runoff potential such that the most environmentally friendly pesticide is used.

7 **Good Management Practices**. In addition to use consistent with the label, there are other general management practices associated with pesticides that can help reduce their environmental impact. Such practices include:

S Buy only the amount needed for a year or a growing season.

S Minimize the amount of product kept in storage.

S Calculate how much diluted pesticide will be needed for a job and mix only that amount.

S Apply pesticides with properly-calibrated equipment.

S Purchase pesticide products packaged in such a way as to minimize disposal problems.

S Work with the state to locate a pesticide handler who can use the excess pesticide.

S Return unused product to the dealer, formulator, or manufacturer.

- Implement setbacks from wellheads for application and storage.

- If possible, choose nonleachable pesticides labeled for the pest.

III.G. Maintaining and Repairing Agricultural Machinery and Vehicles

Day-to-day maintenance and repair activities keep agricultural machinery and vehicles safe and reliable. Maintenance activities include oil and filter changes, battery replacement, and repairs, including metal machining.

Potential Pollution Outputs and Environmental Impacts
The wastes from maintenance and repair activities can include used oil, spent fluids, spent batteries, metal machining wastes, spent organic solvents, and tires. These wastes have the potential to be released to the environment if not handled properly, stored in secure areas with secondary containment, protected from exposure to weather, and properly disposed of. If released to the environment, the impact of these releases can be contamination of surface waters, groundwater, and soils, as well as toxic releases to the atmosphere. Groundwater pollution can also result from discharges of wastes to Class V wells.

Pollution Prevention/Waste Minimization Opportunities
Preventive maintenance programs can minimize waste generation, increase equipment life, and minimize the probability of significant impacts and accidents. Where the wastes cannot be eliminated, safe handling and recycling can minimize environmental impacts. The following presents pollution prevention/waste minimization opportunities for each type of waste.

Used Oil. The impact of oil changes can be minimized by preventing releases of used oil to the environment, and recycling or reusing used oil whenever possible. Spills can be prevented by using containment around used oil containers, keeping floor drains closed when oil is being drained, and by training employees on spill prevention techniques. Oil that is contained rather than released can be recycled, thus saving money, and protecting the environment.

Recycling used oil requires equipment like a drip table with a used oil collection bucket to collect oil dripping from parts. Drip pans can be placed under machinery and vehicles awaiting repairs to capture any leaking fluids. By using catch pans or buckets, rather than absorbent materials to contain leaks or spills of used oil, the used oil can be more easily recycled. To encourage recycling, the publication "How To Set Up A Local Program To Recycle Used Oil" is available at no cost from the RCRA/Superfund Hotline at 1-800-424-9346 or 1-703-412-9810.

Proper Disposal of Oil-Based Fluids. Spent petroleum-based fluids and solids should be sent to a recycling center whenever possible. Solvents that are hazardous waste must not be mixed with used oil or, under RCRA regulations, the entire mixture may be considered hazardous waste. Non-listed hazardous wastes can be mixed with waste oil, and as long as the resulting mixture is not hazardous, can be handled as waste oil. All used drip pans and containers should be properly labeled.

Spent Fluids. Farm machinery and vehicles require regular changing of fluids, including oil, coolant, and others. To minimize releases to the environment, these fluids should be drained and replaced in areas where there are no connections to storm drains or municipal sewers. Minor spills should be cleaned up prior to reaching drains. Used fluid should be collected and stored in separate containers. Fluids can often be recycled. For example, brake fluid, transmission fluid, and gear oil are recyclable. Some liquids are able to be legally mixed with used motor oil which, in turn, can be reclaimed.

During the process of engine maintenance, spills of fluids are likely to occur. The "dry shop" principle encourages spills to be cleaned immediately so that spilled fluid will not evaporate to air, be transported to soil, or be discharged to waterways or sewers. The following techniques help prevent and minimize the impact of spills:

- Collect leaking or dripping fluids in designated drip pans or containers. Keep all fluids separated so they may be properly recycled.

- Keep a designated drip pan under the vehicle while unclipping hoses, unscrewing filters, or removing other parts. The drip pan prevents splattering of fluids and keeps chemicals from penetrating the shop floor or outside area where the maintenance is occurring.

- Immediately transfer used fluids to proper containers. Never leave drip pans or other open containers unattended.

Radiator fluids are often acceptable to antifreeze recyclers. This includes fluids used to flush out radiators during cleaning. Reusing the flushing fluid minimizes waste discharges. If a licensed recycler does not accept the spent flushing fluids, consider changing to another brand of fluid that can be recycled.

Batteries. Farm operators have three options for managing used batteries: recycling through a supplier, recycling directly though a battery reclamation facility, or direct disposal. Most suppliers now accept spent batteries at the time of new battery purchase. While some waste batteries must be handled as hazardous waste, lead acid batteries are not considered hazardous waste as long as they are recycled. In general, recycling batteries may reduce the amount of hazardous waste stored at a farm, and thus reduce the farm's responsibilities under RCRA.

The following best management practices are recommended to prevent used batteries from impacting the environment prior to disposal:

7 Place on pallets and label by battery type (e.g., lead-acid, nickel, and cadmium).

7 Protect them from the weather with a tarp, roof, or other means.

7 Store them on an open rack or in a watertight secondary containment unit to prevent leaks.

7 Inspect them for cracks and leaks as they come to the farm. If a battery is dropped, treat it as if it is cracked. Acid residue from cracked or leaking batteries is likely to be hazardous waste under RCRA because it is likely to demonstrate the characteristic of corrosivity, and may contain lead and other metals.

7 Neutralize acid spills and dispose of the resulting waste as hazardous if it still exhibits a characteristic of a hazardous waste.

7 Avoid skin contact with leaking or damaged batteries.

Machine Shop Wastes. The major hazardous wastes from metal machining are waste cutting oils, spent machine coolant, and degreasing solvents. Scrap metal can also be a component of hazardous waste produced at a machine shop. Material substitution and recycling are the two best means to reduce the volume of these wastes.

The preferred method of reducing the amount of waste cutting oils and degreasing solvents is to substitute with water-soluble cutting oils. If non-water-soluble oils must be used, recycling waste cutting oil reduces the potential environmental impact. Machine coolant can be recycled, either by an outside recycler, or through a number of in-house systems. Coolant recycling is most easily implemented when a standardized type of coolant is used throughout the shop. Reuse and recycling of solvents also is easily achieved, although it is generally done by a permitted recycler. Most shops collect scrap metals from machining operations and sell these to metal recyclers. Metal chips which have been removed from the coolant by filtration can be included in the scrap metal collection. Wastes should be carefully segregated to facilitate reuse and recycling.

III.H. Fuel Use and Fueling Activities

Fuel is used to operate agricultural machinery, equipment, and vehicles that are used throughout the livestock operation. Agricultural machinery and vehicles are typically fueled using an above ground fueling dispenser that is connected to an above ground or underground fuel tank.

Potential Pollution Outputs and Environmental Impacts
Agricultural machinery and vehicles that use fuel most likely emit pollutants to the atmosphere. The activity of fueling itself can emit air pollutants, and spills of fuel can cause water, soil and groundwater contamination. Underground fueling systems that are not monitored or maintained properly can leak into the surrounding soils and eventually contaminate groundwater.

Pollution Prevention/Waste Minimization Opportunities
Properly maintaining fuel tanks, lines, and fueling systems can substantially reduce the probability of accidental fuel spills or leaks. All leaking pipe joints, nozzle connections, and any damage to the fueling hose (e.g., kinks, crushing, breaks in the carcass, bulges, blistering, soft spots at the coupling, deep cracks or cuts, spots wet with fuel, or excessive wear) should be fixed immediately to reduce the amount of pollution to the environment. Spill and overflow protection devices can be installed to prevent fuel spills and secondary

containment can be used to contain spills or leaks. Additional pollution prevention techniques for fueling include the following:

7 Inspect fueling equipment daily to ensure that all components are in satisfactory condition. While refueling, check for leaks.

7 If refueling occurs at night, make sure it is carried out in a well-lighted area.

7 Never refuel during maintenance as it might provide a source of ignition to fuel vapors.

7 Do not leave a fuel nozzle unattended during fueling or wedge or tie the nozzle trigger in the open position.

7 Discourage topping off of fuel tanks.

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IV. SUMMARY OF APPLICABLE FEDERAL STATUTES AND REGULATIONS

This section discusses the federal regulations that may apply to this sector. The purpose of this section is to highlight and briefly describe the applicable federal requirements, and to provide citations for more detailed information. The three following sections are included:

- Section IV.A contains a general overview of major statutes
- Section IV.B contains a list of regulations specific to this industry
- Section IV.C contains a list of pending and proposed regulatory requirements.

The descriptions within Section IV are intended solely for general information. Depending upon the nature or scope of the activities at a particular facility, these summaries may or may not necessarily describe all applicable environmental requirements. Moreover, they do not constitute formal interpretations or clarifications of the statutes and regulations. For further information, readers should consult the Code of Federal Regulations and other state or local regulatory agencies. EPA Hotline contacts are also provided for each major statute. For specific agricultural information, contact The National Agricultural Compliance Assistance Center at (888) 663-2155 or visit the website at http://www.epa.gov/agriculture.

IV.A. General Description of Major Statutes

Clean Water Act

The primary objective of the Federal Water Pollution Control Act Amendments of 1972, commonly referred to as the Clean Water Act (CWA), is to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. Pollutants regulated under the CWA are classified as either "toxic" pollutants; "conventional" pollutants, such as biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, oil and grease, and pH; or "non-conventional" pollutants, including any pollutant not identified as either conventional or priority.

The CWA regulates both direct and "indirect" dischargers (those who discharge to publicly owned treatment works). The National Pollutant Discharge Elimination System (NPDES) permitting program (CWA §402) controls direct discharges into navigable waters. Direct discharges or "point source" discharges are from sources such as pipes and sewers. NPDES permits, issued by either EPA or an authorized state (EPA has authorized 43 states and 1 territory to administer the NPDES program), contain industry-specific, technology-based water quality limits and establish pollutant monitoring and reporting requirements. A facility that proposes to discharge into the nation's waters must obtain a permit prior to initiating a discharge. A permit applicant must provide quantitative analytical data identifying the types of pollutants present in the facility's effluent. The permit will then set forth the conditions and effluent limitations under which a facility may make a discharge.

Water quality-based discharge limits are based on federal or state water quality criteria or standards, that were designed to protect designated uses of surface waters, such as supporting aquatic life or recreation. These standards, unlike the technology-based standards, generally do not take into account technological feasibility or costs. Water quality criteria and standards vary from state to state, and site to site, depending on the use classification of the receiving body of water. Most states follow EPA guidelines which propose aquatic life and human health criteria for many of the 126 priority pollutants.

Storm Water Discharges

In 1987 the CWA was amended to require EPA to establish a program to address storm water discharges. In response, EPA promulgated NPDES permitting regulations for storm water discharges. These regulations require that facilities with the following types of storm water discharges, among others, apply for an NPDES permit: (1) a discharge associated with industrial activity; (2) a discharge from a large or medium municipal storm sewer system; or (3) a discharge which EPA or the state determines to contribute to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States.

The term “storm water discharge associated with industrial activity” means a storm water discharge from one of 11 categories of industrial activity defined at 40 CFR §122.26. Six of the categories are defined by SIC codes while the other five are identified through narrative descriptions of the regulated industrial activity. If the primary SIC code of the facility is one of those identified in the regulations, the facility is subject to the storm water permit application requirements. If any activity at a facility is covered by one of the five narrative categories, storm water discharges from those areas where the activities occur are subject to storm water discharge permit application requirements.

Those facilities/activities that are subject to storm water discharge permit application requirements are identified below. To determine whether a particular facility falls within one of these categories, the regulation should be consulted.

Category i: Facilities subject to storm water effluent guidelines, new source performance standards, or toxic pollutant effluent standards.

Category ii: Facilities classified as SIC 24-lumber and wood products (except wood kitchen cabinets); SIC 26-paper and allied products (except paperboard containers and products); SIC 28-chemicals and allied products (except drugs and paints); SIC 29-petroleum refining; SIC 311-leather tanning and finishing; SIC 32 (except 323)-stone, clay, glass, and concrete; SIC 33-primary metals; SIC 3441-fabricated structural metal; and SIC 373-ship and boat building and repairing.

Category iii: Facilities classified as SIC 10-metal mining; SIC 12-coal mining; SIC 13-oil and gas extraction; and SIC 14-nonmetallic mineral mining.

Category iv: Hazardous waste treatment, storage, or disposal facilities.

Category v: Landfills, land application sites, and open dumps that receive or have received industrial wastes.

Category vi: Facilities classified as SIC 5015-used motor vehicle parts; and SIC 5093-automotive scrap and waste material recycling facilities.

Category vii: Steam electric power generating facilities.

Category viii: Facilities classified as SIC 40-railroad transportation; SIC 41-local passenger transportation; SIC 42-trucking and warehousing (except public warehousing and storage); SIC 43-U.S. Postal Service; SIC 44-water transportation; SIC 45-transportation by air; and SIC 5171-petroleum bulk storage stations and terminals.

Category ix: Sewage treatment works.

Category x: Construction activities except operations that result in the disturbance of less than five acres of total land area.

Category xi: Facilities classified as SIC 20-food and kindred products; SIC 21-tobacco products; SIC 22-textile mill products; SIC 23-apparel related products; SIC 2434-wood kitchen cabinets manufacturing; SIC 25-furniture and fixtures; SIC 265-paperboard containers and boxes; SIC 267-converted paper and paperboard products; SIC 27-printing, publishing, and allied industries; SIC 283-drugs; SIC 285-paints, varnishes, lacquer, enamels, and allied products; SIC 30-rubber and plastics; SIC 31-leather and leather products (except leather and tanning and finishing); SIC 323-glass products; SIC 34-fabricated metal products (except fabricated structural metal); SIC 35-industrial and commercial machinery and computer equipment; SIC 36-electronic and other electrical equipment and components; SIC 37-transportation equipment (except ship and boat building and repairing); SIC 38-measuring, analyzing, and controlling instruments; SIC 39-miscellaneous manufacturing industries; and SIC 4221-4225-public warehousing and storage.

Pretreatment Program

Another type of discharge that is regulated by the CWA is one that goes to a publicly owned treatment works (POTW). The national pretreatment program (CWA § 307(b)) controls the indirect discharge of pollutants to POTWs by "industrial users." Facilities regulated under §307(b) must meet certain pretreatment standards. The goal of the pretreatment program is to protect municipal wastewater treatment plants from damage that may occur when hazardous, toxic, or other wastes are discharged into a sewer system and to protect the quality of sludge generated by these plants.

EPA has developed technology-based standards for industrial users of POTWs. Different standards apply to existing and new sources within each category. "Categorical" pretreatment standards applicable to an industry on a nationwide basis are developed by EPA. In addition, another kind of pretreatment standard, "local limits," are developed by the POTW in order to assist the POTW in achieving the effluent limitations in its NPDES permit.

Regardless of whether a state is authorized to implement either the NPDES or the pretreatment program, if it develops its own program, it may enforce requirements more stringent than federal standards.

Wetlands

Wetlands, commonly called swamps, marshes, fens, bogs, vernal pools, playas, and prairie potholes, are a subset of "waters of the United States," as defined in Section 404 of the CWA. The placement of dredge and fill material into wetlands and other water bodies (i.e., waters of the United States) is regulated by the U.S. Army Corps of Engineers (Corps) under 33 CFR Part 328. The Corps regulates wetlands by administering the CWA Section 404 permit program for activities that impact wetlands. EPA's authority under Section 404 includes veto power of Corps permits, authority to interpret statutory exemptions and jurisdiction, enforcement actions, and delegating the Section 404 program to the states.

EPA's Office of Water, at (202) 260-5700, will direct callers with questions about the CWA to the appropriate EPA office. EPA also maintains a bibliographic database of Office of Water publications which can be accessed *through the Ground Water and Drinking Water resource center, at (202) 260-7786.*

Oil Pollution Prevention Regulation

Section 311(b) of the CWA prohibits the discharge of oil, in such quantities as may be harmful, into the navigable waters of the United States and adjoining shorelines. The EPA Discharge of Oil regulation, 40 CFR Part 110, provides information regarding these discharges. The Oil Pollution Prevention regulation, 40 CFR Part 112, under the authority of Section 311(j) of the CWA, requires regulated facilities to prepare and implement Spill Prevention Control and Countermeasure (SPCC) plans. The intent of a SPCC plan is to prevent the discharge of oil from onshore and offshore non-transportation-related facilities. In 1990 Congress passed the Oil Pollution Act which amended Section 311(j) of the CWA to require facilities that because of their location could reasonably be expected to cause "substantial harm" to the environment by a discharge of oil to develop and implement Facility Response Plans (FRP). The intent of a FRP is to provide for planned responses to discharges of oil.

A facility is SPCC-regulated if the facility, due to its location, could reasonably be expected to discharge oil into or upon the navigable waters of the United Stated or adjoining shorelines, and the facility meets one of the following criteria regarding oil storage: (1) the capacity of any aboveground storage tank exceeds 660 gallons, or (2) the total aboveground storage capacity exceeds 1,320 gallons, or (3) the underground storage capacity exceeds 42,000 gallons. 40 CFR § 112.7 contains the format and content requirements for a SPCC plan. In New Jersey, SPCC plans can be combined with DPCC plans, required by the state, provided there is an appropriate cross-reference index to the requirements of both regulations at the front of the plan.

According to the FRP regulation, a facility can cause "substantial harm" if it meets one of the following criteria: (1) the facility has a total oil storage capacity greater than or equal to 42,000 gallons and transfers oil over water to or from vessels; or (2) the facility has a total oil storage capacity greater than or equal to 1 million gallons and meets any one of the following conditions: (i) does not have adequate secondary containment, (ii) a discharge could cause "injury" to fish and wildlife and sensitive environments, (iii) shut down a public drinking water intake, or (iv) has had a reportable oil spill greater than or equal to 10,000 gallons in the past 5 years. Appendix F of 40 CFR Part 112 contains the format and content requirements for a FRP. FRPs that meet EPA's requirements can be combined with U.S. Coast Guard FRPs or other contingency plans, provided there is an appropriate cross-reference index to the requirements of all applicable regulations at the front of the plan.

For additional information regarding SPCC plans, contact EPA's RCRA, Superfund, and EPCRA Hotline, at (800) 424-9346. Additional documents and resources can be obtained from the hotline's homepage at www.epa.gov/epaoswer/hotline. The hotline operates weekdays from 9:00 a.m. to 6:00 p.m., EST, excluding federal holidays.

Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) encourages states/tribes to preserve, protect, develop, and where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. It includes areas bordering the Atlantic, Pacific, and Arctic Oceans, Gulf of Mexico, Long Island Sound, and Great Lakes. A unique feature of this law is that participation by states/tribes is voluntary.

In the Coastal Zone Management Act Reauthorization Amendments (CZARA) of 1990, Congress identified nonpoint source pollution as a major factor in the continuing degradation of coastal waters. Congress also recognized that effective solutions to nonpoint source pollution could be implemented at the state/tribe and local levels. In CZARA, Congress added Section 6217 (16 U.S.C. § 1455b), which calls upon states/tribes with federally-approved coastal zone management programs to develop and implement coastal nonpoint pollution control programs. The Section 6217 program is administered at the federal level jointly by EPA and the National Oceanic and Atmospheric Agency (NOAA).

Section 6217(g) called for EPA, in consultation with other agencies, to develop guidance on "management measures" for sources of nonpoint source pollution in coastal waters. Under Section 6217, EPA is responsible for developing technical guidance to assist states/tribes in designing coastal nonpoint pollution control programs. On January 19, 1993, EPA issued its *Guidance Specifying Management Measures For Sources of Nonpoint Pollution in Coastal Waters*, which addresses five major source categories of nonpoint pollution: (1) urban runoff, (2) agriculture runoff, (3) forestry runoff, (4) marinas and recreational boating, and (5) hydromodification.

Additional information on coastal zone management may be obtained from EPA's Office of Wetlands, Oceans, and Watersheds at http://www.epa.gov/owow or from the Watershed Information Network at http://www.epa.gov/win. The NOAA website at http://www.nos.noaa.gov/ocrm/czm/ also contains additional information on coastal zone management.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) mandates that EPA establish regulations to protect human health from contaminants in drinking water. The law authorizes EPA to develop national drinking water standards and to create a joint federal-state system to ensure compliance with these standards. The SDWA also directs EPA to protect underground sources of drinking water through the control of underground injection of fluid wastes.

EPA has developed primary and secondary drinking water standards under its SDWA authority. EPA and authorized states enforce the primary drinking water standards, which are, contaminant-specific concentration limits that apply to certain public drinking water supplies. Primary drinking water standards consist of maximum contaminant level goals (MCLGs), which are non-enforceable health-based goals, and maximum contaminant levels (MCLs), which are enforceable limits set generally as close to MCLGs as possible, considering cost and feasibility of attainment.

The SDWA Underground Injection Control (UIC) program (40 CFR Parts 144-148) is a permit program which protects underground sources of drinking water by regulating five classes of injection wells. UIC permits include design, operating, inspection, and monitoring requirements. Wells used to inject hazardous wastes must also comply with RCRA corrective action standards in order to be granted a RCRA permit, and must meet applicable RCRA land disposal restrictions standards. The UIC permit program is often state/tribe-enforced, since EPA has authorized many states/tribes to administer the program. Currently, EPA shares the UIC permit program responsibility in seven states and completely runs the program in 10 states and on all tribal lands.

The SDWA also provides for a federally-implemented Sole Source Aquifer program, which prohibits federal funds from being expended on projects that may contaminate the sole or principal source of drinking water for a given area, and for a state-implemented Wellhead Protection program, designed to protect drinking water wells and drinking water recharge areas.

The SDWA Amendments of 1996 require states to develop and implement source water assessment programs (SWAPs) to analyze existing and potential threats to the quality of the public drinking water throughout the state. Every state is required to submit a program to EPA and to complete all assessments within 3 ½ years of EPA approval of the program. SWAPs include: (1) delineating the source water protection area, (2) conducting a contaminant source inventory, (3) determining the susceptibility of the public water supply to contamination from the inventories sources, and (4) releasing the results of the assessments to the public.

EPA's Safe Drinking Water Hotline, at (800) 426-4791, answers questions and distributes guidance pertaining to SDWA standards. The Hotline operates from 9:00 a.m. through 5:30 p.m., EST, excluding federal holidays. Visit the website at www.epa.gov/ogwdw for additional material.

Resource Conservation and Recovery Act

The Solid Waste Disposal Act (SWDA), as amended by the Resource Conservation and Recovery Act (RCRA) of 1976, addresses solid and hazardous waste management activities. The Act is commonly referred to as RCRA. The Hazardous and Solid Waste Amendments (HSWA) of 1984 strengthened RCRA's waste management provisions and added Subtitle I, which governs underground storage tanks (USTs).

Regulations promulgated pursuant to Subtitle C of RCRA (40 CFR Parts 260-299) establish a "cradle-to-grave" system governing hazardous waste from the point of generation to disposal. RCRA hazardous wastes include the specific materials listed in the regulations (discarded commercial chemical products, designated with the code "P" or "U"; hazardous wastes from specific industries/sources, designated with the code "K"; or hazardous wastes from non-specific sources, designated with the code "F") or materials which exhibit a hazardous waste characteristic (ignitability, corrosivity, reactivity, or toxicity and designated with the code "D").

Entities that generate hazardous waste are subject to waste accumulation, manifesting, and recordkeeping standards. A hazardous waste facility may accumulate hazardous waste for up to 90 days (or 180 days depending on the amount generated per month) without a permit or interim status. Generators may also treat hazardous waste in accumulation tanks or containers (in accordance with the requirements of 40 CFR 262.34) without a permit or interim status.

Facilities that treat, store, or dispose of hazardous waste are generally required to obtain a RCRA permit. Subtitle C permits for treatment, storage, or disposal facilities contain general facility standards such as contingency plans, emergency procedures, recordkeeping and reporting requirements, financial assurance mechanisms, and unit-specific standards. RCRA also contains provisions (40 CFR Subparts I and S) for conducting corrective actions which govern the cleanup of releases of hazardous waste or constituents from solid waste management units at RCRA treatment, storage, or disposal facilities.

Although RCRA is a federal statute, many states implement the RCRA program. Currently, EPA has delegated its authority to implement various provisions of RCRA to 47 of the 50 states and two U.S. territories. Delegation has not been given to Alaska, Hawaii, or Iowa.

Most RCRA requirements are not industry specific but apply to any company that generates, transports, treats, stores, or disposes of hazardous waste. Here are some important RCRA regulatory requirements:

- **Criteria for Classification of Solid Waste Disposal Facilities and Practices** (40 CFR Part 257) establishes the criteria for determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment. The criteria were adopted to ensure non-municipal, non-hazardous waste disposal units that receive conditionally exempt small quantity generator waste do not present risks to human health and environment.

- **Criteria for Municipal Solid Waste Landfills** (40 CFR Part 258) establishes minimum national criteria for all municipal solid waste landfill units, including those that are used to dispose of sewage sludge.

- **Identification of Solid and Hazardous Wastes** (40 CFR Part 261) establishes the standard to determine whether the material in question is considered a solid waste and, if so, whether it is a hazardous waste or is exempted from regulation.

- **Standards for Generators of Hazardous Waste** (40 CFR Part 262) establishes the responsibilities of hazardous waste generators including obtaining an EPA ID number, preparing a manifest, ensuring proper packaging and labeling, meeting standards for waste accumulation units, and recordkeeping and reporting requirements. Generators can accumulate hazardous waste on-site for up to 90 days (or 180 days depending on the amount of waste generated) without obtaining a permit.

- **Land Disposal Restrictions** (LDRs) (40 CFR Part 268) are regulations prohibiting the disposal of hazardous waste on land without prior treatment. Under the LDRs program, materials must meet treatment standards prior to placement in a RCRA land disposal unit (landfill, land treatment unit, waste pile, or surface impoundment). Generators of waste subject to the LDRs must provide notification of such to the designated TSD facility to ensure proper treatment prior to disposal.

- **Used Oil Management Standards** (40 CFR Part 279) impose management requirements affecting the storage, transportation, burning, processing, and re-refining of the used oil. For parties that merely generate used oil, regulations establish storage standards. For a party considered a used oil processor, re-refiner, burner, or marketer (one who generates and sells off-specification used oil directly to a used oil burner), additional tracking and paperwork requirements must be satisfied.

- RCRA contains unit-specific standards for all units used to store, treat, or dispose of hazardous waste, including **Tanks and Containers**. Tanks and containers used to store hazardous waste with a high volatile organic concentration must meet emission standards under RCRA. Regulations (40 CFR Part 264-265, Subpart CC) require generators to test the waste to determine the concentration of the waste, to satisfy tank and container emissions standards, and to inspect and monitor regulated units. These regulations apply to all facilities who store such waste, including large quantity generators accumulating waste prior to shipment offsite.

- **Underground Storage Tanks** (USTs) containing petroleum and hazardous substances are regulated under Subtitle I of RCRA. Subtitle I regulations (40 CFR Part 280) contain tank design and release detection requirements, as well as financial responsibility and corrective action standards for USTs. The UST program also includes upgrade requirements for existing tanks that were to be met by December 22, 1998.

- **Boilers and Industrial Furnaces** (BIFs) that use or burn fuel containing hazardous waste must comply with design and operating standards. BIF regulations (40 CFR Part 266, Subpart H) address unit design, provide performance standards, require emissions monitoring, and, in some cases, restrict the type of waste that may be burned.

EPA's RCRA, Superfund, and EPCRA Hotline, at (800) 424-9346, responds to questions and distributes guidance regarding all RCRA regulations. Additional documents and resources can be obtained from the hotline's homepage at www.epa.gov/epaoswer/hotline. The RCRA Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., EST, excluding federal holidays.

Comprehensive Environmental Response, Compensation, And Liability Act

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a 1980 law commonly known as Superfund, authorizes EPA to respond to releases, or threatened releases, of hazardous substances that may endanger public health, welfare, or the environment. CERCLA also enables EPA to force parties responsible for environmental contamination to clean it up or to reimburse the Superfund for response or remediation costs incurred by EPA. The Superfund Amendments and Reauthorization Act (SARA) of 1986 revised various sections of CERCLA, extended the taxing authority for the Superfund, and created a free-standing law, SARA Title III, also known as the Emergency Planning and Community Right-to-Know Act (EPCRA).

The CERCLA hazardous substance release reporting regulations (40 CFR Part 302) direct the person in charge of a facility to report to the National Response Center (NRC) any environmental release of a hazardous substance which equals or exceeds a reportable quantity. Reportable quantities are listed in 40 CFR §302.4. A release report may trigger a response by EPA, or by one or more federal or state emergency response authorities.

EPA implements hazardous substance responses according to procedures outlined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR Part 300). The NCP includes provisions for cleanups. The National Priorities List (NPL) currently includes approximately 1,300 sites. Both EPA and states can act at other sites; however, EPA provides responsible parties the opportunity to conduct cleanups and encourages community involvement throughout the Superfund response process.

EPA's RCRA, Superfund and EPCRA Hotline, at (800) 424-9346, answers questions and references guidance pertaining to the Superfund program. Documents and resources can be obtained from the hotline's homepage at www.epa.gov/epaoswer/hotline. The Superfund Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., EST, excluding federal holidays.

Emergency Planning And Community Right-To-Know Act

The Superfund Amendments and Reauthorization Act (SARA) of 1986 created the Emergency Planning and Community Right-to-Know Act (EPCRA, also known as SARA Title III), a statute designed to improve community access to information about chemical hazards and to facilitate the development of chemical emergency response plans by state and local governments. Under EPCRA, states establish State Emergency Response Commissions (SERCs), responsible for coordinating certain emergency response activities and for appointing Local Emergency Planning Committees (LEPCs).

EPCRA and the EPCRA regulations (40 CFR Parts 350-372) establish four types of reporting obligations for facilities which store or manage specified chemicals:

- **EPCRA § 302** requires facilities to notify the SERC and LEPC of the presence of any extremely hazardous substance at the facility in an amount in excess of the established threshold planning quantity. The list of extremely hazardous substances and their threshold planning quantities is found at 40 CFR Part 355, Appendices A and B.

- **EPCRA § 303** requires that each LEPC develop an emergency plan. The plan must contain (but is not limited to) the identification of facilities within the planning district, likely routes for transporting extremely hazardous substances, a description of the methods and procedures to be followed by facility owners and operators, and the designation of community and facility emergency response coordinators.

- **EPCRA § 304** requires the facility to notify the SERC and the LEPC in the event of a release exceeding the reportable quantity of a CERCLA hazardous substance (defined at 40 CFR 302) or an EPCRA extremely hazardous substance.

- **EPCRA § 311 and § 312** requires a facility at which a hazardous chemical, as defined by the Occupational Safety and Health Act, is present in an amount exceeding a specified threshold to submit to the SERC, LEPC and local fire department material safety data sheets (MSDSs) or lists of MSDSs and hazardous chemical inventory forms (also known as Tier I and II forms). This information helps the local government respond in the event of a spill or release of the chemical.

- **EPCRA § 313** requires certain covered facilities, including SIC codes 20 through 39 and others, which have ten or more employees, and which manufacture, process, or use specified chemicals in amounts greater than threshold quantities, to submit an annual toxic chemical release report. This report, commonly known as the Form R, covers releases and transfers of toxic chemicals to various facilities and environmental media. EPA maintains the data reported in a publically accessible database known as the Toxics Release Inventory (TRI).

All information submitted pursuant to EPCRA regulations is publicly accessible, unless protected by a trade secret claim.

EPA's RCRA, Superfund and EPCRA Hotline, at (800) 535-0202, answers questions and distributes guidance regarding the emergency planning and community right-to-know regulations. Documents and resources can be obtained from the hotline's homepage at http://www.epa.gov/epaoswer/hotline. The EPCRA Hotline operates weekdays from 9:00 a.m. to 6:00 p.m., EST, excluding federal holidays.

Clean Air Act

The Clean Air Act (CAA) and its amendments are designed to "protect and enhance the nation's air resources so as to promote the public health and welfare and the productive capacity of the population." The CAA consists of six sections, known as Titles, which direct EPA to establish national standards for ambient air quality and for EPA and the states to implement, maintain, and enforce these standards through a variety of mechanisms. Under the CAA, many facilities are required to obtain operating permits that consolidate their air emission requirements. State and local governments oversee, manage, and enforce many of the requirements of the CAA. CAA regulations appear at 40 CFR Parts 50-99.

Pursuant to Title I of the CAA, EPA has established national ambient air quality standards (NAAQSs) to limit levels of "criteria pollutants," including carbon monoxide, lead, nitrogen dioxide, particulate matter, ozone and sulfur dioxide. Geographic areas that meet NAAQSs for a given pollutant are designated as attainment areas; those that do not meet NAAQSs are designated as non-attainment areas. Under §110 and other provisions of the CAA, each state must develop a State Implementation Plan (SIP) to identify sources of air pollution and to determine what reductions are required to meet federal air quality standards. Revised NAAQSs for particulates and ozone were proposed in 1996 and will become effective in 2001.

Title I also authorizes EPA to establish New Source Performance Standards (NSPS), which are nationally uniform emission standards for new and modified stationary sources falling within particular industrial categories. The NSPSs are based on the pollution control technology available to that category of industrial source (*see* 40 CFR Part 60).

Under Title I, EPA establishes and enforces National Emission Standards for Hazardous Air Pollutants (NESHAPs), nationally uniform standards oriented toward controlling specific hazardous air pollutants (HAPs). Section 112(c) of the CAA further directs EPA to develop a list of sources that emit any of 188 HAPs, and to develop regulations for these categories of sources. To date EPA has listed 185 source categories and developed a schedule for the establishment of emission standards. The emission standards are being developed for both new and existing sources based on "maximum achievable control technology" (MACT). The MACT is defined as the control technology achieving the maximum degree of reduction in the emission of the HAPs, taking into account cost and other factors.

Title II of the CAA pertains to mobile sources, such as cars, trucks, buses, and planes. Reformulated gasoline, automobile pollution control devices, and vapor recovery nozzles on gas pumps are a few of the mechanisms EPA uses to regulate mobile air emission sources.

Title IV-A establishes a sulfur dioxide and nitrogen oxides emissions program designed to reduce the formation of acid rain. Reduction of sulfur dioxide releases will be obtained by granting to certain sources limited emissions allowances that are set below previous levels of sulfur dioxide releases.

Title V of the CAA establishes an operating permit program for all "major sources" (and certain other sources) regulated under the CAA. One purpose of the operating permit is to include in a single document all air emissions requirements that apply to a given facility. States have developed the permit programs in accordance with guidance and regulations from EPA. Once a state program is approved by EPA, permits are issued and monitored by that state.

Title VI is intended to protect stratospheric ozone by phasing out the manufacture of ozone-depleting chemicals and restricting their use and distribution. Production of Class I substances, including 15 kinds of chlorofluorocarbons (CFCs), were phased out (except for essential uses) in 1996. Methyl bromide, a common pesticide, has been identified as a significant stratospheric ozone depleting chemical. The production and importation of methyl bromide, therefore, is currently being phased out in the United States and internationally. As specified in the Federal Register of June 1, 1999 (Volume 64, Number 104) and in 40 CFR Part 82, methyl bromide production and importation will be reduced from 1991 levels by 25 percent in 1999, by 50 percent in 2001, by 70 percent in 2003, and completely phased out by 2005. Some uses of methyl bromide such as the production, importation, and consumption of methyl bromide to fumigate commodities entering or leaving the United States or any state (or political subdivision thereof) for purposes of compliance with Animal and Plant Health Inspection Service requirements or with any international, federal, state, or local sanitation or food protection standard, will be exempt from this rule. After 2005, exceptions may also be made for critical agricultural uses. The United States EPA and the United Nations Environment Programme have identified alternatives to using methyl bromide in agriculture. Information on the methyl bromide phase-out, including alternative, can be found at the EPA Methyl Bromide Phase-Out Website: (http://www.epa.gov/docs/ozone/mbr/mbrqa.html).

EPA's Clean Air Technology Center, at (919) 541-0800 and at the Center's homepage at http://www.epa.gov/ttn/catc, provides general assistance and information on CAA standards. The Stratospheric Ozone Information Hotline, at (800) 296-1996 and at http://www.epa.gov/ozone, provides general information about regulations promulgated under Title VI of the CAA; EPA's EPCRA Hotline, at (800) 535-0202 and at http://www.epa.gov/epaoswer/hotline, answers questions about accidental release prevention under CAA §112(r); and information on air toxics can be accessed through the Unified Air Toxics website at http://www.epa.gov/ttn/uatw. In addition, the Clean Air Technology Center's website includes recent CAA rules, EPA guidance documents, and updates of EPA activities.

Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was first passed in 1947, and amended numerous times, most recently by the Food Quality Protection Act (FQPA) of 1996. FIFRA provides EPA with the authority to oversee, among other things, the registration, distribution, sale and use of pesticides. The Act applies to all types of pesticides, including insecticides, herbicides, fungicides, rodenticides and antimicrobials. FIFRA covers both intrastate and interstate commerce.

Establishment Registration
Section 7 of FIFRA requires that establishments producing pesticides, or active ingredients used in producing a pesticide subject to FIFRA, register with EPA. Registered establishments must report the types and amounts of pesticides and active ingredients they produce. The Act also provides EPA inspection authority and enforcement authority for facilities/persons that are not in compliance with FIFRA.

Product Registration
Under §3 of FIFRA, all pesticides (with few exceptions) sold or distributed in the United States must be registered by EPA. Pesticide registration is very specific and generally allows use of the product only as specified on the label. Each registration specifies the use site, i.e., where the product may be used, and the amount that may be applied. The person who seeks to register the pesticide must file an application for registration. The application process often requires either the citation or submission of extensive environmental, health or safety data.

To register a pesticide, the EPA Administrator must make a number of findings, one of which is that the pesticide, when used in accordance with widespread and commonly recognized practice, will not generally cause unreasonable adverse effects on the environment.

FIFRA defines “unreasonable adverse effects on the environment” as “(1) any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of the pesticide, or (2) a human dietary risk from residues that result from a use of a pesticide in or on any food inconsistent with the standard under §408 of the Federal Food, Drug, and Cosmetic Act (21 U.S.C. 346a).”

Under FIFRA § 6(a)(2), after a pesticide is registered, the registrant must also notify EPA of any additional facts and information concerning unreasonable adverse environmental effects of the pesticide. Also, if EPA determines that additional data are needed to support a registered pesticide, registrants may be requested to provide additional data. If EPA determines that the registrant(s) did not comply with their request for more information, the registration can be suspended under FIFRA § 3(c)(2)(B) and § 4.

Use Restrictions

As a part of the pesticide registration, EPA must classify the product for general use, restricted use, or general for some uses and restricted for others (Miller, 1993). For pesticides that may cause unreasonable adverse effects on the environment, including injury to the applicator, EPA may require that the pesticide be applied either by or under the direct supervision of a certified applicator.

Reregistration

Due to concerns that much of the safety data underlying pesticide registrations becomes outdated and inadequate, in addition to providing that registrations be reviewed every 15 years, FIFRA requires EPA to reregister all pesticides that were registered prior to 1984 (§ 4). After reviewing existing data, EPA may approve the reregistration, request additional data to support the registration, cancel, or suspend the pesticide.

Tolerances and Exemptions

A tolerance is the maximum amount of pesticide residue that can be on a raw product and still be considered safe. Before EPA can register a pesticide that is used on raw agricultural products, it must grant a tolerance or exemption from a tolerance (40 CFR.163.10 through 163.12). Under the Federal Food, Drug, and Cosmetic Act (FFDCA), a raw agricultural product is deemed unsafe if it contains a pesticide residue, unless the residue is within the limits of a tolerance established by EPA or is exempt from the requirement.

Cancellation and Suspension

EPA can cancel a registration if it is determined that the pesticide or its labeling does not comply with the requirements of FIFRA or causes unreasonable adverse effects on the environment (Haugrud, 1993).

In cases where EPA believes that an "imminent hazard" would exist if a pesticide were to continue to be used through the cancellation proceedings, EPA may suspend the pesticide registration through an order and thereby halt the sale, distribution, and usage of the pesticide. An "imminent hazard" is defined as an unreasonable adverse effect on the environment or an unreasonable hazard to the survival of a threatened or endangered species that would be the likely result of allowing continued use of a pesticide during a cancellation process.

When EPA believes an emergency exists that does not permit a hearing to be held prior to suspending, EPA can issue an emergency order that makes the suspension immediately effective.

Imports and Exports

Under FIFRA §17(a), pesticides not registered in the United States and intended solely for export are not required to be registered provided that the exporter obtains and submits to EPA, prior to export, a statement from the foreign purchaser acknowledging that the purchaser is aware that the product is not registered in the United States and cannot be sold for use there. EPA sends these statements to the government of the importing country. FIFRA sets forth additional requirements that must be met by pesticides intended solely for export. The enforcement policy for exports is codified at 40 CFR 168.65, 168.75, and 168.85.

Under FIFRA §17(c), imported pesticides and devices must comply with United States pesticide law. Except where exempted by regulation or statute, imported pesticides must be registered. FIFRA §17(c) requires that EPA be notified of the arrival of imported pesticides and devices. This is accomplished through the Notice of Arrival (NOA) (EPA Form 3540-1), which is filled out by the importer prior to importation and submitted to the EPA regional office applicable to the intended port of entry. United States Customs regulations prohibit the importation of pesticides without a completed NOA. The EPA-reviewed and signed form is returned to the importer for presentation to United States Customs when the shipment arrives in the United States. NOA forms can be obtained from contacts in the EPA Regional Offices or www.epa.gov/oppfead1/international/noalist.htm.

Additional information on FIFRA and the regulation of pesticides can be obtained from a variety of sources, including EPA's Office of Pesticide Programs homepage at www.epa.gov/pesticides, *EPA's Office of Compliance, Agriculture and Ecosystem Division at http://es.epa.gov/oeca/agecodiv, or The National Agriculture Compliance Assistance Center toll-free at 888-663-2155 or http://www.epa.gov/oeca/ag. Other sources include the National Pesticide Telecommunications Network toll-free at 800-858-7378 and the National Antimicrobial Information Network toll-free at 800-447-6349.*

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) granted EPA authority to create a regulatory framework to collect data on chemicals in order to evaluate, assess, mitigate, and control risks which may be posed by their manufacture, processing, and use. TSCA provides a variety of control methods to prevent chemicals from posing unreasonable risk. It is important to note that pesticides as defined in FIFRA are not included in the definition of a "chemical substance" when manufactured, processed, or distributed in commerce for use as a pesticide.

TSCA standards may apply at any point during a chemical's life cycle. Under TSCA §5, EPA has established an inventory of chemical substances. If a chemical substance is not already on the inventory, and has not been excluded by TSCA, a premanufacture notice (PMN) must be submitted to EPA prior to manufacture or import. The PMN must identify the chemical and provide available information on health and environmental effects. If available data are not sufficient to evaluate the chemical's effects, EPA can impose restrictions pending the development of information on its health and environmental effects. EPA can also restrict significant new uses of chemicals based upon factors such as the projected volume and use of the chemical.

Under TSCA § 6, EPA can ban the manufacture or distribution in commerce, limit the use, require labeling, or place other restrictions on chemicals that pose unreasonable risks. Among the chemicals EPA regulates under § 6 authority are asbestos, chlorofluorocarbons (CFCs), lead, and polychlorinated biphenyls (PCBs).

Under TSCA § 8(e), EPA requires the producers and importers (and others) of chemicals to report information on a chemicals' production, use, exposure, and risks. Companies producing and importing chemicals can be required to report unpublished health and safety studies on listed chemicals and to collect and record any allegations of adverse reactions or any information indicating that a substance may pose a substantial risk to humans or the environment.

EPA's TSCA Assistance Information Service, at (202) 554-1404, answers questions and distributes guidance pertaining to Toxic Substances Control Act standards. The Service operates from 8:30 a.m. through 4:30 p.m., EST, excluding federal holidays.

IV.B. Industry-Specific Requirements for Agricultural Livestock Production Industry

The agricultural livestock production industry discussed in this notebook is regulated by several different federal, state, and local agencies. EPA has traditionally relied on delegation to states to meet environmental standards, in many cases without regard to the methods used to achieve certain performance standards. This has resulted in states with more stringent air, water, and hazardous waste requirements than the federal minimum requirements. This document does not attempt to discuss state standards, but rather highlights relevant federal laws and proposals that affect the agricultural livestock production industry.

Clean Water Act

Under the CWA, there are five program areas that potentially affect agricultural establishments and businesses. These include: point source discharges, storm water discharges, nonpoint source pollution, wetland regulation, and sludge management. Key provisions addressing each of these areas are summarized below:

- **Point Source Discharges**: The CWA establishes a permitting program known as the NPDES program for "point sources" of pollution. The term "point source" includes facilities from which pollutants are or may be discharged to waters of the United States and is further defined at 40 CFR Part 122. If granted, the permit will place limits and conditions on the proposed discharges based on the performance of available control technologies and on any applicable (more stringent) water quality considerations. Usually the permit also will require specific compliance measures, establish schedules, and specify monitoring and reporting requirements.
  - **Concentrated Animal Feeding Operations (CAFOs):** The CWA defines CAFOs as point sources. Therefore, CAFOs are subject to the NPDES permitting program. See 40 CFR Part 122.23 and 40 CFR 122 Appendix B. A CAFO is prohibited from discharging pollutants to waters of the U.S. unless it has obtained an NPDES permit for the discharge.
    - Definition of an AFO – An AFO is defined in EPA regulations as a lot or facility where (1) animals have been,

are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and (2) crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

< Definition of a CAFO – CAFOs are a subset of all AFOs. Whether an AFO is a CAFO under the regulations depends on the number of animals confined at the facility. A CAFO is defined as follows:

(1) More than 1,000 AUs are confined at the facility [40 CFR 122, Appendix B (a)]; **OR**

(2) ***From 301 to 1,000 AUs*** are confined at the facility and:

– Pollutants are discharged into waters of the U.S. through a man-made ditch, flushing system, or other similar man-made device; or

– Pollutants are discharged directly into waters of the U.S. that originate outside of and pass over, across, or through the facility or come into direct contact with the confined animals. [40 CFR 122, Appendix B (b)] OR

(3) The facility has been **designated as a CAFO** by the permitting authority on a ***case-by-case basis*** [40 CFR 122.23(c)], based on the permitting authority's determination that the operation is a "significant contributor of pollution." In making this determination, the permitting authority considers the following factors:

- Size of the operation;
- Amount of waste reaching waters of the United States;
- Location of the operation relative to waters of the U.S.;
- The means of conveyance of animal wastes and process wastewater into waters of the United States;

- The slope, vegetation, rainfall, and other factors affecting the likelihood or frequency of discharge of animal wastes and process wastewater into waters of the U.S.; and
- Other relevant factors (e.g.,waste handling and storage, land application timing, methods, rates and areas, etc.).

A permit application shall not be required from a concentrated animal feeding designated under the case-by-case authority until after the Director has conducted an on-site inspection and determined that the operation should and could be regulated under the NPDES permit program.

No animal feeding operation with less than the number of animals set forth in 40 CFR 122, Appendix B shall be designated as a concentrated animal feeding operation unless either (1) pollutants are discharged into waters of the U.S. through a manmade ditch, flushing system, or other similar means, or (2) pollutants are discharged directly into waters of the U.S. which originate outside of the facility and pass over, across, or through the facility, or otherwise come into direct contact with the animals confined in the operation.

The NPDES permit regulations [40 CFR 122, Appendix B] contain an exemption for any AFO from being defined as a CAFO if it discharges only in the event of a 25 year, 24-hour, or larger, storm event. To be eligible for an exemption, the facility must demonstrate to the permitting authority that it has not had a discharge. It must also demonstrate that the entire facility is designed, constructed, and operated to contain a storm event of this magnitude in addition to process wastewater. An operation that qualifies for this exemption from being defined as a CAFO may still be designated as a CAFO by the permitting authority on a case-by-case basis.

> A 25-year, 24-hour rainfall event means the maximum precipitation event with a probable occurrence of once in 25 years, as defined by the National Weather Service in Technical Paper Number 40, “Rainfall Frequency Atlas of the United States,” May 1961, and subsequent amendments, or equivalent regional or state rainfall probability information developed therefrom [40 CFR Part 412.11(e)].

- **Storm Water Discharges:** Under 40 CFR §122.2, the definition of “point source” excludes agricultural storm water runoff. Thus, such runoff is not subject to the storm water permit application regulations at 40 CFR §122.26. Non-agricultural storm water discharges, however, are regulated if the discharge results from construction over 5 acres or certain other types of industrial activity such as landfills, automobile junk yards, vehicle maintenance facilities, etc.

  – **Concentrated Aquatic Animal Production Facilities**. Under 40 CFR Part 122.24, a *concentrated aquatic animal production facility* is defined and designated as a point source subject to the NPDES permit program.

    < Definition of concentrated aquatic animal production facility (40 CFR Part 122 Appendix C) -- A *concentrated aquatic animal production facility* is a hatchery, fish farm, or other facility that meets one of the following criteria:

    (1) A facility that contains, grows, or holds cold water fish species or other cold water aquatic animals in ponds, raceways, or similar structures which discharge at least 30 days per year. The term does not include (a) facilities which produce less than 9,090 harvest weight kilograms (approximately 20,000 pounds) of aquatic animals per year, and (b) facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) of food during the calendar month of maximum feeding. Cold water aquatic animals include, but are not limited to, the *salmonidae* family (e.g., trout and salmon).

    (2) A facility that contains, grows, or holds warm water fish species or other warm water aquatic animals in ponds, raceways, or similar structures which discharge at least 30

days per year. The term does not include (a) facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) of aquatic animals per year or (b) closed ponds which discharge only during periods of excess runoff. Warm water aquatic animals include, but are not limited to, the *Ameiuridae*, *Centrarchidae,* and *Cyprinidae* families of fish (e.g., respectively catfish, sunfish, and minnows).

Designated facility -- A facility that does not otherwise meet the criteria in 40 CFR Part 122 Appendix C (described above) may be *designated* as a concentrated aquatic animal production facility if EPA or an authorized state determines the production facility is a significant contributor of pollution to waters of the U.S. No permit is required for such a designated facility until the EPA or state officials have conducted an onsite inspection and determined that the facility should be regulated under the NPDES permit program.

– **Aquaculture Projects**. Under 40 CFR Part 122.25(b), *aquaculture* means a defined, managed water area that uses discharges of pollutants to maintain or produce harvestable freshwater, estuarine, or marine plants or animals. Discharges into approved aquaculture projects are not required to meet effluent limitations that might otherwise apply. The entire aquaculture project (discharges into and out of the project) is addressed in an NPDES permit.

Wastewater Effluent Guidelines for Dairy Product Processing Establishments. Under 40 CFR Part 405, discharges from twelve categories of dairy products processing are subject to the NPDES permit program. Effluent limitations are established for BOD, TSS, and pH. The effluent guidelines establish technology-based pretreatment standards and effluent limitations for each category.

– **Wastewater Effluent Guidelines for Feedlots (CAFOs)**. Under 40 CFR Part 412, feedlot (beef cattle, dairy cattle, swine, sheep, etc.) point sources are subject to the NPDES permit program. The effluent guidelines establish technology-based pretreatment standards and effluent limitations for this category. In general, the current guidelines for feedlots prohibit any discharge of process wastewater to navigable waters, except in the case of a 25-year, 24-hour rainfall event. CAFOs over 1,000 animal units with NPDES permits may discharge pollutants when chronic or catastrophic rainfall events cause an overflow from a facility designed, constructed, and operated to contain all process wastewater plus the runoff from a 25-year, 24-hour storm for the location of the point source.

- **Nonpoint Source Pollution**. Under the CWA §319 Nonpoint Source (NPS) Management Program and 40 CFR §130.6, states (tribes, and territories) establish programs to manage NPS pollution, including runoff and leaching of fertilizers and pesticides, and irrigation return flows. These NPS management programs must identify: (a) best management practices (BMPs) to be used in reducing NPS pollution loadings; (b) programs to be used to assure implementation of BMPs; (c) a schedule for program implementation with specific milestones; and (d) sources of federal or other funding that will be used each year for the support of the state's NPS pollution management program. Congress provides grant funds to the states annually for the administration of these management programs.

- **Discharges to Publicly Owned Treatment Works (POTWs)**. Under 40 CFR Part 403, facilities, including agricultural establishments, may discharge certain substances to a POTW if the facility has received prior written permission from the POTW and has completed any required pretreatment. Facilities must check with their POTWs for information about permitted discharges and for conditions and limitations.

- **Discharges of Designated Hazardous Substances**. Under 40 CFR Parts 116-117, facilities, including agricultural establishments, must immediately notify the National Response Center (1-800-424-8802) and their state agency of any unauthorized discharge of a designated hazardous substance into (1) navigable waters, (2) the shorelines of navigable waters, or (3) contiguous zones, if the quantity discharged in any 24-hour period equals or exceeds the reportable quantity. A *designated hazardous substance* is any chemical listed in Section 311 of the Clean Water Act. The *reportable quantity* is the amount of the hazardous substance that EPA has determined might cause harm. The list of hazardous substances along with each chemical's reportable quantity is found in 40 CFR Parts 116 and 117. Ammonia and several pesticides are on the list.

- **Discharges of Oil**. Under 40 CFR Part 110, facilities must immediately notify EPA's National Response Center (1-800-424-8802) of any unauthorized discharge of a *harmful quantity of oil* (including petroleum, fuel oil, sludge, oil refuse, or oil mixed with other wastes) into (1) navigable waters, (2) the shorelines of navigable waters, or (3) contiguous zones and beyond. A discharge of oil is considered harmful if it violates applicable water quality standards, causes a sludge or emulsion to be deposited under the surface of the water or on adjoining shorelines, or causes a film or sheen on, or discoloration of, the water or adjoining shorelines. In practice, any quantity of oil or a petroleum product is a harmful quantity, since even small amounts will cause a film or sheen on surface water.

– **Oil Spill Prevention Control and Countermeasure (SPCC) Program**. Under 40 CFR Part 112, facilities, including agricultural establishments, must comply with EPA's SPCC program when they store oil at their facility. SPCC requirements apply to non-transportation related onshore and offshore facilities of specified size engaged in storing, processing, refining, transferring or consuming oil products, which due to their location, could potentially discharge oil into waters of the U.S. or adjoining shorelines.

  Facilities must comply with the SPCC program: (1) if they have a single aboveground container with an oil storage capacity of more than 660 gallons, multiple aboveground containers with a combined oil storage capacity of more than 1,320 gallons, or a total underground oil storage capacity of more than 42,000 gallons *and* (2) if there is a reasonable expectation that a discharge (spill, leak, or overfill) from the tank will release harmful quantities of oil into navigable waters or adjoining shorelines. The requirements are triggered by tank capacity, regardless of whether tanks are completely filled.

  Facilities subject to the SPCC requirements must prepare an SPCC plan. This plan must include: (1) *prevention* measures that keep oil releases from occurring, (2) *control* measures installed to prevent oil releases from reaching navigable waters, and (3) *countermeasures* to contain, clean up, and mitigate the effects of any oil release that reaches navigable waters. Each plan must be unique to the facility and must be signed by a registered professional engineer.

• **Wetlands on Agricultural Lands**. Swamps, marshes, fens, bogs, vernal pools, playas, and prairie potholes are common names for wetlands. Wetlands provide a habitat for threatened and endangered species as well as a diversity of other plant, wildlife, and fish species. In addition to providing habitat, wetlands serve other functions, including stabilizing shorelines; storing flood waters; filtering sediments, nutrients, and toxic chemicals from water; and providing an area for the recharge and discharge of groundwater. It is important to note that not all wetlands will be obvious to the untrained observer. For example, an area can appear dry during much of the year and still be classified as a wetland. Your local Natural Resources Conservation Service (NRCS) office can help to identify and delineate wetlands on your property.

NRCS, formerly the Soil Conservation Service, is the lead agency for identifying wetlands on *agricultural lands*. According to NRCS, agricultural lands means those lands intensively used and managed for the production of food or fiber to the extent that the natural vegetation has been removed and therefore does not provide reliable indicators of wetland vegetation. Areas that meet this definition may include intensively used and managed cropland, hayland, pastureland, orchards, vineyards, and areas that support wetland crops (e.g., cranberries, taro, watercress, rice). Lands not included in the definition of *agricultural lands* include rangelands, forest lands, woodlots, and tree farms.

– ***Exemption to Section 404 Permit Requirements***. The placement of dredge and fill material into wetlands and other water bodies (i.e., waters of the United States) is regulated by the U.S. Army Corps of Engineers (Corps) under 33 CFR Part 328. The Corps regulates wetlands by administering the CWA Section 404 permit program for activities that impact wetlands. The 404 permit program requires a permit for point source discharges of dredged and fill material into waters of the United States. However, many normal established farming activities (e.g., plowing, cultivating, minor drainage, and harvesting), silviculture, and ranching activities that involve discharges of dredged or fill materials into U.S. waters are **exempt from Section 404 permits** and do **NOT** require a permit (33 CFR §323.4). In order to be exempt, the activity must be part of an ongoing operation and cannot be associated with bringing a wetland into agricultural production or converting an agricultural wetland to a non-wetland area.

If not covered by the above exemption, a permit is required before discharging dredged or fill material into U.S. waters, including most wetlands (33 CFR Part 323). The Army Corps of Engineers (Corps) reviews Section 404 permit applications to determine if a project is the least environmentally damaging and practicable alternative.

- **POTW Sludge Management - Land Application of Biosolids**. Land application is the application of biosolids to land to either condition the soil or fertilize crops or other vegetation grown in the soil. Biosolids are a primarily organic solid product produced by wastewater treatment processes that can be beneficially recycled.

  EPA regulates the land application of biosolids under 40 CFR Part 503. As described in *A Plain English Guide to the EPA Part 503 Biosolids Rule* (EPA/832/R-93-003, September 1994), the Part 503 rule includes general provisions, and requirements for land application, surface disposal, pathogen and vector attraction reduction, and incineration. For each regulated use or disposal practice, a Part 503 standard includes general requirements, pollutant limits, management practices, operational standards, and requirements for the frequency of monitoring, recordkeeping, and reporting. For the most part, the requirements of the Part 503 rule are ***self-implementing*** and must be followed even without the issuance of a permit covering biosolids use or disposal requirements.

- **Total Maximum Daily Load (TMDL) Program**. There are still waters in the nation that do not meet the CWA national goal of "fishable, swimmable" despite the fact that nationally required levels of pollution control technology have been implemented by many pollution sources. The TMDL program, established under Section 303(d) of the Clean Water Act, focuses on identifying and allocating pollutant loads to these waterbodies. The goal of a TMDL is the attainment of water quality standards.

  A TMDL identifies the amount a pollutant needs to be reduced to meet water quality standards, allocates pollutant load reductions among pollutant sources in a watershed, and provides the basis for taking actions needed to restore a waterbody. It can identify the need for point source and nonpoint source controls.

  Under this provision, States are required to (1) identify and list waterbodies where State water quality standards are not being met following the application of technology-based point source pollution controls; and (2) establish TMDLs for these waters. EPA must review and approve (or disapprove) State lists and TMDLs. If State actions are not adequate, EPA must prepare lists and TMDLs. TMDLs are to be implemented using existing federal, state, and local authorities and voluntary programs.

  TMDLs should address all significant pollutants which cause or threaten to cause waterbody use impairment, including:

- Point sources (e.g., sewage treatment plant discharges)
- Nonpoint sources (e.g., runoff from fields, streets, range, or forest land)
- Naturally occurring sources (e.g., runoff from undisturbed lands)

A TMDL is the sum of the individual wasteload allocations for point sources, load allocations for nonpoint sources and natural background pollutants, and an appropriate margin of safety. TMDLs may address individual pollutants or groups of pollutants, as long as they clearly identify the links between: (1) the waterbody use impairment or threat of concern, (2) the causes of the impairment or threat, and (3) the load reductions or actions needed to remedy or prevent the impairment.

TMDLs may be based on readily available information and studies. In some cases, complex studies or models are needed to understand how pollutants are causing waterbody impairment. In many cases, simple analytical efforts provide an adequate basis for pollutant assessment and implementation planning.

Where inadequate information is available to draw precise links between these factors, TMDLs may be developed through a phased approach. The phased approach enables states to use available information to establish interim targets, begin to implement needed controls and restoration actions, monitor waterbody response to these actions, and plan for TMDL review and revision in the future. Phased approach TMDLs are particularly appropriate to address nonpoint source issues.

Numerous TMDLs are under development in many states and TMDLs are likely to impact agricultural activities by prompting states and stakeholders to mitigate water pollution caused by agricultural sources (assuming agriculture-related industries are identified as significant contributors to water quality impairment).

Coastal Zone Act Reauthorization Amendments of 1990

The Coastal Nonpoint Pollution Control Program, which is implemented under the authority of Section 6217 of the Coastal Zone Act Reauthorization Amendments (CZARA) of 1990, is administered at the federal level jointly by EPA and the National Oceanic and Atmospheric Agency (NOAA). The Section 6217 program requires the 29 states and territories with NOAA-approved coastal zone management programs to develop and implement coastal nonpoint pollution control programs. These submitted programs must include: (1) management measures that are in conformity with applicable federal guidance and (2) state-developed management measures as necessary to achieve and maintain applicable water quality standards.

On January 19, 1993, EPA issued its *Guidance Specifying Management Measures For Sources of Nonpoint Pollution in Coastal Waters.* The federal guidance specifies management measures for the following agricultural sources: (1) erosion from cropland, (2) confined animal facilities, (3) the application of nutrients to croplands, (4) the application of pesticides to cropland, (5) grazing management, and (6) irrigation of cropland.

Once approved, the programs are implemented through state nonpoint source programs (under CWA §319) and state coastal zone management programs (authorized under §306 of the Coastal Zone Management Act). Agricultural establishments located in coastal states should determine whether their land is included in the state's coastal management area. If so, they must comply with their state's applicable coastal nonpoint programs. Currently, all state coastal nonpoint management programs have been conditionally approved and have begun to be implemented.

Coastal Zone Management Act

The 1996 amendments to the Coastal Zone Management Act that may affect agriculture-related industries include those that relate to aquaculture in the coastal zone. Eligible states may now receive grants for developing a coordinated process among state agencies to regulate and issue permits for aquaculture facilities in the coastal zone. States may also receive grants for adopting procedures and policies to evaluate facilities in the coastal zone that will enable the states to formulate, administer, and implement strategic plans for marine aquaculture. Each state that receives such grants will make its own determination as part of its coastal management plan on how to specifically use the funds. Therefore, persons engaged in aquaculture productivity in the coastal zone may be eligible for technical or financial assistance under their state's plan.

Safe Drinking Water Act

The SDWA, which has been amended twice since 1974, protects the water supply through water quality regulations and source protection, such as underground injection control (UIC) regulations. SDWA requirements apply to all public water systems (PWSs). Currently, 54 of 56 states and territories have been delegated primacy to run the drinking water program.

- **Public Water Systems**. Under 40 CFR Parts 141-143, facilities that operate a PWS or receive water from a PWS and provide treatment to it are subject to SDWA regulations. Prior to 1996, SDWA defined a PWS as "a system for the provision to the public of piped water *for human consumption* if such system has at least 15 service connections or regularly serves at least 25 individuals." The 1996 Amendments expanded the means of delivering water to include not only pipes, but also other constructed conveyances such as ditches and waterways.

While there are three categories of PWSs, an agricultural establishment will most likely operate a non-transient, non-community system. This type of system serves at least 25 people for over 6 months of the year, but the people generally do not live at the facility. All PWSs must comply with the national primary drinking water regulations (40 CFR 141). Under 40 CFR Part 141 Subpart G, EPA has established drinking water standards for numerous pesticides.

Establishments that operate a non-transient, non-community system, in general, will need to: (1) monitor for the contaminants the state has established for that type of system, (2) keep records of the monitoring results, (3) report results from all tests and analyses to the state/tribe on a set schedule, (4) take immediate action to correct any violations in the allowable contaminant levels, (5) make a public announcement of any violations to warn people about potential adverse effects and to describe the steps taken to remedy the problem, and (6) keep records of actions taken to correct violations.

- **Comprehensive State Ground Water Protection Program**. Under the SDWA §1429, states/tribes are allowed to establish a Comprehensive State Ground Water Protection Program to protect underground sources of drinking water. Under this program, a state/tribe can require facilities, including agricultural establishments, to use designated best management practices (BMPs) to help prevent contamination of groundwater by nitrates, phosphates, pesticides, microorganisms, or petroleum products. These requirements generally apply only to facilities that are subject to the public water system supervision program. Persons applying pesticides or fertilizers must know the location of all the public water supply source areas in the vicinity that are protected by state/tribal (and sometimes local) requirements.

- **Source Water and Protection Program**. Under the SDWA, states are required to develop comprehensive Source Water Assessment Programs (SWAP). The statutorily defined goals for SWAPs are to provide for the protection and benefit of public water systems and for the support of monitoring flexibility. These programs plan to identify the areas that supply public tap water, inventory contaminants and assess water system susceptibility to contamination, and inform the public of the result.

- **Wellhead Protection Program**. Under the SDWA §1428, if a facility, has an onsite water source (e.g., well) that qualifies as a PWS, it must take the steps required by the state/tribe to protect the wellhead from contaminants. A wellhead protection area is the surface and subsurface area surrounding a water well or wellfield supplying a PWS through which contaminants are reasonably likely to move toward and reach such water well or wellfield.

  Since drinking water standards (40 CFR Part 141 Subpart G) exist for numerous pesticides, which may be used in various agriculture-related activities, some state/tribe and local wellhead and source water protection programs restrict the use of agricultural chemicals in designated wellhead protection areas. In addition, persons applying pesticides or fertilizers must know the location of all the public water supply source areas in the vicinity that are protected by state/tribal (and sometimes local) requirements, and the requirements for mixing, loading, and applying agricultural chemicals within any designated wellhead or source water protection areas.

- **Sole Source Aquifer Protection Program**. Under the SDWA §1424 and 40 CFR Part 149 Subpart B, EPA can establish requirements for protecting sole source aquifers. EPA designates an aquifer as a ***sole source aquifer*** if it supplies at least 50 percent of the drinking water consumed in the area overlying the aquifer and no alternative drinking water sources are feasible. The Sole Source Aquifer program prohibits federal financial assistance (any grant, contract, loan guarantee, or otherwise) for any project, including agricultural projects, that may result in contamination to the aquifer and create a hazard to public heath. Currently, only a few aquifers have been designated as protected sole source aquifers.

- **Underground Injection Control (UIC) Program**. The UIC program (40 CFR Parts 144 and 146-148) is a permit program that protects underground sources of drinking water by regulating five classes of injection wells (I - V). *Underground injection* means depositing fluids beneath the surface of the ground by injecting them into a hole (any hole that is deeper than it is wide). *Fluids* means any material or substance which flows or moves whether in a semisolid, liquid, sludge, gas, or any other form or state.

  If a facility disposes of (or formerly disposed of) waste fluids onsite in an injection well, it triggers the UIC requirements. In general, a facility may not inject contaminants into any well if the contaminant could cause a violation of any primary drinking water regulation or endanger an underground source of water if the activity would adversely affect the public health. Most deep well underground injections are prohibited without a UIC permit. No Class I, II, or III injection well may be constructed or opened before a permit has been issued. UIC permits include design, operating, inspection, and monitoring requirements. In many states/tribes, EPA has authorized the state/tribal agency to administer the program.

Class V Wells. Owners/operators of Class V wells (shallow wells that inject fluids above an underground source of water) must not construct, operate, maintain, convert, plug, abandon, or conduct any other injection activity in a manner that allows the movement of fluid containing any contaminant into underground sources of drinking water, if the presence of that contaminant may cause a violation of any primary drinking water regulation (40 CFR Part 142) or may otherwise adversely affect the health of persons. Examples of Class V wells potentially applicable to agricultural establishments include, but are not limited to:

(1) Drainage wells, such as agricultural drainage wells, primarily used for storm runoff.

(2) Cesspools with open bottoms (and sometimes perforated sides) and septic system wells used to inject waste or effluent from multiple dwellings or businesses (the UIC requirements do not apply to single family residential septic system or cesspool wells or to non-residential septic system or cesspool wells that are used solely for the disposal of sanitary wastes and have the capacity to serve fewer than 20 persons per day).

(3) Dry wells used for waste injection.

(4) Recharge wells used to replenish aquifers.

(5) Injection wells associated with the recovery of geothermal energy for heating, aquaculture, and production of electric power.

(6) Floor drains in maintenance shops/work areas.

Agricultural drainage wells typically drain water from low-lying farm land, but some serve to recharge aquifers from which irrigation water is withdrawn. These wells are usually constructed in areas with poor soil drainage, but where underlying geologic formations allow rapid infiltration of water. Sometimes abandoned water supply wells are adapted for use in agricultural drainage. Agricultural drainage wells typically receive field drainage from saturated topsoil and subsoil, and from precipitation, snowmelt, floodwaters, irrigation return flow, and animal feedlots. The types of pollutants injected into these wells include (1) pesticide runoff, (2) nitrate, nitrite, and salts, such as those of calcium, magnesium, sodium, potassium, chloride, sulfate, and carbonate from fertilizer runoff, (3) salts and metals (i.e., iron, lead, cadmium, and mercury) from biosolid sludges and compost, (4) microbes (i.e., bacteria and viruses) from animal waste runoff, and (5) petroleum contaminants, such as fuel and oil, from runoff from roads or equipment maintenance areas.

If a facility has a Class V well, it must furnish inventory information about the well to the appropriate state/tribal agency. If at any time EPA or the state/tribal agency learns that a Class V well may cause a violation of primary drinking water regulations (40 CFR Part 142) or may be otherwise adversely affecting the health of persons, it may require the injector to obtain an individual UIC permit, or order the injector to take such actions (including, where required, closure of the injection well) as may be necessary to prevent the violation.

Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act (RCRA) was enacted to address problems related to hazardous and solid waste management. RCRA gives EPA the authority to establish a list of solid and hazardous wastes and to establish standards and regulations for the treatment, storage, and disposal of these wastes. Regulations in Subtitle C of RCRA address the identification, generation, transportation, treatment, storage, and disposal of hazardous wastes. These regulations are found in 40 CFR Part 124 and 40 CFR Parts 260-279. Under RCRA, persons who generate waste must determine whether the waste is defined as solid waste or hazardous waste. Solid wastes are considered hazardous wastes if they are listed by EPA as hazardous or if they exhibit characteristics of a hazardous waste: toxicity, ignitability, corrosivity, or reactivity.

Most agriculture-related activities do not generate significant amounts of hazardous waste. Generally, the activities potentially subject to RCRA involve the use of pesticides and fertilizers, and the use and maintenance of different types of machinery.

Hazardous Waste Generator Categories. Facilities that generate hazardous waste can be classified into one of three hazardous waste generator categories as defined in 40 CFR Part 262:

- ***Conditionally exempt small quantity generator (CESQG)***. A facility is classified as a CESQG if it generates no more than 220 lbs (100 kg) of hazardous waste in a calendar month. There is no time limit for accumulating #2,200 lbs of hazardous waste onsite. However, CESQGs cannot store more than 2,200 lbs (1,000 kg) of hazardous waste onsite at any time. In addition, CESQGs cannot accumulate onsite more than 2.2 lbs (1 kg) of acutely hazardous waste or more than 220 lbs spill residue from acutely hazardous waste for any period of time.

- ***Small quantity generator (SQG)***. A facility is classified as a SQG if it generates >220 lbs (100 kg) and <2,200 lbs (1,000 kg) of hazardous waste in a calendar month. SQGs can accumulate onsite no more than 13,200 lbs (6,000 kg) of hazardous waste. SQGs can store hazardous waste onsite for up to 180 days (or up to 270 days if the waste treatment/disposal facility is more than 200 miles away).

- ***Large quantity generator (LQG)***. A facility is classified as a LQG if it generates > 2,200 lbs (1,000 kg) of hazardous waste in a calendar month. While there is no limit on the amount of hazardous waste that LQGs can accumulate onsite, they can only store it onsite for up to 90 days.

If a facility is a CESQG and generates #2.2 lbs (1 kg) of acutely hazardous waste; or #220 lbs (100 kg) of acutely hazardous waste spill residues in a calendar month, and never stores more than that amount for any period of time, it may manage the acutely hazardous waste according to CESQG requirements. If it generates more than 2.2 lbs (1 kg) of acutely hazardous waste or >220 lbs (100 kg) of acutely hazardous waste spill residues in a calendar month, the facility must manage it according to LQG requirements.
The hazardous wastes that must be measured are those: (1) accumulated at the facility for any period of time before disposal or recycling, (2) packaged and transported away from the facility, (3) placed directly into a treatment or disposal unit at the facility, or (4) generated as still bottoms or sludges *and* removed from product storage tanks.

Requirements for CESQGs. Based on the quantity of hazardous waste generated per month, most agricultural establishments will qualify as CESQGs. As CESQGs, facilities must comply with three basic waste management requirements:

(1) Identify all hazardous waste generated.

(2) Do not generate per month more than 220 lbs (100 kg) of hazardous waste; more than 2.2 lbs (1 kg) of acutely hazardous waste; or more than 220 lbs (100 kg) of acutely hazardous waste spill residues; and never store onsite more than 2,200 lbs (1,000 kg) of hazardous waste; 2.2 lbs of acutely hazardous waste; or more than 220 lbs of acutely hazardous waste spill residues for any period of time.

(3) Ensure proper treatment and disposal of the waste. This means ensuring that the disposal facility is one of the following:

- A state or federally regulated hazardous waste management treatment, storage, or disposal facility.
- A facility permitted, licensed, or registered by a state to manage municipal or industrial solid waste.
- A facility that uses, reuses, or legitimately recycles the waste (or treats the waste before use, reuse, or recycling).
- A universal waste handler or destination facility subject to the requirements for universal wastes.

CESQGs are allowed to transport their own wastes to the treatment or storage facility, unlike SQGs and LQGs who are required to use a licensed, certified transporter. While there are no specific RCRA requirements for CESQGs who transport their own wastes, the U.S. Department of Transportation (DOT) requires all transporters of hazardous waste to comply with all applicable DOT regulations. Specifically, DOT regulations require all transporters, including CESQGs, transporting hazardous waste that qualifies as a DOT hazardous material to comply with EPA hazardous waste transporter requirements found in 40 CFR Part 263. CESQGs are not required by federal hazardous waste laws to train their employees on waste handling or emergency preparedness.

Requirements for SQGs and LQGs. Facilities determined to be SQGs or LQGs must meet many requirements under the RCRA regulations. These requirements, found in 40 CFR 260-279, include identifying hazardous waste; obtaining an EPA identification numbers; meeting requirements for waste accumulation and storage limits; container management; conducting personnel training; preparing a manifest; ensuring proper hazardous waste packaging, labeling, and placarding; reporting and recordkeeping; and contingency planning, emergency procedures, and accident prevention.

Notes: Facilities that fall into different generator categories during different months may choose to simplify compliance by satisfying the more stringent requirements all the time.

Specific Provisions. RCRA regulations include several specific provisions addressing agriculture-related materials and activities. Key provisions are briefly summarized below:

- ***Exemption for Certain Solid Wastes Used as Fertilizers***. Under 40 CFR §261.4(b), solid wastes generated by (1) growing and harvesting of agricultural crops, or (2) raising animals (including animal manure), and that are returned to the soils as fertilizers are excluded from regulation as hazardous waste.

- ***Exemption for Certain Hazardous Waste Pesticides***. Under 40 CFR §262.70, farmers who generate any amount of hazardous waste pesticides from their own use are excluded from the generator, treatment/storage/disposal facility, land disposal, and permit requirements under RCRA Subtitle C, provided that the farmer: (1) disposes of the waste pesticide in a manner consistent with the label on the pesticide container; (2) triple rinses each empty container in accordance with requirements at 40 CFR §261.7(b)(3); and (3) disposes of the rinsate on his own farm in accordance with the instructions on the label. If the label does not include disposal instruction, or no instructions are available from the pesticide manufacturer, the waste pesticide and rinsate must be disposed of in accordance with Subtitle C hazardous waste requirements. (Also see 40 CFR Part 165 - FIFRA)

- ***Exemption for Commercial Fertilizers***. Under 40 CFR §266.20, commercial fertilizers produced for general public (including agricultural) use that contain recyclable materials are not presently subject to regulation provided they meet the applicable land disposal restriction (LDR) standards for each recyclable material they contain. For example, zinc-containing fertilizers containing K061 (emission control dust from the primary production of steel in electric furnaces) are not subject to regulation.

- ***Fertilizers Made from Hazardous Wastes***. Under 40 CFR Parts 266 and 268, EPA regulates fertilizers containing hazardous wastes as ingredients. Hazardous wastes may be used as ingredients in fertilizers under certain conditions, since such wastes can be a beneficial component of legitimate fertilizers. EPA has established standards that specify limits on the levels of heavy metals and other contents used as fertilizer ingredients. These standards are based on treatment, by the best technology currently available, to reduce the toxicity and mobility of all the contents of the hazardous waste components. These standards are based on waste management considerations and do not include consideration of the potential agronomic or dietary risk.

- ***Food Chain Crops Grown on Hazardous Waste Land Treatment Units***. Under 40 CFR Part 264.276, food chain crops (including feed for animals consumed by humans) may be grown in or on hazardous waste land treatment units under certain conditions and only with a permit. The permit for a facility will list the specific food-chain crops that may be grown. To obtain a permit, the owner/operator of the facility wishing to grow the food-chain crops must demonstrate -- prior to the planting of such crops -- that there is no substantial risk to human health caused by the growth of such crops in or on the treatment zone.

- ***Solid Waste Disposal Criteria***. Under RCRA Subtitle D, 40 CFR 257.3 establishes solid waste disposal criteria addressing floodplains, endangered species, groundwater protection, application to land used for food chain crops, disease vectors, air pollution, and safety. These criteria are largely guidelines used by states in developing solid waste regulations, which control the disposal of waste on a farmer's property.
- ***Land Application of Fertilizers Derived from Drinking Water Sludge***. Under 40 CFR Part 257, EPA regulates the land application of solid wastes, including drinking water sludge applied as fertilizer. These requirements include: (1) cadmium limits on land used for the production of food-chain crops (tobacco, human food, and animal feed) or alternative less stringent cadmium limits on land used solely for production of animal feed; (2) polychlorinated biphenyls (PCBs) limits on land used for producing animal feed, including pasture crops for animals raised for milk; and (3) minimization of disease vectors, such as rodents, flies, and mosquitoes, at the site of application through incorporation of the fertilizer into soil so as to impede the vectors' access to the sludge.

- ***Pesticides That Are Universal Wastes***. Under 40 CFR Part 273, EPA has established a separate set of requirements for three types of wastes called *universal wastes.* Universal wastes include certain batteries, certain pesticides, and mercury thermostats. Pesticides designated as universal wastes include (1) recalled pesticides that are stocks of a suspended or canceled pesticide and part of a voluntary or mandatory recall under FIFRA §19(b); (2) recalled pesticides that are stocks of a suspended or canceled pesticide, or a pesticide that is not in compliance with FIFRA, that are part of a voluntary recall [see FIFRA §19(b)(2)] by the registrant; and (3) stocks of other unused pesticide products that are collected and managed as part of a waste pesticide collection program.

  The Universal Waste rule is *optional* for states/tribe to adopt. In those states/tribes that have not adopted the Universal Waste rule, these wastes must be disposed of in accordance with the hazardous (or acutely hazardous) waste requirements (see 40 CFR Part 262).

- ***Exemption for Small Quantities of Used Oil***. Under 40 CFR §279.20, agricultural establishments that generate an average of 25 gallons or less of used oil per month per calendar year from vehicles or machinery used on the establishment are not subject to the requirements of 40 CFR Part 279.

- ***Exemption for "Farm Tanks" and Tanks of 110 Gallons or Less***. Under the underground storage tank (UST) regulations (RCRA Subtitle I, 40 CFR §280.12), "farm tanks" of 1,100 gallons or less capacity used for storing motor fuel for non-commercial purposes are not regulated as underground storage tanks. *"Farm tanks"* include tanks located on a tract of land devoted to the production of crops or raising animals (including fish) and associated residences and improvements. Also under 40 CFR §280.10, the UST program does not apply to UST systems of 110 gallons or less capacity, or that contain a *de minimis* concentration of a regulated substance.

  Even with the above exemptions, keep in mind that many agricultural establishments may be subject to the UST program (40 CFR Part 280). The UST regulations apply to facilities that store either petroleum products or hazardous substances (except hazardous wastes) identified under CERCLA. UST regulations address design standards, leak detection, operating practices, response to releases, financial responsibility for releases, and closure standards.

Comprehensive Environmental Response, Compensation, and Liability Act

Under CERCLA, there are a limited number of statutory and regulatory requirements that potentially affect agricultural businesses. The key provisions are summarized below:

- **Emergency Release Notification Requirements**. Under CERCLA §103(a), facilities are required to notify the National Response Center about any release of a CERCLA hazardous substance in quantities equal to or greater than its reportable quantity (RQ). Releases include discharges into the air, soil, surface water, or groundwater. Any release at or above the RQ must be reported regardless of whether there is a potential for offsite exposure.

  – ***Hazardous Substances***. The term "hazardous substance" is defined in CERCLA §101(14) and these substances (more than

700) are listed at 40 CFR Part 302, Table 302.4. Several agricultural chemicals are on the CERCLA hazardous substance list, including many pesticides, anhydrous ammonia, and ethylene glycol.

– ***Reportable Quantities***. For each hazardous substance, EPA has designated a RQ of 1, 10, 100, 1,000, or 5,000 pounds. RQs are listed in 40 CFR Part 355, Appendices A and B and 40 CFR Part 302, Table 302.4.

– ***When No Notification is Required***. There are several types of releases that are excluded from the requirements of CERCLA release notification. Two of these releases, excluded under CERCLA §§101(22) and 103(e), include the normal application of fertilizer and the application of pesticide products registered under FIFRA. *Keep in mind that spills, leaks, or other accidental or unintended releases of fertilizers and pesticides are subject to the reporting requirements.*

- **Facility Notification and Recordkeeping Requirements - Exemption for Agricultural Producers**. Under CERCLA §§103(c) and (d), certain facilities must notify EPA of their existence and the owners/operators must keep records. However, CERCLA §103(e) exempts agricultural producers who store and handle FIFRA-registered pesticides from the facility notification and recordkeeping requirements. CERCLA does not define the term *agricultural producer*.

- **Liability for Damages**. Under CERCLA §107(a), an owner/operator of a facility that has CERCLA hazardous substances onsite may be liable for cleanup costs, response costs, and natural resource damages associated with a release or threatened release of hazardous substances. Agricultural establishments are potentially liable under this section, and that liability extends to past practices.

Emergency Planning and Community Right-to-Know Act

A summary of the potential applicability of specific sections of EPCRA on the agricultural sector follows below.

- **Emergency Planning and Notification**. Under EPCRA §302, owners or operators of any facility, including agricultural establishments, that have *extremely hazardous substances* (40 CFR Part 355 Appendices A and B) present in excess of the *threshold planning quantity* must notify in writing their state emergency response commission (SERC) and their local emergency planning committee (LEPC) that they are subject to EPCRA planning requirements. Under EPCRA §303, they must also notify the LEPC of the name of a person at their facility whom the LEPC may contact in regard to planning issues related to these extremely hazardous substances. They must also inform the LEPC promptly of any relevant changes, and when requested, must provide information to the LEPC necessary for emergency planning.

Ammonia, several agricultural pesticides, and certain fuels are included on the list of extremely hazardous substances found in 40 CFR Part 355 Appendices A and B. If a listed substance is a solid, two different planning quantities are listed (e.g., 500 lbs/10,000 lbs). The smaller amount (e.g., 500 lbs.) applies if the substance is in powder form, such as a soluble or wettable powder, or if it is in solution or molten form. The larger quantity (10,000 lbs.) applies for most other forms of the substance. If the extremely hazardous substance is part of a mixture or solution, then the amount is calculated by multiplying its percent by weight times the total weight of the mixture or solution. If the percent by weight is less than one percent, the calculation is not required (40 CFR Part 355.30).

- Ammonia -- The quantity of anhydrous ammonia that triggers the planning requirement is 500 pounds.

- Pesticides -- Examples of pesticides on the list with the quantity in pounds that triggers the planning requirement include: ethion (1,000), nicotine (100), dichlorvos (1,000), parathion (100), chlordane (1,000), methyl bromide (1,000), ethylene oxide (1,000), fenitrothion (500), phorate (10), zinc phosphide (500), aluminum phosphide (500), terbufos (100), phosphamidon (100), demeton (500), ethoprop (1,000), and disulfoton (500).

- Solid Pesticides -- Examples of pesticides with dual quantities that trigger the planning requirements include: coumaphos (100/10,000), strychnine (100/10,000), dimethoate (500/10,000), warfarin (500/10,000), azinphos-methyl (10/10,000), methyl parathion (100/10,000), phosmet (10/10,000), methidathion (500/10,000), carbofuran (10/10,000), paraquat (10/10,000), methiocarb (500/10,000), methamidophos (100/10,000), methomyl (500/10,000), fenamiphos (10/10,000), and oxamyl (100/10,000).

- **§304 Emergency Release Notification**. Under 40 CFR 355, facilities must *immediately* notify the SERC and LEPC of releases of EPCRA extremely hazardous substances and CERCLA hazardous substances when the release equals or exceeds the reportable quantity within a 24-hour period and has the *potential* for offsite exposure. There are two notifications required: the initial notification and the written followup notification.

Exemption for Substances Used in Agricultural Operations. Only facilities that produce, use or store *hazardous chemicals* are subject to EPCRA release reporting. EPCRA §311(e) excludes from the definition of *hazardous chemicals* those substances used in routine agricultural operations. The exemption covers fertilizers and pesticides used in routine agricultural operations and fuels for operating farm equipment (including to transport crops to market). If all the hazardous chemicals present at the facility do not fall within this exemption, the facility must report all releases of any EPCRA extremely hazardous substance or CERCLA hazardous substance. Additionally, spills, leaks, or other accidental or unintended releases of fertilizers and pesticides are subject to the EPCRA release reporting requirements.

- **§311 and §312 Hazardous Chemical Inventory and Reporting**. Under EPCRA §311 and §312, facilities must inventory the hazardous chemicals present onsite in amounts equal to or in excess of the threshold planning quantities, and meet two reporting requirements:

  – A one-time notification of the presence of hazardous chemicals onsite in excess of threshold levels (EPCRA §311) to the SERC, LEPC, and the local fire department; and

  – An annual notification (Tier I or Tier II report) to the SERC, LEPC, and the local fire department detailing the locations and hazards associated with the hazardous chemicals found on facility grounds (EPCRA §312).

  Exemption for Substances Used in Agricultural Operations. As mentioned above, the term "hazardous chemical," as defined in EPCRA §311(e), *excludes* substances used in routine agricultural operations.

Clean Air Act

Agriculture-related industries generally do not include those industry sectors considered to be major sources of air pollution. Nevertheless, some agriculture-related activities are potentially subject to regulation under the CAA. The provisions identified below summarize the CAA requirements applicable to certain agriculture-related activities:

- **Risk Management Program**. Under §112(r) of the Clean Air Act, EPA has promulgated the Risk Management Program Rule. The rule's main goals are to prevent accidental releases of regulated substances and to reduce the severity of those releases that do occur by requiring facilities to develop risk management programs. A facility's risk management program must incorporate three elements: a hazard assessment, a prevention program, and an emergency response program. These programs are to be summarized in a risk management plan (RMP) that will be made available to state and local government agencies and the public.

  Under 40 CFR Part 68, facilities that have more than the threshold quantity of any of the listed regulated substances in a single process are required to comply with the regulation. *Process* means any regulated activity involving a regulated substance, including manufacturing, storing, distributing, or handling a regulated substance or using it in any other way. Any group of interconnected vessels (including piping), or separate vessels located close enough together to be involved in a single accident, are considered a single process. Transportation is not included.

  Listed regulated substances are acutely toxic substances, flammable gases, volatile liquids, and highly explosive substances listed by EPA in the Risk Management Program rule. The *threshold quantity* is the amount of a regulated substance that triggers the development of a RMP. The list of regulated substances and their corresponding threshold quantities are found at 40 CFR Part 68. Examples of threshold quantities of listed regulated substances include: formaldehyde -- 15,000 pounds; ethylene oxide -- 10,000 pounds; methyl isocyanate -- 10,000 pounds; anydrous ammonia -- 10,000 pounds; and mixtures containing ammonia in a concentration of 20 percent or greater -- 20,000 pounds.

  Exception: Ammonia that farmers are holding for use as fertilizer is not a regulated substance under the risk management program. Farmers are not responsible for preparing a risk management plan if ammonia held for use as a fertilizer is the only listed regulated substance that they have in more than threshold quantities. However, ammonia that is on a farm for any other use, such as for distribution or as a coolant/refrigerant, is not exempt.

  Three program levels. The risk management planning regulation (40 CFR Part 68) defines the activities facilities must undertake to address the risks posed by regulated substances in covered processes. To ensure that individual processes are subject to appropriate requirements that match their size and the risks they may pose, EPA has classified them into 3 categories ("programs"):

– **Program 1** requirements apply to processes for which a worst-case release, as evaluated in the hazard assessment, would not affect the public. These are processes that have **not** had an accidental release that caused serious offsite consequences.

– **Program 2** requirements apply to less complex operations that do **not** involve chemical processing.

– **Program 3** requirements apply to higher risk, complex chemical processing operations and to processes already subject to the **OSHA Process Safety Management Standard (29 CFR 1910.119)**.

Risk Management Planning. Facilities with more than a threshold quantity of any of the 140 regulated substances in a single process are required to develop a risk management program and to summarize their program in a risk management plan (RMP). A facility subject to the requirements was required to have submitted a registration and RMP by June 21, 1999, or whenever it first exceeds the threshold for a listed regulated substance after that date.

All facilities with processes in Program 1 must carry out the following elements of risk management planning:

– An offsite consequence analysis that evaluates specific potential release scenarios, including worst-case and alternative scenarios.

– A five-year history of certain accidental releases of regulated substances from covered processes.

– A risk management plan, revised at least once every five years, that describes and documents these activities for all covered processes.

Facilities with processes in Programs 2 and 3 must also address each of the following elements:

- An integrated prevention program to manage risk. The prevention program will include identification of hazards, written operating procedures, training, maintenance, and accident investigation.

- An emergency response program.

- An overall management system to put these program elements into effect.

- **National Ambient Air Quality Standards (NAAQS)/SIPS**. Under the CAA §10, each state must develop a State Implementation Plan (SIP) to identify sources of air pollution and to determine what reductions are required to meet federal air quality standards. If the applicable SIP imposes requirements on an agricultural establishment, that facility must comply with the SIP. The most likely pollutant of concern with respect to agriculture-related businesses is particulate matter.

Federal Insecticide, Fungicide, and Rodenticide Act

For agricultural producers, FIFRA is the environmental statute that most significantly impacts day-to-day operations of pesticide use. It also imposes administrative requirements on pesticide users, including agricultural producers. A summary of major provisions applicable to agricultural producers is provided below.

- **Use Restrictions**. The pesticide product label is information printed on or attached to the pesticide container. Users are legally required to follow the label. Labeling is the pesticide product label and other accompanying materials which contain directions that pesticide users are legally required to follow. Under FIFRA §12, each pesticide must be used only in a way that is consistent with its labeling.

  - As a part of the pesticide registration, EPA must classify the product for general use, restricted use, or general for some uses and restricted for others (Miller, 1993). For pesticides that may cause unreasonable adverse effects on the environment, including injury to the applicator, EPA may require that the pesticide be applied either by or under the direct supervision of a certified applicator.

  - It is against the law (Endangered Species Act) to harm an endangered species. Harm includes not only acts that directly injure or kill the protected species, but also significant habitat modification or degradation that disrupts breeding, feeding, or sheltering. Pesticide users must comply with any pesticide labeling restrictions or requirements that concern the protection of endangered species or their habitats.

- **Tolerances and Exemptions**. A tolerance is the maximum amount of pesticide residue that can be on a raw product and still be considered safe. Before EPA can register a pesticide that is used on raw agricultural products, it must grant a tolerance or exemption from a tolerance (40 CFR.163.10 through 163.12). Under the Federal Food, Drug, and Cosmetic Act (FFDCA), a raw agricultural product is deemed unsafe if it contains a pesticide residue, unless the residue is within the limits of a tolerance established by EPA or is exempt from the requirement.

  To avoid being responsible for products being over tolerance, users must be particularly careful to comply with the label instructions concerning application rate and minimum days between pesticide application and harvest (i.e., preharvest interval), slaughter, freshening, or grazing.

- **Worker Protection Standard (WPS) Requirements for Users**. The WPS for Agricultural Pesticides (40 CFR Parts 156 and 170) covers pesticides that are used in the commercial production of agricultural plants on farms, forests, nurseries, and greenhouses. The WPS requires pesticide users to take steps to reduce the risk of pesticide-related illness and injury if they or their employees may be exposed to pesticides used in the commercial production of agricultural plants.

- **Cancellation and Suspension**. EPA can cancel a registration if it is determined that the pesticide or its labeling does not comply with the requirements of FIFRA or causes unreasonable adverse effects on the environment (Haugrud, 1993).

  In cases where EPA believes that an “imminent hazard” would exist if a pesticide were to continue to be used through the cancellation proceedings, EPA may suspend the pesticide registration through an order and thereby halt the sale, distribution, and usage of the pesticide. An “imminent hazard” is defined as an unreasonable adverse effect on the environment or an unreasonable hazard to the survival of a threatened or endangered species that would be the likely result of allowing continued use of a pesticide during a cancellation process.

When EPA believes and emergency exists that does not permit a hearing to be held prior to suspending, EPA can issue an emergency order that makes the suspension immediately effective.

Toxic Substances Control Act

TSCA has a limited impact on the agricultural sector. TSCA §3, Definitions, specifies that the term chemical substance means any organic or inorganic substance of a particular molecular identity. The definition also states, as declared at subsection (2)(B)(ii), that such term does not include any pesticide (as defined in FIFRA) when manufactured, processed, or distributed in commerce for use as a pesticide. Since the majority of potentially hazardous substances used by agricultural producers are pesticides, they are regulated under FIFRA. Regulation of hazardous substances under other authorities is part of TSCA's overall scheme which allows EPA to decline to regulate a chemical under TSCA if other federal regulatory authorities (e.g., FIFRA) are sufficiently addressing the risks posed from those substances.

- **Asbestos and Asbestos-Containing Material**. Under TSCA §6 and 40 CFR Part 61, Subpart M, EPA regulates the renovation/demolition activities, notification, work practices and removal, and disposal of asbestos-containing material (ACM). ACM should be carefully monitored; however, the mere presence of asbestos in a building is not considered hazardous. ACM that becomes damaged, however, may pose a health risk since it may release asbestos fibers over time. If a material is suspected of containing asbestos and it is more than slightly damaged, or if changes need to be made to a building that might disturb it, repair or removal of the ACM by a professional is needed.

- **Asbestos Brake Pads**. Facilities that repair their own brakes should be aware of asbestos requirements. Asbestos brake pads must be removed using appropriate control measures so that no visible emissions of asbestos will be discharged to the outside air. These measures can include one of the following: (1) wetting that is generally done through the use of a brake washing solvent bath, such as those provided by a service; (2) vacuuming that is usually performed with a commercial brake vacuum specifically designed for use during brake pad changing or pad re-lining operations; or (3) combination of wetting and vacuuming.

  Asbestos brake pads and wastes must be managed by: (1) labeling equipment, (2) properly disposing of spent solvent, (3) properly disposing of used vacuum filters, and (4) sealing used brake pads. The containers or

wrapped packages must be labeled using warning labels as specified by OSHA [29 CFR 1910.001 (j) (2) or 1926.58 (k)(2)(iii)].
Asbestos waste must be disposed of as soon as practical at an EPA-approved disposal site. The asbestos containers must be labeled with the name and location of the waste generator. Vehicles used to transport the asbestos must be clearly labeled during loading and unloading. The waste shipment records must be maintained (40 CFR 61.150) so that the asbestos shipment can be tracked and substantiated.

- **Polychlorinated Biphenyls (PCBs)**. PCBs were widely used in electrical equipment manufactured from 1932 to 1978. Types of equipment potentially containing PCBs include transformers and their bushings, capacitors, reclosers, regulators, electric light ballasts, and oil switches. Any equipment containing PCBs in their dielectric fluid at concentrations of greater than 50 ppm are subject to the PCB requirements.

  Under TSCA §6 and 40 CFR Part 761, facilities must ensure through activities related to the management of PCBs (e.g., inspections for leaks, proper storage) that human food or animal feed are not exposed to PCBs. While the regulations do not establish a specific distance limit, any item containing PCBs is considered to pose an unacceptable exposure risk to food or feed if PCBs released in any form have the potential to reach/contaminate food or feed.

- **Lead**. Approximately 1.7 million children have blood-lead levels high enough to raise health concerns. Studies suggest that lead exposure from deteriorated residential lead-based paint, contaminated soil, and lead in dust are among the major existing sources of lead exposure among children in the U.S.

  Section 1018 of the Residential Lead-Based Paint Hazard Reduction Act of 1992 directs EPA and the Department of Housing and Urban Development (HUD) to jointly issue regulations requiring disclosure of known lead-based paint and/or lead-based paint hazards by persons selling or leasing housing constructed before the phaseout of residential lead-based paint use in 1978. Under that authority, EPA and HUD jointly issued on March 6, 1996, regulations titled *Lead; Requirements for Disclosure of Known Lead-Based Paint and/or Lead-Based Paint Hazards in Housing* (40 CFR Part 35 and 40 CFR Part 745). In these regulations, EPA and HUD established requirements for sellers/lessors of residential housing built before 1978.

***Pre-Renovation Lead Information Rule**.* If conducted improperly, renovations in housing with lead-based paint can create serious health hazards to workers and occupants by releasing large amounts of lead dust and debris. Under TSCA §406 and through a rule published on June 1, 1998 entitled *Lead; Requirements for Hazard Education Before Renovation of Target Housing* (40 CFR Part 745), EPA required the distribution of lead hazard information (i.e., EPA-developed pamphlet) prior to professional renovations on residential housing built before 1978.

IV.C. Proposed and Pending Regulations

Clean Water Act

Feedlots Effluent Limitation Guidelines. EPA is in the process of reviewing and revising the effluent limitation guidelines for feedlots. EPA is under a court-ordered schedule to revise the guidelines for poultry and swine by December 2001 and for beef and dairy cattle by December 2002.

NPDES Implementing Regulations. EPA intends to revise the existing NPDES permitting regulations to clarify expectations and requirements for CAFOs as well as to reflect the changes in the industry. NRCS and other USDA agencies will participate on the regulatory workgroup to advise EPA on the technical and implementation aspects related to any proposed revisions. Revision of the permitting regulations is expected to be closely coordinated with the revision of the Feedlots Effluent Limitation Guidelines (40 CFR Part 412) because of the commonality of issues and the administrative efficiencies for EPA, States and all interested groups. Permits in effect on the date of new regulations will remain in effect until subsequently changed to incorporate the new requirements.

Coastal Zone Act Reauthorization Amendments of 1990

Implementation of Management Measures. Under Section 6217, states/tribes must fully implement the management measures in their Coastal Nonpoint Pollution Control Programs by January 2004. States/tribes are required to perform effectiveness monitoring between 2004 and 2006 and implement other measures between 2006 and 2009.

Safe Drinking Water Act

Management of Class V Wells. EPA plans to propose additional requirements addressing the environmental risks posed by the highest risk Class V wells. This rulemaking potentially affects agricultural operations that use industrial and commercial disposal wells and large capacity cesspools.

Federal Insecticide, Fungicide, and Rodenticide Act

Pesticide Management and Disposal: Proposed Rule - issued on May 5, 1993 (FR26857). The regulations for this rule will be found in the Code of Federal Regulations (CFR) at 40 CFR Part 165 - Regulations for the Acceptance of Certain Pesticides and Recommended Procedures for the Disposal and Storage of Pesticides and Pesticides Containers. This final rule will:

- Describe procedures for voluntary and mandatory recall actions.
- Establish criteria for acceptable storage and disposal plans which registrants may submit to EPA to become eligible for reimbursement of storage costs.
- Establish procedures for the indemnification of owners of suspended and canceled pesticides.
- Amend the Agency's responsibility for accepting for disposal suspended and canceled pesticides.

V. Compliance and Enforcement History

V.A. Background

Until recently, EPA has focused much of its attention on measuring compliance with specific environmental statutes. This approach allows the Agency to track compliance with the Clean Air Act, the Resource Conservation and Recovery Act, the Clean Water Act, and other environmental statutes. Within the last several years, the Agency has begun to supplement single-media compliance indicators with facility-specific, multimedia indicators of compliance. In doing so, EPA is in a better position to track compliance with all statutes at the facility level and within specific industrial sectors.

A major step in building the capacity to compile multimedia data for industrial sectors was the creation of EPA's Integrated Data for Enforcement Analysis (IDEA) system. IDEA has the capacity to "read into" the Agency's single-media databases, extract compliance records, and match the records to individual facilities. The IDEA system can match air, water, waste, toxics/pesticides, EPCRA, Toxics Release Inventory (TRI), and enforcement docket records for a given facility and generate a list of historical permit, inspection, and enforcement activity. IDEA also has the capability to analyze data by geographic area and corporate holder. As the capacity to generate multimedia compliance data improves, EPA will make available more in-depth compliance and enforcement information. Additionally, EPA is developing sector-specific measures of success for compliance assistance efforts.

V.B. Compliance and Enforcement Profile Description

This section uses inspection, violation, and enforcement data from the IDEA system to provide information about the historical compliance and enforcement activity of this sector. While other sector notebooks have used Standard Industrial Classification (SIC) data from the Toxics Release Inventory System (TRIS) to define their data sampling universes, none of the SIC codes associated with the livestock production sector identifies facilities that report to the TRI program. As such, sector-defining data have been provided from EPA data systems

> **Note:** Many of the previously published sector notebooks contained a chapter titled *"Chemical Release and Transfer Profile."* The information and data for that chapter were taken primarily from EPA's Toxic Release Inventory (TRI). Because the industries discussed in this notebook do not, in general, directly report to TRI, that chapter has not been included in this sector notebook.

linked to EPA's Facility Indexing System (FINDS), which tracks facilities in all media databases. This section does not attempt to define the actual number of facilities that fall within each sector. Instead, the section portrays the records of a subset of facilities within the sector that are well defined within EPA databases.

As a check on the relative size of the full sector universe, most notebooks contain an estimated number of facilities within the sector according to the Bureau of Census. With sectors dominated by small businesses, such as metal finishers and printers, the reporting universe within the EPA databases may be small in comparison to Census data. However, the group selected for inclusion in this data analysis section should be consistent with this sector's general make-up.

Before presenting the data, the next section defines general terms and the column heads used in the data tables. The data represent a retrospective summary of inspections and enforcement actions and solely reflect EPA, state, and local compliance assurance activities that have been entered into EPA databases. To identify trends, EPA ran two data queries, one for five calendar years (March 7, 1992 to March 6, 1997) and the other for a twelve-month period (March 7, 1996 to March 6, 1997). The five-year analysis gives an average level of activity for that period for comparison to the more recent activity.

Because most inspections focus on single-media requirements, the data queries presented in this section are taken from single media databases. These databases do not provide data on whether inspections are state/local or EPA-led. However, the table breaking down the universe of violations does give the reader a crude measurement of the EPA's and state's efforts within each media program. The presented data illustrate the variations across EPA regions for certain sectors[1]. This variation may be attributable to state/local data entry variation, specific geographic concentrations, proximity to population centers, sensitive ecosystems, highly toxic chemicals used in production, or historical noncompliance. Hence, the exhibited data do not rank regional performance or necessarily reflect which regions may have the most compliance problems.

[1] EPA Regions are as follows: I (CT, MA, ME, RI, NH, VT); II (NJ, NY, PR, VI); III (DC, DE, MD, PA, VA, WV); IV (AL, FL, GA, KY, MS, NC, SC, TN); V (IL, IN, MI, MN, OH, WI); VI (AR, LA, NM, OK, TX); VII (IA, KS, MO, NE); VIII (CO, MT, ND, SD, UT, WY); IX (AZ, CA, HI, NV, Pacific Trust Territories); X (AK, ID, OR, WA).

Compliance and Enforcement Data Definitions

General Definitions

Facility Indexing System (FINDS) - assigns a common facility number to EPA single-media permit records, establishing a linkage capability to the permit data. The FINDS identification number allows EPA to compile and review all permit, compliance, enforcement, and pollutant release data for any given regulated facility.

***Integrated Data for Enforcement Analysis (IDEA)* -** is a data integration system that can retrieve information from the major EPA program office databases. IDEA uses the FINDS identification number to link separate data records from EPA's databases. This allows retrieval of records from across media or statutes for any given facility, this creating a "master list" of records for that facility. Some of the data systems accessible through IDEA are AFS (Air Facility Indexing and Retrieval System, Office of Air and Radiation), PCS (Permit Compliance System, Office of Water), RCRIS (Resource Conservation and Recovery Information System, Office of Solid Waste), NCBD (National Compliance Data Base, Office of Prevention, Pesticides, and Toxic Substances), CERCLIS (Comprehensive Environmental and Liability Information System, Superfund), and TRIS. IDEA also contains information from outside sources, such as Dun and Bradstreet (DUN) and the Occupational Safety and Health Administration (OSHA). Most data queries displayed in this section were conducted using IDEA.

Data Table Column Heading Definitions

Facilities in Search - based on the universe of TRI reporters within the listed SIC code range. For industries not covered under TRI reporting requirements, or industries in which only a very small fraction of facilities report to TRI, the notebook uses the FINDS universe for executing data queries. The SIC code range selected for each search is defined by each notebook's selected SIC code coverage described in Section II.

Facilities Inspected - indicates the level of EPA and state agency inspections for the facilities in this data search. These values show what percentage of the facility universe is inspected in a one-year or five-year period.

Number of Inspections - measures the total number of inspections conducted in this sector. An inspection event is counted each time it is entered into a single media database.

Average Time Between Inspections - provides an average length of time, expressed in months, between compliance inspections at a facility within the defined universe.

Facilities With One or More Enforcement Actions - expresses the number of facilities that were the subject of at least one enforcement action within the defined time period. This category is broken down further into federal and state actions. Data are obtained for administrative, civil/judicial, and criminal state actions. A facility with multiple enforcement actions is only counted once in this column, e.g., a facility with 3 enforcement actions counts as 1 facility.

Total Enforcement Actions - describes the total number of enforcement actions identified for an industrial sector across all environmental statutes. A facility with multiple enforcement actions is counted multiple times (i.e., a facility with 3 enforcement actions counts as 3).

State Lead Actions - shows what percentage of the total enforcement actions are taken by state and local environmental agencies. Varying levels of use by states of EPA data systems may limit the volume of actions accorded state enforcement activity. Some states extensively report enforcement activities into EPA data systems, while other states may use their own data systems.

Federal Lead Actions - shows what percentage of the total enforcement actions are taken by the U.S. EPA. This value includes referrals from state agencies. Many of these actions result from coordinated or joint federal/state efforts.

Enforcement to Inspection Rate - is a ratio of enforcement actions to inspections, and is presented for comparative purposes only. The ratio is a rough indicator of the relationship between inspections and enforcement. It relates the number of enforcement actions and the number of inspections that occurred within the one-year or five-year period. This ratio includes inspections and enforcement actions reported under the Clean Water Act (CWA), the Clean Air Act (CAA) and the Resource Conservation and Recovery Act (RCRA). Inspections and actions from the TSCA/FIFRA/EPCRA database are not factored into this ratio because most of the actions taken under these programs are not the result of facility inspections. Also, this ratio does not account for enforcement actions arising from non-inspection compliance monitoring activities (e.g., self-reported water discharges) that can result in enforcement action within the CAA, CWA and RCRA.

Facilities with One or More Violations Identified - expresses the percentage of inspected facilities having a violation identified in one of the following data categories: In Violation or Significant Violation Status (CAA); Reportable Noncompliance, Current Year Noncompliance, Significant Noncompliance (CWA); Noncompliance and Significant Noncompliance (FIFRA, TSCA, and EPCRA); Unresolved Violation and Unresolved High Priority Violation (RCRA). The values presented for this column reflect the extent of noncompliance within the measured time frame, but do not distinguish between the severity of the noncompliance. Violation status may be a precursor to an enforcement action, but does not necessarily indicate that an enforcement action will occur.

Media Breakdown of Enforcement Actions and Inspections - four columns identify the proportion of total inspections and enforcement actions within EPA Air, Water, Waste, and TSCA/FIFRA/EPCRA databases. Each column is a percentage of either the "Total Inspections," or the "Total Actions" column.

V.C. Livestock Production Industry Compliance History

Exhibit 19 provides an overview of the reported compliance and enforcement data for the livestock sector over a 5-year period (March 1992 to March 1997). These data are also broken out by EPA regions thereby permitting geographical comparisons. A few points evident from the data are listed below.

> **Note:** It should be noted that the data presented in this section represent federal enforcement activity only. Enforcement activity conducted at the state level is not included in this analysis.

- Of the 1,001 facilities identified through IDEA with livestock SIC codes, approximately 20 percent (205) were inspected in the last 5 years.

- Region 4 had more inspections (163) than other regions and the most enforcement actions (9), accounting for 29 percent of the total enforcement actions.

- Region 10 had only 3 percent of the total inspections, but had 16 percent of the total enforcement actions yielding the highest enforcement/inspection ratio of 0.29.

- The total inspections (600) conducted nationwide have resulted in 31 enforcement actions, which results in an enforcement-to-inspection rate of 0.05. This means that for every 100 inspections conducted, there are approximately 5 resulting enforcement actions.

- Enforcement actions were primarily state-led (84%). Regions 7 and 9 had no enforcement actions.

- Several regions (1, 4, 6, 7, 8, 10) had an average time between inspections of greater than 100 months.

Exhibit 19. Five-Year Enforcement and Compliance Summary for the Livestock Industry

A	B	C	D	E	F	G	H	I	J
Region	Facilities in Search	Facilities Inspected	Number of Inspections	Average Months Between Inspections	Facilities with 1 or More Enforcement Actions	Total Enforcement Actions	Percent State Lead Actions	Percent Federal Lead Actions	Enforcement to Inspection Rate
I	16	3	5	192	2	1	100%	0%	0.20
II	20	12	33	36	3	6	100%	0%	0.18
III	49	24	161	18	3	5	100%	0%	0.03
IV	304	67	163	112	7	9	56%	44%	0.06
V	69	18	42	99	2	3	100%	0%	0.07
VI	96	6	14	411	1	1	100%	0%	0.07
VII	217	11	20	651	0	0	--	--	--
VIII	122	23	67	109	1	1	100%	0%	0.01
IX	40	35	78	31	0	0	--	--	--
X	68	6	17	240	1	5	80%	20%	0.29
TOTAL	1,001	205	600	100	20	31	84%	16%	0.05

Comparison of Enforcement Activity Between Selected Industries

Exhibits 20 and 21 allow the compliance history of the livestock production sector to be compared to other industries covered by the sector notebooks. Comparisons between these exhibits permit the identification of trends in compliance and enforcement records of the various industries by comparing data covering a 5-year period (March 1992 to March 1997) to that of a 1-year period (March 1996 to March 1997). Some points evident from the data are listed below.

- The one-year enforcement-to-inspection ratio (0.01) is one-fifth of the five-year ratio (0.05).

- In the 5-year comparison, the average months between inspections (100) was more than any other sector.

- In Exhibit 20, the livestock production industry data approximate the averages of the industries shown for percent state-lead versus federal-led actions.

- In Exhibit 21, when compared to all sectors over the period March 1996 - March 1997, the livestock sector had the third fewest number of inspections conducted (146) and fewest enforcement actions (2).

Exhibits 22 and 23 provide a more in-depth comparison between the livestock production sector and other sectors by breaking out compliance and enforcement data by environmental statute. As in the previous exhibits (Exhibits 20 and 21), the data cover a 5-year period (Exhibit 22) and a 1-year period (Exhibit 23) to facilitate the identification of recent trends. Points evident from the data are listed below.

- As shown in Exhibit 22, over the past 5 years, more than half (57%) of all inspections conducted at livestock facilities and nearly two-thirds (65%) of all enforcement actions have been under the Clean Water Act. It should be noted that 3 percent of all enforcement actions were taken under the FIFRA/TSCA/EPCRA/Other category although no inspections were conducted within that category. This number is possible because in many EPA regions, media inspectors are being trained to examine the facility from a multimedia viewpoint.

- As shown in Exhibits 22 and 23, Clean Water Act inspections account for more than half (57% and 51%, respectively) of all inspections, with the Clean Air Act representing nearly all of the remaining inspections (38% and 48%, respectively). However, from March 1996 - March

1997, every single enforcement action taken was under the Clean Water Act.

Exhibit 20. Five-Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E	F	G	H	I	J
Industry Sector	**Facilities in Search**	**Facilities Inspected**	**Number of Inspections**	**Average Months Between Inspections**	**Facilities with 1 or More Enforcement Actions**	**Total Enforcement Actions**	**Percent State Lead Actions**	**Percent Federal Lead Actions**	**Enforcement to Inspection Rate**
Livestock	**1,001**	**205**	**600**	**100**	**20**	**31**	**84%**	**16%**	**0.05**
Crop Production	6,688	3,046	10,453	38	141	262	73%	27%	0.03
Metal Mining	1,232	378	1,600	46	63	111	53%	47%	0.07
Coal Mining	3,256	741	3,748	52	88	132	89%	11%	0.04
Oil and Gas Extraction	4,676	1,902	6,071	46	149	309	79%	21%	0.05
Non-Metallic Mineral Mining	5,256	2,803	12,826	25	385	622	77%	23%	0.05
Textiles	355	267	1,465	15	53	83	90%	10%	0.06
Lumber and Wood	712	473	2,767	15	134	265	70%	30%	0.10
Furniture	499	386	2,379	13	65	91	81%	19%	0.04
Pulp and Paper	484	430	4,630	6	150	478	80%	20%	0.10
Printing	5,862	2,092	7,691	46	238	428	88%	12%	0.06
Inorganic Chemicals	441	286	3,087	9	89	235	74%	26%	0.08
Resins and Manmade Fibers	329	263	2,430	8	93	219	76%	24%	0.09
Pharmaceuticals	164	129	1,201	8	35	122	80%	20%	0.10
Organic Chemicals	425	355	4,294	6	153	468	65%	35%	0.11
Agricultural Chemicals	263	164	1,293	12	47	102	74%	26%	0.08
Petroleum Refining	156	148	3,081	3	124	763	68%	32%	0.25
Rubber and Plastic	1,818	981	4,383	25	178	276	82%	18%	0.06
Stone, Clay, Glass and Concrete	615	388	3,474	11	97	277	75%	25%	0.08
Iron and Steel	349	275	4,476	5	121	305	71%	29%	0.07
Metal Castings	669	424	2,535	16	113	191	71%	29%	0.08
Nonferrous Metals	203	161	1,640	7	68	174	78%	22%	0.11
Fabricated Metal Products	2,906	1,858	7,914	22	365	600	75%	25%	0.08
Electronics	1,250	863	4,500	17	150	251	80%	20%	0.06
Automobile Assembly	1,260	927	5,912	13	253	413	82%	18%	0.07
Aerospace	237	184	1,206	12	67	127	75%	25%	0.10
Shipbuilding and Repair	44	37	243	9	20	32	84%	16%	0.13
Ground Transportation	7,786	3,263	12,904	36	375	774	84%	16%	0.06
Water Transportation	514	192	816	38	36	70	61%	39%	0.09
Air Transportation	444	231	973	27	48	97	88%	12%	0.10
Fossil Fuel Electric Power	3,270	2,166	14,210	14	403	789	76%	24%	0.06
Dry Cleaning	6,063	2,360	3,813	95	55	66	95%	5%	0.02

Exhibit 21. One-Year Enforcement and Compliance Summary for Selected Industries

A	B	C	D	E		F		G	H
Industry Sector	Facilities in Search	Facilities Inspected	Number of Inspections	Facilities with 1 or More Violations		Facilities with 1 or more Enforcement Actions		Total Enforcement Actions	Enforcement to Inspection Rate
				Number	Percent*	Number	Percent*		
Livestock	**1001**	**107**	**146**	**22**	**21%**	**2**	**2%**	**2**	**0.01**
Crop Production	6688	1012	1459	866	86%	23	2%	29	0.02
Metal Mining	1,232	142	211	102	72%	9	6%	10	0.05
Coal Mining	3,256	362	765	90	25%	20	6%	22	0.03
Oil and Gas Extraction	4,676	874	1,173	127	15%	26	3%	34	0.03
Non-Metallic Mineral Mining	5,256	1,481	2,451	384	26%	73	5%	91	0.04
Textiles	355	172	295	96	56%	10	6%	12	0.04
Lumber and Wood	712	279	507	192	69%	44	16%	52	0.10
Furniture	499	254	459	136	54%	9	4%	11	0.02
Pulp and Paper	484	317	788	248	78%	43	14%	74	0.09
Printing	5,862	892	1,363	577	65%	28	3%	53	0.04
Inorganic Chemicals	441	200	548	155	78%	19	10%	31	0.06
Resins and Manmade Fibers	329	173	419	152	88%	26	15%	36	0.09
Pharmaceuticals	164	80	209	84	105%	8	10%	14	0.07
Organic Chemicals	425	259	837	243	94%	42	16%	56	0.07
Agricultural Chemicals	263	105	206	102	97%	5	5%	11	0.05
Petroleum Refining	156	132	565	129	98%	58	44%	132	0.23
Rubber and Plastic	1,818	466	791	389	83%	33	7%	41	0.05
Stone, Clay, Glass and Concrete	615	255	678	151	59%	19	7%	27	0.04
Iron and Steel	349	197	866	174	88%	22	11%	34	0.04
Metal Castings	669	234	433	240	103%	24	10%	26	0.06
Nonferrous Metals	203	108	310	98	91%	17	16%	28	0.09
Fabricated Metal	2,906	849	1,377	796	94%	63	7%	83	0.06
Electronics	1,250	420	780	402	96%	27	6%	43	0.06
Automobile Assembly	1,260	507	1,058	431	85%	35	7%	47	0.04
Aerospace	237	119	216	105	88%	8	7%	11	0.05
Shipbuilding and Repair	44	22	51	19	86%	3	14%	4	0.08
Ground Transportation	7,786	1,585	2,499	681	43%	85	5%	103	0.04
Water Transportation	514	84	141	53	63%	10	12%	11	0.08
Air Transportation	444	96	151	69	72%	8	8%	12	0.08
Fossil Fuel Electric Power	3,270	1,318	2,430	804	61%	100	8%	135	0.06
Dry Cleaning	6,063	1,234	1,436	314	25%	12	1%	16	0.01

**Percentages in Columns E and F are based on the number of facilities inspected (Column C). Percentages can exceed 100% because violations and actions can occur without a facility inspection.*

Exhibit 22. Five-Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Facilities Inspected	Total Inspections	Total Enforcement Actions	Clean Air Act		Clean Water Act		RCRA		FIFRA/TSCA/ EPCRA/Other	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Livestock	**205**	**600**	**31**	**38%**	**26%**	**57%**	**65%**	**3%**	**6%**	**0%**	**3%**
Crop Production	3,046	10,453	262	72%	35%	11%	23%	13%	25%	3%	17%
Metal Mining	378	1,600	111	39%	19%	52%	52%	8%	12%	1%	17%
Coal Mining	741	3,748	132	57%	64%	38%	28%	4%	8%	1%	1%
Oil and Gas Extraction	1,902	6,071	309	75%	65%	16%	14%	8%	18%	0%	3%
Non-Metallic Mineral Mining	2,803	12,826	622	83%	81%	14%	13%	3%	4%	0%	3%
Textiles	267	1,465	83	58%	54%	22%	25%	18%	14%	2%	6%
Lumber and Wood	473	2,767	265	49%	47%	6%	6%	44%	31%	1%	16%
Furniture	386	2,379	91	62%	42%	3%	0%	34%	43%	1%	14%
Pulp and Paper	430	4,630	478	51%	59%	32%	28%	15%	10%	2%	4%
Printing	2,092	7,691	428	60%	64%	5%	3%	35%	29%	1%	4%
Inorganic Chemicals	286	3,087	235	38%	44%	27%	21%	34%	30%	1%	5%
Resins and Manmade Fibers	263	2,430	219	35%	43%	23%	28%	38%	23%	4%	6%
Pharmaceuticals	129	1,201	122	35%	49%	15%	25%	45%	20%	5%	5%
Organic Chemicals	355	4,294	468	37%	42%	16%	25%	44%	28%	4%	6%
Agricultural Chemicals	164	1,293	102	43%	39%	24%	20%	28%	30%	5%	11%
Petroleum Refining	148	3,081	763	42%	59%	20%	13%	36%	21%	2%	7%
Rubber and Plastic	981	4,383	276	51%	44%	12%	11%	35%	34%	2%	11%
Stone, Clay, Glass and Concrete	388	3,474	277	56%	57%	13%	9%	31%	30%	1%	4%
Iron and Steel	275	4,476	305	45%	35%	26%	26%	28%	31%	1%	8%
Metal Castings	424	2,535	191	55%	44%	11%	10%	32%	31%	2%	14%
Nonferrous Metals	161	1,640	174	48%	43%	18%	17%	33%	31%	1%	10%
Fabricated Metal	1,858	7,914	600	40%	33%	12%	11%	45%	43%	2%	13%
Electronics	863	4,500	251	38%	32%	13%	11%	47%	50%	2%	7%
Automobile Assembly	927	5,912	413	47%	39%	8%	9%	43%	43%	2%	9%
Aerospace	184	1,206	127	34%	38%	10%	11%	54%	42%	2%	9%
Shipbuilding and Repair	37	243	32	39%	25%	14%	25%	42%	47%	5%	3%
Ground Transportation	3,263	12,904	774	59%	41%	12%	11%	29%	45%	1%	3%
Water Transportation	192	816	70	39%	29%	23%	34%	37%	33%	1%	4%
Air Transportation	231	973	97	25%	32%	27%	20%	48%	48%	0%	0%
Fossil Fuel Electric Power	2,166	14,210	789	57%	59%	32%	26%	11%	10%	1%	5%
Dry Cleaning	2,360	3,813	66	56%	23%	3%	6%	41%	71%	0%	0%

Exhibit 23. One-Year Inspection and Enforcement Summary by Statute for Selected Industries

Industry Sector	Facilities Inspected	Total Inspections	Total Enforcement Actions	Clean Air Act		Clean Water Act		RCRA		FIFRA/TSCA/ EPCRA/Other	
				% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions	% of Total Inspections	% of Total Actions
Livestock	**107**	**146**	**2**	**48%**	**0%**	**51%**	**100%**	**1%**	**0%**	**0%**	**0%**
Crop Production	1012	1459	29	71%	31%	13%	34%	16%	28%	0%	7%
Metal Mining	142	211	10	52%	0%	40%	40%	8%	30%	0%	30%
Coal Mining	362	765	22	56%	82%	40%	14%	4%	5%	0%	0%
Oil and Gas Extraction	874	1,173	34	82%	68%	10%	9%	9%	24%	0%	0%
Non-Metallic Mineral Mining	1,481	2,451	91	87%	89%	10%	9%	3%	2%	0%	0%
Textiles	172	295	12	66%	75%	17%	17%	17%	8%	0%	0%
Lumber and Wood	279	507	52	51%	30%	6%	5%	44%	25%	0%	40%
Furniture	254	459	11	66%	45%	2%	0%	32%	45%	0%	9%
Pulp and Paper	317	788	74	54%	73%	32%	19%	14%	7%	0%	1%
Printing	892	1,363	53	63%	77%	4%	0%	33%	23%	0%	0%
Inorganic Chemicals	200	548	31	35%	59%	26%	9%	39%	25%	0%	6%
Resins and Manmade Fibers	173	419	36	38%	51%	24%	38%	38%	5%	0%	5%
Pharmaceuticals	80	209	14	43%	71%	11%	14%	45%	14%	0%	0%
Organic Chemicals	259	837	56	40%	54%	13%	13%	47%	34%	0%	0%
Agricultural Chemicals	105	206	11	48%	55%	22%	0%	30%	36%	0%	9%
Petroleum Refining	132	565	132	49%	67%	17%	8%	34%	15%	0%	10%
Rubber and Plastic	466	791	41	55%	64%	10%	13%	35%	23%	0%	0%
Stone, Clay, Glass and Concrete	255	678	27	62%	63%	10%	7%	28%	30%	0%	0%
Iron and Steel	197	866	34	52%	47%	23%	29%	26%	24%	0%	0%
Metal Castings	234	433	26	60%	58%	10%	8%	30%	35%	0%	0%
Nonferrous Metals	108	310	28	44%	43%	15%	20%	41%	30%	0%	7%
Fabricated Metal	849	1,377	83	46%	41%	11%	2%	43%	57%	0%	0%
Electronics	420	780	43	44%	37%	14%	5%	43%	53%	0%	5%
Automobile Assembly	507	1,058	47	53%	47%	7%	6%	41%	47%	0%	0%
Aerospace	119	216	11	37%	36%	7%	0%	54%	55%	1%	9%
Shipbuilding and Repair	22	51	4	54%	0%	11%	50%	35%	50%	0%	0%
Ground Transportation	1,585	2,499	103	64%	46%	11%	10%	26%	44%	0%	1%
Water Transportation	84	141	11	38%	9%	24%	36%	38%	45%	0%	9%
Air Transportation	96	151	12	28%	33%	15%	42%	57%	25%	0%	0%
Fossil Fuel Electric Power	1,318	2,430	135	59%	73%	32%	21%	9%	5%	0%	0%
Dry Cleaning	1,234	1,436	16	69%	56%	1%	6%	30%	38%	0%	0%

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VI. REVIEW OF MAJOR LEGAL ACTIONS AND COMPLIANCE/ENFORCEMENT STRATEGIES

This section provides summary information about major cases that have affected the livestock production industry, as well as regional highlights of CAFO compliance/enforcement strategies.

Usually, this section also contains information on any supplemental environmental projects (SEPs) that were negotiated. SEPs are compliance agreements that reduce a facility's stipulated penalty in return for an environmental project that exceeds the value of the reduction. However, no information on SEPs in this sector was discovered during the research process. Often, these projects fund pollution prevention activities that can significantly reduce the future pollutant loadings of a facility. To learn more about SEPs, go to http://www.epa.gov/oeca/sep.

Review of Major Cases

A review of EPA's FY92 and FY93 *Enforcement Accomplishments Report* and the FY94 through FY98 *Enforcement and Compliance Assurance Accomplishments Report* identified several cases involving the livestock production industry. These cases are discussed below.

- In February 1999, EPA cited David Jaindl, president of Jaindl Land Company, for filling in federally protected wetlands at a turkey farm. EPA has alleged that Mr. Jaindl violated the Clean Water Act by filling three acres of wetlands at the farm in September and October 1998 without a required permit from the U.S. Army Corps of Engineers. EPA is seeking a $44,000 penalty for this violation.

- In October 1996, an Administrative Penalty Order (APO) with a $25,000 penalty was administered against *Del Oro Dairy* of New Mexico for failing to provide a Pollution Prevention Plan as required by the NPDES General Permit for Concentrated Animal Feeding Operations. This violation occurred from 1994 thru 1996. In March 1997, another Administrative Penalty Order and $5,500 fine was issued for failure to complete and implement a Pollution Prevention Plan. These enforcement actions are intended to prevent the pollution of the groundwater by requiring the facility to apply good management practices.

- *United States v. Harry James Saul and Ronnie Snead*: Harry Saul, part owner and operator of Harry Saul Minnow Farm, Inc., Prairie County, Arkansas, and a company employee, Ronnie Snead, were sentenced on June 19, 1996 by Federal Magistrate Henry Jones for a misdemeanor violation of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). The defendants had mixed furadan, a restricted use pesticide, with minnows and spread the treated minnows on a levee on the minnow farm to control nuisance birds. Saul was ordered to pay a $5,000 fine and Snead a $1,000 fine for use inconsistent with the label. The defendants are appealing the Court's judgement.

- During fiscal year 1996, *Esplin Dairy* allegedly discharged approximately 900,000 pounds per year of animal waste to a slough discharging to Nehalem Bay, Oregon. In response to an EPA order, the dairy set up a system to keep manure from contaminating clean water and installed a 10,000 gallon tank to collect wastewater before pumping it to larger containment facilities. The wastewater is high in fecal coliform bacteria, BOD, TSS, and nutrients.

- The *Four Brothers Dairy* paid a penalty of $7,350 in fiscal year 1996 for the alleged unpermitted discharge of an estimated 561,000 gallons of wastewater from its Shoshone, Idaho dairy to a canal draining to the Snake River. EPA measured fecal coliform levels as high as 180,000 colonies/100ml in the wastewater in the canal.

- *Gienger Farms, Inc.* allegedly discharged approximately 1.3 million gallons of manure-laden wastewater to drainage ditches flowing into the Tillamook Bay, Oregon, without a permit. In fiscal year 1996, in response to an EPA administrative complaint, the farm paid a $20,000 penalty and modified its operations to separate clean water from contaminated material, thereby extending the holding capacity of its wastewater storage lagoon from two to 57 days. In addition, the facility began monitoring and managing its land application practices, thus preventing the discharge of wastewater containing about 6,435 pounds of BOD and TSS to waters of the U.S.

- In fiscal year 1996, *Misty Meadow Dairy* agreed to pay a $6,000 fine for the alleged unpermitted discharge of about 685,000 pounds of manure per year to navigable waters flowing into Tillamook Bay, Oregon. The dairy is expected to sell half of its herd in order to allow more flexibility in managing waste accumulations.

- In fiscal year 1996, *Veeman Dairy* paid a $1,000 penalty for allegedly discharging 52 to 78 million gallons of wastewater to navigable waters flowing into the Willamette River, Oregon. In response to a separate compliance order, the dairy will repair and maintain its wastewater storage ponds to eliminate future discharges.

- In March 1998, a significant criminal enforcement case was taken by the California Resource Board. The U.S. District Court assessed the operator of the *3H Dairy Farm* in Oakdale, CA a $100,000 fine; $101,000 in farm improvements; 90 days in jail; 90 days of home confinement; and 4 years of probation for repeatedly violating state water pollution laws.

Regional Initiatives

According to the FY 1997 and FY 1998 *Enforcement and Compliance Assurance Accomplishments Reports*, several regions targeted their enforcement efforts on agricultural practices during these fiscal years. It should be noted that while CAFOs were the primary focus within the agriculture sector, there were other agriculture activities as well. Some of the Regional initiatives included the following:

- During FY 96, **Region 6** conducted CAFO inspections in the states of Oklahoma, Texas, and New Mexico. These resulted in the EPA issuing five Orders for non-compliance and two Administrative Penalty Orders. The State of Texas also issued penalty actions to three dairies for violation of the State permit. Region 6's emphasis on CAFOs was on the NPDES general permit and its implementation. Six EPA and 24 state CAFO inspections were conducted in FY97 to determine whether facilities were compliant with the CAFO general permit. The region continues to improve its knowledge of the numbers of facilities by the improvement of the database in all states.

- In FY 1997, **Region 7** states took 26 enforcement actions against feedlots for water quality-related violations. In FY 1998, Iowa settled 13 CAFO cases with penalties of $21,238; Kansas settled 4 CAFO cases with $77,520 in penalties; Missouri settled 12 CAFO cases with $20,256 in penalties; and Nebraska settled 2 CAFO cases with $1,700 in penalties.

- In February 1997, **Region 9** initiated a Regional Agriculture Team to complement the Agriculture Initiative team by developing a Regional Agriculture Strategy and incorporating agriculture pollution prevention principles into core agency programs.

- Through the **Region 10** CAFO Whatcom County Initiative, the Region conducted NPDES inspections at 67 targeted facilities; six were issued penalties, three were designated as significant contributors of pollutants, six were issued certificates of merit, and 52 were issued warning letters.

CAFO Compliance/Enforcement Strategies

EPA concluded a total of 93 enforcement cases against this sector in fiscal years 1997, 1998, and 1999 with a total of $163,000 in penalties. In FY 98, Regions conducted 339 compliance inspections. Each Region is working with its NPDES States to develop and implement individual state specific CAFO strategies. Regional highlights include:

- **Region 3** served as the EPA lead on the recently concluded national Poultry Dialog which included recommendations for actions by the poultry industry. Recently, in a key action growing out of the dialog, Perdue Farms Inc. agreed to help farmers dispose of chicken waste in the Delmarva peninsula region.

- **Region 6** held 5 outreach meetings in 4 states in 1998. The Region conducted 95 inspections resulting in 20 administrative orders and 2 administrative penalties.

- **Region 7** initiated a compliance tracking system to collect accurate and readily available information about state CAFO enforcement actions and penalty amounts. The Region also developed maps of CAFO locations in Iowa and Kansas by using state databases.

- **Region 9's** approach combines compliance assistance and inspections/enforcement. The Region is one of 20+ partners of the California Dairy Initiative which seeks to combine education, outreach, nutrient management plans with third party certification. In addition, the Region has developed an inspection targeting approach based on herd size and proximity to surface water. In 1998, the region conducted 133 inspections in 3 counties. The region issued 3 compliance orders and 2 penalty orders against dairy operators.

- **Region 10** expanded its compliance enforcement focus to include an additional 4 other counties in Western Washington State. The Region conducted 58 inspections resulting in 11 compliance orders/penalties; 3 compliance orders only; and 33 warning letters. Facilities found in compliance were issued courtesy letters. EPA's efforts have succeeded in raising public awareness as indicated by real-estate appraisers asking if EPA has any concerns about the facilities they are appraising.

VII. COMPLIANCE ASSURANCE ACTIVITIES AND INITIATIVES

This section highlights the activities undertaken by this industry sector and public agencies to voluntarily improve the sector's environmental performance. These activities include those independently initiated by industrial trade associations. In this section, the notebook also contains a listing and description of national and regional trade associations.

VII.A. Sector-Related Environmental Programs and Activities

There are several federal programs available to the agricultural community to assist agricultural producers in complying with environmental regulations and reducing pollution. The following examples represent some industry initiatives that promote compliance or assess methods to reduce environmental contamination.

National Agriculture Compliance Assistance Center

The U.S. Environmental Protection Agency (EPA), with the support of the Department of Agriculture (USDA), has developed a national Agriculture Compliance Assistance Center (Ag Center) to provide a base for “first-stop shopping” for the agricultural community -- one place for the development of comprehensive, easy-to-understand information about approaches to compliance that are both environmentally protective and agriculturally sound. The Ag Center, a program offered by EPA’s Office of Compliance, seeks to increase compliance by helping the agricultural community identify flexible, common sense ways to comply with the many environmental requirements that affect their business. Initial efforts will focus on providing information about EPA's requirements. The Ag Center will rely heavily on existing sources of agricultural information and established distribution mechanisms. The Ag Center is designed so growers, livestock producers, other agribusinesses, and agricultural information/education providers can access its resources easily -- through telephone, fax, mail, and Internet. The Ag Center website can be accessed at http://www.epa.gov/oeca/ag.

Unified National Strategy for Animal Feeding Operations

As part of President Clinton’s Clean Water Action Plan (CWAP), a USDA-EPA unified national strategy has been developed to minimize the water quality and public health impacts of animal feeding operations (AFOs). AFOs are agricultural enterprises where animals are kept and raised in confined situations and have been shown to contribute to significant problems in surface waters. Such problems have included nutrient loading, fish kills, and odors. AFOs are agricultural livestock facilities that confine feeding activities, concentrating livestock and their manure. There are approximately

450,000 AFOs in the U.S. Of these, 6,600 were concentrated AFOs, or CAFOs. CAFOs pose a greater environmental threat, since they confine larger numbers of animals. Less than a quarter of CAFOs have Clean Water Act permits to control the amount of wastes that run off into waterways.

The Unified National Strategy for Animal Feeding Operations presents USDA and EPA's plan for addressing the water quality and public health impacts associated with AFOs. USDA and EPA issued the final Strategy in March 1999. The USDA-EPA Unified National Strategy for Animal Feeding Operations reflects several guiding principles:

- Minimize water quality and public health impacts from AFOs.
- Focus on AFOs that represent the greatest risks to the environment and public health.
- Ensure that measures to protect the environment and public health complement the long-term sustainability of livestock production in the United States.
- Establish a national goal and environmental performance expectations for all AFOs.
- Promote, support, and provide incentives for the use of sustainable agricultural practices and systems.
- Build on the strengths of USDA, EPA, State and Tribal agencies, and other partners and make appropriate use of incentive-base approaches.
- Foster public confidence that AFOs are meeting their performance expectations and that USDA, EPA, local governments, States, and Tribes are ensuring the protection of water quality and public health.
- Coordinate activities among the USDA, EPA, and related State and Tribal agencies and other organizations that influence the management and operation of AFOs.
- Focus technical and financial assistance to support AFOs in meeting the national goal and performance expectation established in this Strategy.

USDA and EPA's goal is for AFO owners and operators to take actions to minimize water pollution from confinement facilities and land application of manure. To accomplish this goal, this Strategy is based on a national performance expectation that all AFOs should develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (CNMPs) to minimize impacts on water quality and public health.

This Strategy describes short- and long- term activities to implement and improve the existing regulatory program using a two-phased approach to permitting CAFOs. During Round I, beginning in about 2000, EPA and States will issue permits to CAFOs under the existing National Pollutant Discharge

Elimination System (NPDES) regulations. During Round II, beginning in about 2005, EPA and States will reissue NPDES permits to CAFOs based on revised effluent guidelines for feedlots, as well as revised regulations for NPDES permitting and any other new information. During Round I and Round II, State NPDES permitting authorities will have flexibility to define specific permitting approaches within their existing programs. For more information, the complete unified national strategy can be accessed at http://www.epa.gov/owm/finafost.htm.

Compliance Assurance Implementation Plan For Concentrated Animal Feeding Operations

The Office of Enforcement and Compliance Assurance (OECA) is making implementation of the existing concentrated animal feeding operation (CAFO) regulations a priority. The purpose of the implementation plan is to protect and enhance water quality by ensuring compliance with the Clean Water Act and its implementing requirements. The Plan's major elements are: 1) strong state and regional compliance/enforcement partnerships; 2) effective state specific compliance/enforcement strategies; 3) productive, coordinated compliance assistance activities; 4) strong compliance monitoring programs; 5) effective enforcement; 6) better data/information on CAFOs for targeting compliance assistance and inspections; and 7) plans for developing a feedback mechanism to EPA, states, and other federal agencies. This plan was finalized in March 1998. For more information, refer to http://es.epa.gov/oeca/strategy.html.

VII.B. EPA Programs and Activities

Section 319 Nonpoint Source Management Program

In 1987, Congress amended the Clean Water Act (CWA) to establish the §319 Nonpoint Source Management Program in recognition of the need for greater federal leadership to help focus state and local nonpoint source efforts. Under §319, states, territories, and Indian tribes receive grant money to support a wide variety of activities, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects. For more information about the Clean Water Act §319 Program refer to EPA's Office of Water website at http://www.epa.gov/OWOW/NPS/sec319.html.

Clean Lakes Program

EPA's Clean Lakes Program supports a variety of lake management activities including classification, assessment, study, and restoration of lakes. The program, authorized in §314 of the Clean Water Act, was established to provide technical and financial assistance to states/tribes for restoring the quality of publicly owned lakes. The Clean Lakes Program has funded approximately $145 million for grant activities since 1976 to address lake problems, but there have been no appropriations for the program since 1994. EPA has not requested funds for the Clean Lakes Program in recent years, but has encouraged states to use §319 funds to fund "eligible activities that might have been funded in previous years under Section 314." Information on the Clean Lakes Program is available at the following Internet site: http://www.epa.gov/owow/lakes/cllkspgm.html.

National Estuary Program
EPA's National Estuary Program is a national demonstration program, authorized in §320 of the Clean Water Act, that uses a comprehensive watershed management approach to address water quality and habitat problems in 17 estuaries. Nonpoint source pollution is a major contributor of contaminants in the estuary and coastal waters around the country. In this program, EPA and states/tribes develop conservation and management plans that recommend priority corrective actions to restore estuarine water quality, fish populations, and other designated uses of the waters. Information on the National Estuary Program is available at the following Internet site: http://www.epa.gov/owowwtr1/estuaries/nep.html or by contacting the National Estuary Program Office at (202) 260-1952.

Chesapeake Bay Program and The Great Lakes National Program
EPA's Chesapeake Bay Program and the Great Lakes National Program focus substantial resources on understanding the extent of nonpoint source pollution problems in their respective watersheds and supporting State implementation of non-point source pollution controls. Since 1984, the Chesapeake Bay Program, in particular, has supported the implementation of a substantial amount of animal waste management practices through State cost share programs funded jointly by the Bay States and EPA. Information on the Chesapeake Bay Program is available at http://www.epa.gov/owowwtr1/ecoplaces/part1/site2.html. Information on The Great Lakes National Program is available at http://www.epa.gov/glnpo/.

AgSTAR Program
The AgSTAR program is a voluntary program that promotes the use of profitable manure management systems that reduce pollution. The program, a component of President Clinton's Climate Action Plan, is based on a computer model that shows the economic value of capturing the methane naturally produced by manure.

AgSTAR, a joint program of EPA, USDA, and the Department of Energy, helps agricultural producers determine which methane recovery and use technologies will work best for them, and develops financing sources to help with start-up costs. By investing in these technologies, AgSTAR participants realize substantial returns through reduced electrical, gas, and oil bills, revenues from high quality manure by-products, and savings on manure management operational costs. Partners also reduce pollution associated with water resources, odors, and global warming. Information on AgSTAR is available at the following Internet site: http://yosemite.epa.gov/methane/home.nsf/pages/agstar.

Ruminant Livestock Efficiency Program (RLEP)

Ruminant livestock such as cattle and sheep are the largest source of methane emissions resulting from human activity. Methane, produced as part of the animals' normal digestive process, is a potent greenhouse gas that contributes to global climate change. By improving livestock production efficiency, producers can both increase profits and reduce methane emissions.

The RLEP is a joint EPA-USDA program helping livestock producers improve their operations' efficiency, preserve the nation's natural resources and reduce methane emissions. The program focuses on reducing livestock methane emissions and producing economic benefits by offering technical assistance to producers around the country. For more information, review the Program Overview at http://yosemite.epa.gov/methane/home.nsf/pages/rlep to learn how RLEP is helping improve the environment and livestock producers' profits.

Pesticide Environmental Stewardship Program

EPA's Pesticide Environmental Stewardship Program (PESP) is a voluntary program dedicated to protecting human health and preserving the environment by reducing the risks associated with pesticide use. The partnership is a key element of the program, which is sponsored by EPA, USDA, and FDA. Current partners include agricultural producers as well as non-agricultural interests. Partners in PESP volunteer to develop and implement a well designed pesticide management plan that will produce the safest and most effective way to use pesticides. In turn, EPA provides a liaison to assist the partner in developing comprehensive, achievable goals. Liaisons act as "customer service representatives" for EPA, providing the partner with access to information and personnel. EPA also promises to integrate the partners' stewardship plans into its agricultural policies and programs.

So far, agricultural producers have committed to a number of projects, including conducting more research into IPM techniques, developing computer prediction models for more precise pesticide applications, educating their members and the public regarding pesticide use, and working with

Focus on Pesticides

EPA's Endangered Species Protection Program is designed to protect Federally-listed endangered and threatened species from exposure to pesticides.

equipment manufacturers to refine application techniques. Information on PESP is available at the following Internet site: http://www.pesp.org, or contact the PESP hotline at (800) 972-7717.

Endangered Species Protection Program

The Endangered Species Protection Program (ESPP) began in 1988. This program is largely voluntary at the present time and relies on cooperation between the U.S. Fish and Wildlife Service (FWS), EPA Regions, States, and pesticide users. ESPP is intended to provide information concerning and regulation for the use of pesticides that may adversely affect the survival, reproduction and/or food supply of listed species. Due to labeling requirements, potential users will be informed prior to making a purchase that there may be local limitations on product use due to endangered species concerns. Information on the Endangered Species Protection Program is available at the following Internet site: http://www.epa.gov/oppfead1/endanger/index.htm.

Energy Star® Buildings and Green Lights® Partnership

In 1991, EPA introduced Green Lights®, a program designed for businesses and organizations to proactively combat pollution by installing energy-efficient lighting technologies in their commercial and industrial buildings. In April 1995, Green Lights® expanded into Energy Star® Buildings— a strategy that optimizes whole-building energy-efficiency opportunities. The energy needed to run commercial and industrial buildings in the United States produces 19 percent of U.S. carbon dioxide emissions, 12 percent of nitrogen oxides, and 25 percent of sulfur dioxide, at a cost of $110 billion a year. If implemented in every U.S. commercial and industrial building, the Energy Star® Buildings upgrade approach could prevent up to 35 percent of the emissions associated with these buildings and cut the nation's energy bill by up to $25 billion annually.

The more than 2,900 participants include corporations, small businesses, universities, health care facilities, nonprofit organizations, school districts, and federal and local governments. As of March 31, 1999, Energy Star®Buildings and Green Lights® Program participants are saving $775 million in energy bills with an annual savings of 31.75 kilowatt per square foot and annual cost savings of $0.47 per square foot. By joining, participants agree to upgrade 90 percent of their owned facilities with energy-efficient lighting and 50 percent of their owned facilities with whole-building upgrades, where profitable, over a seven-year period. Energy Star® participants first reduce their energy loads with the Green Lights® approach to building tune-ups, then focus on "right sizing" their heating and cooling equipment to match their new energy needs. EPA's Office of Air and Radiation is responsible for operating the Energy Star® Buildings and Green Lights® Program. (Contact: Energy Star Hotline, 1-888-STAR-YES (1-888-782-7937) or Maria Tikoff Vargas, Co-Director at (202) 564-9178 or visit the website at http://www.epa.gov/buildings.

WasteWi$e Program

The WasteWi$e Program was started in 1994 by EPA's Office of Solid Waste and Emergency Response. The program is aimed at reducing municipal solid wastes by promoting waste prevention, recycling collection, and the manufacturing and purchase of recycled products. As of 1998, the program had about 700 business, government, and institutional partners. Partners agree to identify and implement actions to reduce their solid wastes by setting waste reduction goals and providing EPA with yearly progress reports for a three-year period. EPA, in turn, provides partners with technical assistance, publications, networking opportunities, and national and regional recognition. (Contact: WasteWi$e Hotline at (800) 372-9473 or Joanne Oxley, EPA Program Manager, (703) 308-0199.)

Climate Wise Program

In October 1993, President Clinton unveiled the Climate Change Action Plan (CCAP) in honor of the United States' commitment to reducing its greenhouse gas emissions to 1990 levels by the year 2000. Climate Wise, a project jointly sponsored by the U.S. Department of Energy and EPA, is one of the projects initiated under CCAP.

Climate Wise is a partnership between government and industry that offers companies a nonregulatory approach to reducing greenhouse gas emissions. Climate Wise state and local government "allies" work with U.S. industries to develop flexible, comprehensive strategies for achieving energy efficiency and pollution prevention. They help local business identify and implement projects that often require little capital investment, but promise a high rate of return. Companies that become Climate Wise partners receive technical assistance and financing information to help them develop and implement cost-effective changes. (Contact: Climate Wise Clearinghouse at (301) 230-4736 or visit the Climate Wise website at http://www.epa.gov/climatewise/allies.htm or http://www.epa.gov/climatewise/index.htm.)

VII.C. USDA Programs and Activities

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a USDA funded program (led by Natural Resources Conservation Service) that was established in the 1996 Farm Bill to provide a voluntary conservation program for farmers and ranchers who face serious threats to soil, water, and related natural resources. EQIP embodies four of USDA's former conservation programs, including the Agricultural Conservation Program, the Water Quality

Incentives Program, the Great Plains Conservation Program, and the Colorado River Basin Salinity Control Program.

EQIP offers 5 to 10 year contracts that provide *incentive payments* and *cost-sharing* for conservation practices called for in a site-specific conservation plan that is required for all EQIP activities. *Cost-sharing* may include up to 75 percent of the costs of certain conservation practices, such as grassed waterways, filter strips, manure management facilities, capping abandoned wells, and other practices. *Incentive payments* may be made to encourage land management practices such as nutrient management, manure management, integrated pest management, irrigation water management, and wildlife habitat management. These payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the program incentive.

EQIP has an authorized budget of $1.3 billion through the year 2002. It was funded for $174 million in 1999. Total cost-share and incentive payments are limited to $10,000 per person per year and $50,000 for the length of the contract. Eligibility is limited to persons who are engaged in livestock or agricultural production. Fifty percent of the funds must be spent on livestock production. The 1996 Farm Bill prohibits owners of large confined livestock operations from being eligible for cost-share assistance for animal waste storage or treatment facilities. However, technical, educational, and financial assistance may be provided for other conservation practices on such operations. Further information relating to EQIP may be found on NRCS's website located at
http://www.nhq.nrcs.usda.gov/OPA/FB96OPA/eqipfact.html.

Conservation Reserve Program

The Conservation Reserve Program (CRP) is a highly successful conservation program administered by USDA. Since 1986, CRP has provided financial incentives to farmers and ranchers to take land out of agricultural production and plant trees, grass and other types of vegetation. The result has been reduced soil erosion, improved air and water quality and establishment of millions of acres of wildlife habitat.

With the New Conservation Reserve Program, launched with the final rule published in the Federal Register on February 19, 1997, the Farm Service Agency (FSA) begins a renewed effort to achieve the full potential of government-farmer conservation partnerships. Only the most environmentally-sensitive land, yielding the greatest environmental benefits, will be accepted into the program.

The 36.4-million-acre congressionally mandated cap on enrollments is carried over from the previous program, meaning that the new CRP has authority to enroll only about 15 percent of the eligible cropland. To make the most of the program's potential, a new Environmental Benefits Index (EBI) was developed. The new EBI will be used to select areas and acreages offering the greatest environmental benefits.

Conservation priority areas (CPAs) are regions targeted for CRP enrollment. The four national CPAs are the Long Island Sound region, the Chesapeake Bay and surrounding areas, an area adjacent to the Great Lakes, and the Prairie Pothole region. FSA State Committees may also designate up to 10 percent of a State's remaining cropland as a State Conservation Priority Area. The NRCS is responsible for determining the relative environmental benefits of each acre offered for participation.

Continuous Sign-Up. For certain high-priority conservation practices yielding highly desirable environmental benefits, producers may sign up at any time, without waiting for an announced sign-up period. Continuous sign-up allows farmers and ranchers management flexibility in implementing certain conservation practices on their cropland. These practices are specially designed to achieve significant environmental benefits, giving participants a chance to help protect and enhance wildlife habitat, improve air quality, and improve the condition of America's waterways. Unlike the general CRP program, sign-up for these special practices is open continuously. Provided certain eligibility requirements are met, acreage is automatically accepted into the program at a per-acre rental rate not to exceed the Commodity Credit Corporation's maximum payment amount, based on site-specific soil productivity and local prevailing cash-equivalent rental rates. For more information on the CRP, see USDA’s website at http://www.fsa.usda.gov/dafp/cepd/crpinfo.htm.

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program (CREP), a refinement of the CRP, is a state-federal conservation partnership program targeted to address *specific* state and nationally significant water quality, soil erosion and wildlife habitat issues related to agricultural use. The program uses financial incentives to encourage farmers and ranchers to voluntarily enroll in contracts of 10 to 15 years in duration to remove lands from agricultural production. This community-based conservation program provides a flexible design of conservation practices and financial incentives to address environmental issues. For more information about CREP, refer to USDA’s website at http://www.fsa.usda.gov/dafp/cepd/crep/crephome.htm.

Wetlands Reserve Program

Congress authorized the Wetlands Reserve Program (WRP) under the Food Security Act of 1985, as amended by the 1990 and 1996 Farm Bills. USDA’s Natural Resources Conservation Service (NRCS) administers the program in consultation with the Farm Service Agency and other Federal agencies. WRP is a voluntary program to restore wetlands. Landowners who choose to participate in WRP may sell a conservation easement or enter into a cost-share restoration agreement with USDA to restore and protect wetlands. The landowner voluntarily limits future use of the land, yet retains private ownership.

WRP offers landowners three options: *permanent easements*, *30-year easements*, and *restoration cost-share agreements* of a minimum 10-year duration. In exchange for establishing a *permanent easement*, the landowner receives payment up to the agricultural value of the land and 100 percent of the restoration costs for restoring the wetland. In exchange for the *30-year easement*, the landowner receives a payment of 75 percent of what would be provided for a permanent easement on the same site and 75 percent of the restoration cost. The *restoration cost-share agreement* is an agreement (generally for a minimum of 10 years) to re-establish degraded or lost wetland habitat, in which USDA pays the landowner 75 percent of the cost of the restoration activity. Restoration cost-share agreements establish wetland protection and restoration as the primary land use for the duration of the agreement. In all instances, landowners continue to control access to their land. For more information about WRP, see NRCS's website at: http://wl.fb-net.org.

Conservation Farm Option

The Conservation Farm Option (CFO) is a voluntary pilot program for producers of wheat, feed grains, cotton, and rice. The program purposes include conservation of soil, water, and related resources, water quality protection and improvement, wetland restoration, protection and creation, wildlife habitat development and protection, or other similar conservation purposes. Eligibility is limited to owners and producers who have contract acreage enrolled in the Agricultural Market Transition program. Participants are required to develop and implement a conservation farm plan. The plan becomes part of the CFO contract which covers a ten year period. CFO is not restricted as to what measures may be included in the conservation plan, so long as they provide environmental benefits. During the contract period the owner or producer (1) receives annual payments for implementing the CFO contract, and (2) agrees to forgo payments under the Conservation Reserve Program, the Wetlands Reserve Program, and the Environmental Quality Incentives Program in exchange for one consolidated program.

Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program (administered by NRCS) for people who want to develop and improve wildlife habitat primarily on private lands. It provides both technical assistance and cost-share payments to help establish and improve fish and wildlife habitat.

Under this program, NRCS helps participants prepare a wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner's goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the agreement. This plan may or may not be part of a larger conservation plan that addresses other resource needs such as water quality and soil erosion.

USDA and the participant enter into a cost-share agreement that generally lasts between 5 to 10 years from the date the agreement is signed. Under the agreement: the landowner agrees to install and maintain WHIP practices and allow NRCS or its agent access to monitor the effectiveness of the practices; and USDA agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices.

WHIP is currently budgeted for $50 million total through the year 2002. WHIP funds are distributed to States based on State wildlife habitat priorities, which may include wildlife habitat areas, targeted species and their habitats, and specific practices. WHIP may be implemented in cooperation with other Federal, State, or local agencies; conservation districts; or private conservation groups. For more information, see NRCS's website at http://www.nrcs.usda.gov.

Conservation of Private Grazing Land Initiative

The Conservation of Private Grazing Land initiative will ensure that technical, educational, and related assistance is provided to those who own private grazing lands. It is not a cost share program. This technical assistance will offer opportunities for better grazing and land management; protecting soil from erosive wind and water; using more energy-efficient ways to produce food and fiber; conserving water; providing habitat for wildlife; sustaining forage and grazing plants; using plants to sequester greenhouse gases and increase soil organic matter; and using grazing lands as a source of biomass energy and raw materials for industrial products.

The Wetland Conservation Provision (Swampbuster)

This provision, part of the 1985, 1990, and 1996 farm bills, requires all agriculture producers to protect wetlands on the farms they own or operate if they want to be eligible for USDA farm program benefits. The Swampbuster program generally allows the continuation of most ongoing farming practices as long as wetlands are not converted or wetland drainage increased. The program discourages farmers from altering wetlands by withholding Federal farm program benefits from any person who does the following:

- Plants an agricultural commodity on a converted wetland that was converted by drainage, dredging, leveling or any other means after December 23, 1985.
- Converts a wetland for the purpose of or to make agricultural commodity production after November 28, 1990.

In order to ensure farm program benefits under the Swampbuster provisions, the local NRCS office should be contacted before clearing, draining, or manipulating any wet areas on any farmland.

VII.D. Other Voluntary Initiatives

NICE^3

The U.S. Department of Energy sponsors a grant program called National Industrial Competitiveness through Energy, Environment, and Economics (NICE^3). The NICE^3 program provides funding to state and industry partnerships (large and small businesses) for projects demonstrating advances in energy efficiency and clean production technologies. The goal of the NICE^3 program is to demonstrate the performance and economics of innovative technologies in the U.S., leading to the commercialization of improved industrial manufacturing processes. These processes should conserve energy, reduce waste, and improve industrial cost-competitiveness. Industry applicants must submit project proposals through a state energy, pollution prevention, or business development office. Awardees receive a one-time, three-year grant of up to $400,000, representing up to 50 percent of a project's total cost. In addition, up to $25,000 is available to support the state applicant's cost share. (Contact: View the website at http//www.oit.doe.gov/Access/nice3; Steve Blazek, DOE, (303) 275-4723; or Eric Hass, DOE, (303) 275-4728.)

ISO 14000

ISO 14000 is a series of internationally-accepted standards for environmental management. The series includes standards for environmental management systems (EMS), guidelines on conducting EMS audits, standards for auditor qualifications, and standards and guidance for conducting product lifecycle analysis. Standards for auditing and EMS were adopted in September 1996, while other elements of the ISO 14000 series are currently in draft form. While regulations and levels of environmental control vary from country to country, ISO 14000 attempts to provide a common standard for environmental management. The governing body for ISO 14000 is the International Organization for Standardization (ISO), a worldwide federation of over 110 country members based in Geneva, Switzerland. The American National Standards Institute (ANSI) is the United States representative to ISO. Information on ISO is available at the following Internet site: http://www.iso.ch/welcome.html.

VII.E. Summary of Trade Associations

There are more than 200 trade associations that deal with agricultural issues. Many of these are at the national level, while others deal specifically with regions of the country or individual states. The following identify some of the major associations addressing agricultural production.

American Dairy Goat Association
Ronald E. Gelvin, Secretary Treasurer
P.O. Box 865
209 W. Main Street
Spindale, NC 28160
Telephone: 704-286-3801
Fax: 704-287-0476

American Dairy Association
10255 W. Higgins
Rosemont, IL 60018
Telephone: 847-803-2000
Fax: 847-803-2077

Washington, DC office
600 Maryland Avenue, SW
Washington, DC 20024
Telephone: 202-484-3600
Fax: 202-484-3604

American Hereford Association
Craig Huffhines,
Executive Vice President
P.O. Box 014059
Kansas City, MO 64101
Telephone: 816-842-3757
Fax: 816-842-6931

American Horse Council
James J. Hickey, Jr., President
1700 K Street, NW, # 300
Washington, DC 20006
Telephone: 202-296-4031
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[2] Many of the contacts listed above have provided valuable information and comments during the development of this document. EPA appreciates this support and acknowledges that the individuals listed do not necessarily endorse all statements made within this notebook.

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The wealth of waste

The economics of wastewater use in agriculture

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35

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Summary

REUSE AS A RESPONSE TO WATER SCARCITY

The use of reclaimed water in agriculture is an option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations and growing demand for irrigation water. This report presents an economic framework for the assessment of the use of reclaimed water in agriculture, as part of a comprehensive planning process in water resource allocation strategies to provide for a more economically efficient and sustainable water utilization. Many regions of the world are experiencing growing water stress. This arises from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts due to climatic factors. Water stress is also caused by pollution from increasing amounts of wastewater from expanding cities, much of it only partially treated, and from the contamination of aquifers from various sources. Such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use. Water scarcity in all its aspects has serious economic, social and even political costs.

At times of serious scarcity, national authorities are inclined to divert water from farmers to cities since water has a higher economic value in urban and industrial use than for most agricultural purposes. In these circumstances, the use of reclaimed water in agriculture enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water. This exchange also has potential environmental benefits, reducing the pollution of wastewater downstream and allowing the assimilation of its nutrients into plants. Recycling water can potentially offer a "triple dividend" - to urban users, farmers and the environment.

Reclaimed water use can help to mitigate the damaging effects of local water scarcity. It is not the only option for bringing supply and demand into a better balance – and this report shows how different options can be analysed for comparison – but in many cases it is a cost effective solution, as the growing number of reuse schemes in different parts of the world testify. A recent comprehensive survey found over 3,300 water reclamation facilities worldwide. Agriculture is the predominant user of reclaimed water, and its use for this purpose has been reported in around 50 countries, on 10% of all irrigated land.

BENEFITS OF REUSE

The feasibility of reuse will depend on local circumstances, which will affect the balance of costs and benefits. The major benefit in most cases is likely to be the value of the fresh water exchanged for high-value urban or industrial use. This would lessen the cost for municipal authorities of seeking their supplies through more expensive means. In addition, reuse prevents untreated wastewater discharge to coastal and groundwater systems with ecosystem and tourism benefits.

Depending on the local situation, there could also be benefits to farmers if they can avoid some of the costs of pumping groundwater, while the nutrient present in the wastewater could save some of the expense of fertilizer. There could also be benefits to the local environment from reduced flows of untreated wastewater – though the interruption in the downstream water cycle could have other, less beneficial, effects.

The costs and benefits of reuse projects

The costs of the reuse option could include the installation or upgrade of wastewater treatment plants (WWTPs) to produce effluent of the desired standard, any addition or modification to the infrastructure for water and reclaimed water distribution, the extra recurrent costs of treatment, and the cost of any produce restrictions imposed by the use of reclaimed water in irrigation. Where climatic and geographical features are suitable, low-cost treatment of wastewater may be an option through the use of stabilisation ponds, constructed wetlands, etc. The net cost of treatment may also be reduced through the reuse of biogas for energy and power in the intensive treatment processes, or potentially through the sale of carbon offsets.

ECONOMIC JUSTIFICATION

The economic appraisal of the project should be from a regional basin viewpoint, comparing its economic costs and benefits. Judging by the evidence of our case studies, it is unlikely that schemes could be economically justified with reference only to agriculture. Although farmers may be net beneficiaries from using treated wastewater, compared with their previous or alternative sources of water, this depends very much on local circumstances, and in any event their net benefits are unlikely to offset the full costs of the scheme. On the other hand, the benefits to urban and industrial users could be relatively sizeable, and in most cases would be the principal justification for the project. The net impact of the project on the local and downstream environment will also be very site-specific, and there are likely to be both benefits and costs.

FINANCIAL FEASIBILITY

Once the basic economic justification of the project is established, the next step is to examine its financial feasibility. The distribution of the costs and benefits of the project between different stakeholders is crucial to its feasibility. Its impact on the finances of the various stakeholders – national government, regional water authority, farmers, municipal utility and/or other major players – should be assessed. Financial gainers and payers should be identified to gauge the incentives, or conversely the penalties, to be applied and the type of funding that would be appropriate. Water charges, taxes, subsidies, soft loans, environmental service payments, and other instruments could all form part of the financing proposals.

A PLANNING FRAMEWORK

The economic framework for wastewater reuse presented in chapters 3 and 4 is intended to fit within a comprehensive planning framework. A sound and methodical planning approach will assist in identifying all the relevant factors necessary for the decision to proceed with a project. Chapter 5 presents such a planning framework, its key elements being: identification of problem and project objectives; definition of study area and background information; market assessment and market assurances; identification of project alternatives; appraisal and ranking of project alternatives; and implementation. Among the major specific technical issues to be addressed are: facilities and infrastructure, balancing supply and demand, wastewater quality, and public health risks and safeguards.

FACTORS ESSENTIAL FOR THE SUCCESS OF REUSE PROJECTS

The feasibility of reuse projects hinges on several key factors. The physical and geographical features of the area should be conducive to an exchange of water rights between the parties concerned. The extra costs (of treatment and infrastructure) should be affordable in relation to benefits. Farmers should be supportive, which depends on the net impact on their incomes, the status of their rights to freshwater, and what are their alternatives. Public health authorities should be satisfied that the projects pose no undue risks, after reasonable precautions have been taken. Finally, the environmental impact should be acceptable: the same impact may be acceptable or not in different circumstances, and different authorities will place a different weight on specific impacts in forming an overall judgement.[1]

A REALITY CHECK – CASE STUDIES FROM SPAIN AND MEXICO

On a global scale, only a small proportion of treated wastewater is currently used for agriculture, but the practice is growing in many countries, and in some regions a high proportion of reclaimed water is used in irrigation. The variety of case material presented from Spain and Mexico provides a good field testing for the approach presented in Chapter 3 on *Methodologies of Cost-Benefit and Cost-Effective Analyses*. Chapter 4 on case study results demonstrates that the methodology presented for appraising wastewater reuse projects is viable. Although the *Cost-Benefit Analysis* analytical framework is well able to incorporate the interests of municipalities and farmers, there is an important third party at the table – the environment – which needs a champion and a custodian. Reflecting the needs of the environment, valuing its assets and services, and ensuring that its financing needs are met, is a challenge to analysts in this area. The case studies confirm that reuse is an area ripe for the application and refinement of the tools of environmental cost-benefit analysis.

The case material demonstrates that certain items of costs and benefits are more robust than others. On the cost side, the capital costs of treatment units, pumps and canals can be estimated with high confidence, and their operating costs (pumping, chemicals, labour, etc.) are also fairly evident. The technology of wastewater treatment and its future level of unit costs are liable to change, and future options should not be prematurely foreclosed.

Most of the case studies stress the perceived benefits to farmers from the nutrient properties of effluent, plus savings in groundwater pumping and the greater reliability of effluent compared with other sources of water in arid and semi-arid climates. While pumping costs are reasonably firm, the benefits of fertilization depend on local empirical evidence ("with and without project"). The value of *reliable* wastewater also needs to be demonstrated more convincingly, *e.g.*, by a closer study of farmers' response behaviour where water supply is erratic or scarce.

From the viewpoint of urban water demand, the case studies reflect the widespread view that water supply tariffs are too low, hence there is a pervasive underestimation of the benefits created by developing new solutions to growing demand. However, some of the cases illustrate the importance (stressed in chapter 3) of distinguishing genuinely new benefits, on the one hand, from the avoided costs of meeting existing demand in a different way.

The analysis of the case studies has implications for policy towards the use of reclaimed water, depending on what its principal objectives are:

- *as a feasible and cost-effective means of meeting the growing demands of agriculture for water in regions of growing water scarcity and competition for its use.* This motive also applies in situations where demand is not necessarily rising, but where periodic water scarcity is a problem for farmers planning their annual crop patterns. The case studies contain evidence (*revealed preferences*) of farmers responding positively to the use of effluent in these situations, as

[1] Local environmental policy (pollution taxes, payments for environmental services, incentives for the recovery of heat from biogas, etc.) could tilt the balance in favour of reuse schemes.

a temporary expedient or long term solution. However, effluent reuse is one amongst a number of options at farm level to minimizing exposure to water risk. Moreover, the creation of expensive distribution and storage facilities, with a high recurrent cost, in order to furnish water for low value farm purposes, is not always warranted – unless there are benefits to other sectors.

- *as an environmental solution to the growing volume of wastewater effluent and its potential for downstream pollution*. The Mexico City-Tula case is the clearest example of the mutual benefit for the City and farmers from disposing of urban sewage and effluent to agriculture – and allowing natural processes to carry out some of the purification *en route*. Reuse schemes allow the dispersion of effluent and its assimilation across a wide area, as compared to the *point source pollution* from WWTPs. The reuse of effluent nutrients in crop production, rather than their removal and effective destruction during advanced processes of wastewater treatment also has a strong appeal to many Greens. The case studies confirm these environmental benefits of using reclaimed water.
- *as a "win-win" project that is a solution to urban water demand, while also delivering the agricultural and environmental benefits stated above*. The Llobregat sites and Durango City are clear-cut examples of potential win-win propositions since in both cases it is physically and geographically feasible for farmers to exchange their current entitlements to freshwater for effluent, and for the cities to gain access to the freshwater rights that are thus "released."

Whether or not "win-win" outcomes occur depends on legal and other barriers being overcome, as well as successful negotiation over the financial arrangements between the parties to the deal. It must not be assumed that farmers will readily give up their rights to freshwater, without further consideration of their operational situations. Most farmers prefer to have several water sources as insurance against drought. A cost-benefit approach helps to set the parameters for agreements between the main stakeholders, which in this report are assumed to be farmers, cities and the natural environment. It helps to define the interests of the parties in moving towards, or resisting, agreements that change the *status quo.* Where the balance between costs and benefits for one party (*e.g.* farmers) is very fine, the existence of a large potential net benefit to another (*e.g.* city or environment) can provide "headroom" for agreement by indicating the economic or financial bounty available to lubricate the deal.

The overall message the report seeks to convey is that the recycling of urban wastewater is a key link in Integrated Water Resource Management (IWRM) that can fulfill several different, but interrelated objectives. These are expressed as *win-win* propositions, delivering simultaneous benefits to farmers, cities and natural environmental systems, part of the solutions to the urgent global problems of food, clean water, the safe disposal of wastes and the protection of vital aquatic ecosystems. The traditional "linear society" is not a sustainable solution and the "circular society" has to become the new standard.

The annex to the report contains an extensive bibliography, testimony to the large and growing interest amongst the professional and policy communities in this important topic.

List of Acronyms

ACA	Catalonian Water Agency
BAT	Best Available Technology
BCR	Benefit-Cost Ratio
BOD	Biological Oxygen Demand
BOT	Build Operate Transfer
CBA	Cost-Benefit Analysis
CEA	Cost-Effective Analysis
CRF	Capital Recovery Factor
DALY	Disability Adjusted Life Years
DBOT	Design Build Operate Transfer
EA	Economic Appraisal
EDR	Electrodialysis Reversal
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FYRR	First Year Rate of Return
HACCP	Hazard Analysis and Critical Control Points
IRR	Internal Rate of Return
IWRM	Integrated Water Resources Management
MCA	Multi-Criteria Analysis
NDMA	N -nitroso-dimethyamine
NPV	Net Present Value
OC	Opportunity Cost
PES	Payment for Environmental Services
QALY	Quality Adjusted Life Years
QMRA	Quantitative Microbial Risk Analysis
SEEAW	System of Environmental-Economic Accounting for Water
STP	Social Time Presence
WFD	Water Framework Directive
WHO	World Health Organization
WTP	Willingness to Pay
WWTP	Wastewater Treatment Plant

Chapter 1
Introduction to wastewater reuse

1.1 BACKGROUND, CONTEXT AND KEY ISSUES

The reuse of treated wastewater in agriculture is an option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations and growing demand for irrigation water. Many regions of the world are experiencing growing water stress. This arises from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts. Climate change is adding to these pressures: it is estimated that a global warming of 2 degrees Celsius could lead to a situation where 1 to 2 billion more people may no longer have enough water to meet their consumption, hygiene and food needs.

Water stress is also caused by pollution from the growth of wastewater and run-off from expanding cities, much of it only partially treated, from the release of agricultural fertilizer, and from the contamination of aquifers from various sources. This pollution causes eutrophication of surface water, one result of which is the formation of algal blooms, such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use by humans. The same factors are causing hypoxia (oxygen depletion) in estuaries and coastal waters, causing harm to fisheries and other aquatic life and negatively impacting ecosystem integrity. This is concern both to the environment and to local economies dependent on tourism and fisheries.

Water scarcity has heavy economic, social and political costs. The drought in Kenya in 1998-2000 is estimated to have reduced GDP by 16% over this period, falling with particular severity on industrial output, hydropower, agriculture and livestock. The cost of mitigating water crises is currently entailing huge sums in regions as diverse as California, Northern China and Australia.

At times of serious scarcity, national authorities are inclined to divert water from farmers to cities since water has a higher economic value in urban and industrial uses than for most agricultural purposes. In these circumstances, the reuse of treated wastewater for agriculture enables freshwater to be exchanged for more economically and socially valuable purposes, whilst providing farmers with reliable and nutrient-rich water. This exchange also has potential environmental benefits, reducing the release of wastewater effluent downstream, and allowing the assimilation of its nutrients into the soil.

Wastewater reuse projects can therefore offer a potential double or even triple "dividend" - to urban users, farmers and the environment. In typical situations of growing water stress the use of reclaimed water must be considered as an available option. In such cases the "without project" scenario will incur costs that will grow over time, and alternative solutions have serious costs of their own. To reject the reuse option could be costly in such situations.

1.2 PURPOSE OF THE REPORT

Agriculture accounts for around 70% of global water use, mainly in the growth of crops for food and raw materials and for processing agricultural products. When rainfall is insufficient to sustain crops, irrigation is necessary and adds to the cost of agricultural operations.

The lack of natural water resources from aquifers, rivers, and lakes has led to the growing recycling of domestic and municipal wastewater (both treated and untreated) for irrigation. Recycling water[1] for this purpose raises issues of water quality, the health of the general public and farm workers, public acceptability, the marketability of crops, and how such projects can be financed, amongst other matters. Some of these issues also arise with the use of freshwater, while others apply with special emphasis, or specifically, to the use of recycled water. There is a large literature on water resource economics, dealing with the role of water in economic development and the evaluation of alternatives to serve various water needs. The development of the agriculture sector has been the most important and initial phase in the economic development and well-being of many countries, and agriculture remains as a key to food security and growth in much of the world.

Although guidance is available on the economics of water resources in agriculture (Gittinger, 1982; Turner et al., 2004), there is an unfulfilled need for guidance on the specific issues arising in the use of recycled water. This report is an attempt to fill this gap. Recycling includes both untreated and treated wastewater. While the economic concepts discussed in this report are applicable to untreated (raw) and treated (reclaimed) wastewater and to many types of reuse, the main focus of this report is on the use of reclaimed water from community sewerage systems for irrigated agriculture.

This report addresses the economic and financial issues and the methodology and procedures involved in the analysis of water recycling projects. The issue is dealt with in the wider context of water resources and covers human health, water quality, acceptability, institutional constraints, and other factors, all of which have economic implications and affect the feasibility of reuse schemes.

The current chapter provides a contextual background. Chapter 2 introduces the case material, drawn from regions of Spain and Mexico. Chapter 3 contains the methodology proposed for the economic analysis of projects, together with the procedure for determining its financial feasibility. Chapter 4 applies this methodology to the analysis of the case studies. Finally, chapter 5 proposes a broader planning framework into which the economic and financial analyses can fit. Chapter 6 draws some conclusions from the report that are relevant to policy makers and professionals working on this topic.

1.3 THE GLOBAL CONTEXT

Earth contains an estimated 1 351 million cubic km of water. Only 0.003 percent of this is classified as fresh water resources, that is, water that can be a source for drinking, hygiene, agriculture, and industry. Most fresh water is remote from civilization or too difficult to capture for use. The Food and Agriculture Organization of the United Nations (FAO) estimates that only about 9 000 to 14 000 km^3 are economically available for human use each year (FAOWATER, 2008).

The world's population is growing at a rate of about 1.2 percent per annum and is expected to grow by two billion by 2030. Providing adequate water for all these people will be a major challenge. Water is essential not only for direct human consumption and household purposes, but also for producing the food and manufactured goods necessary for life and improved standards of living. The common needs for water fall into the following categories:

- drinking water
- agriculture

[1] In this report, wastewater treated to a level allowing for its beneficial reuse (normally tertiary) is referred to as *reclaimed water*. Otherwise, it is referred to as *wastewater,* which includes both raw sewage and wastewater treated to lesser levels.. *Recycled wate*r includes both reclaimed water and wastewater in the above senses. See the Glossary for these and other definitions.

- personal hygiene and public sanitation
- domestic uses (food preparation, cleaning, outdoor uses)
- commerce and services
- industry
- recreation and tourism
- commercial fisheries, and
- environmental and ecological maintenance, conservation and protection.

Many countries struggle to meet current water needs for basic sustenance and sanitation. The problem is compounded by increasing standards of living which increase the per capita use of water.

Converting from rainfed to irrigated agriculture can increase yields of most crops by 100 to 400 percent and can permit the growth of different crops with higher income value. Humid-climate species can be grown in arid areas. Shifting away from rainfed agriculture often means that water must be available at unnatural times and locations, requiring infrastructure energy and labour. Even relying on groundwater directly beneath farms is becoming a problem as water tables fall. Because irrigation leaves salts behind in the soil, the rate of water application may have to be increased over time to counter salinization, though in many places rainfall can achieve this function. Compared to the daily drinking water requirement of 2 to 4 litres per person, producing a day's food requirement takes 2 000 to 5 000 litres of water per head. As a result, agriculture is by far the largest user of water, accounting for almost 70 percent of all withdrawals - up to 95 percent in developing countries - and demand is increasing (FAOWATER, 2008).

Improvements in lifestyle and the use of labour-saving devices also demand more water. Some examples are:

- community sewerage systems and toilets using water for the conveyance and disposal of human waste;
- household appliances such as dishwashers and garbage grinders;
- domestic hot water devices increasing the use of water for bathing;
- gardening and residential landscaping;
- leisure activities such as golf courses and aquatic parks;
- urban greenery for local amenity;
- increased consumption of manufactured goods;
- dietary changes involving higher consumption of foodstuffs with greater water requirements and;
- tourism and recreation increase with incomes, and many of these activities are water-intensive.

Meeting these water demands has often come with great environmental cost. In a well-known example, the Aral Sea has lost 85 percent of its inflow due to irrigated cotton production on its main feeder rivers. The fall in level by 16 metres between 1981 and 1990 has led to the disappearance of 20 of its 24 species of fish, the loss of almost the entire fish catch, and the creation of toxic dust-salt from the dry seabed, killing crops on nearby farmland (FAOWATER, 2008). This tragic episode illustrates the claim of the natural environment as a legitimate user of water.

Scarcity, stress and competition

Climate change is likely to aggravate the scarcity of water that is being driven by other basic forces. On one authoritative view, global warming of 2 ° C would lead to a situation where "between 100 million and 400 million more people could be at risk of hunger, and 1 to 2 billion more people may no longer have enough water to meet their consumption, hygiene and food needs" (World Bank, 2009).

The heavy economic cost of water scarcity is illustrated by estimates of the impact on Kenya's GDP of the *La Niña* drought of 1998-2000. Overall, this reduced GDP by 16% over this period, the reductions falling with particular severity on industrial production (58%), hydropower (26%), agriculture (10%) and livestock output (6%) (World Bank, 2004).

There are many other partial estimations of the high costs of water scarcity (Orr, 2009):

- The cost of water crisis management in California is estimated to be US$1.6 billion annually by 2020.
- The emergency overhaul of Australia's water supply regime, triggered by the 2007 drought but resulting from a longer period of imbalance between supply and demand, is expected to cost US$ 10 billion.
- In China the scheme to channel billions of cubic meters of water from the Yangtze River to farmers along the dwindling Yellow River involves massive outlays, not yet fully estimated.
- Libya's Man-Made River project to pump 730 million m^3 annually from below the Sahara Desert to coastal water users costs US$ 25 billion each year.

The natural environment, a silent water stakeholder, is bearing much of the water stress, which will rebound at some stage on the supply of water for human needs. In the Australian Murray-Darling basin, 30% of the normal river flow is needed for environmental purposes, yet irrigated farming takes 80% of the available water. Recently, practically no water from the Murray-Darling River has reached the sea. In China 25% of the flow of the Yellow River is needed to maintain the environment, yet less than 10% is actually available after human withdrawal. In 1997 the River was dry up to 600 km inland for 226 days (World Economic Forum, 2009).

Several indicators have been developed to measure the relative scarcity of water (Kumar and Singh, 2005; Falkenmark and Widstrand, 1992). A summary of two common indices is shown in Table 1.1. The Water Scarcity Index, based on per capita availability of renewable fresh surface water and groundwater, represents the potential usable water per person without regard for existing water infrastructure or economic usage. The Water Intensity Use Index expresses the amount of surface water and groundwater withdrawals as a percentage of internal actual renewable water resources available for a region. The distribution of these indices by country is illustrated in Figures 1.1 and 1.2. As of 1995, about 41 percent of the world's population, or 2 300 million people, lived in river basins under water stress (that is, having a Water Scarcity Index below 1 700 m^3/capita·year) (EarthTrends, 2001).

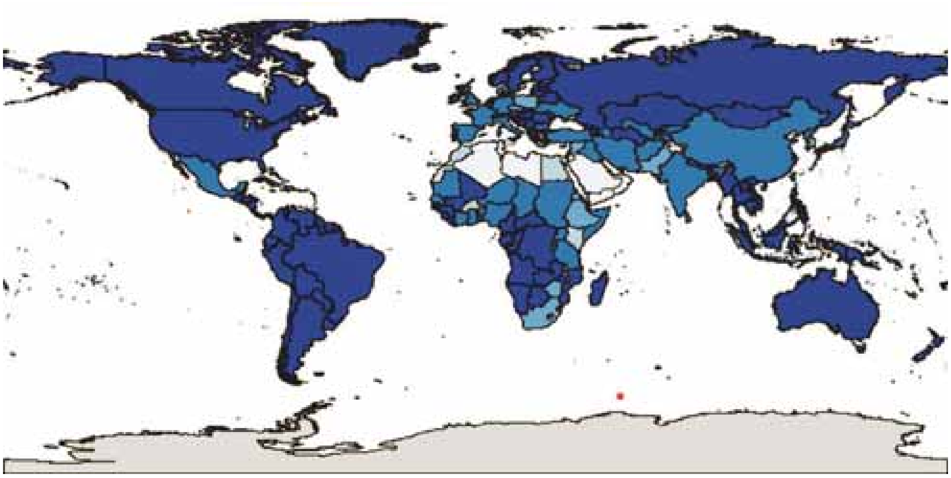
TABLE 1.1
Threshold values used to characterise water stress within a region

Characteristic	Threshold	Situation
Water Scarcity Index, m^3/ capita·yr		
Water stress	<1 700	The region begins to experience water stress and the economy or human health may be harmed
Chronic water scarcity	<1 000	The region experiences frequent water supply problems, both short and long-term
Absolute water stress	<500	The region completes its water supply by desalting seawater, over-exploiting aquifers or performing unplanned water reuse
Minimum survival level	<100	Water supply for domestic and commercial uses is compromised, since the total availability is not enough to fulfil demand for all uses (municipal, agricultural and industrial)
Water Intensity Use Index		
Water stress	>20%	The region is experiencing severe water supply problems that are addressed by reusing wastewater (planned or not), over-exploiting aquifers (by 2-30 times), or desalinating seawater

Source: Adapted from Jiménez and Asano (2008b)

Even within countries with apparently abundant water, there are regions of scarcity or regions without the infrastructure to gain access to the available water resources. Areas of water withdrawals approaching or exceeding sustainable limits, for example, 75 percent or more of renewable water resources, are described as areas of *physical water scarcity*. On the other hand, *economic water scarcity* can occur where water resources are abundant, but deficiencies in human, institutional, or financial capital limit the access to it.

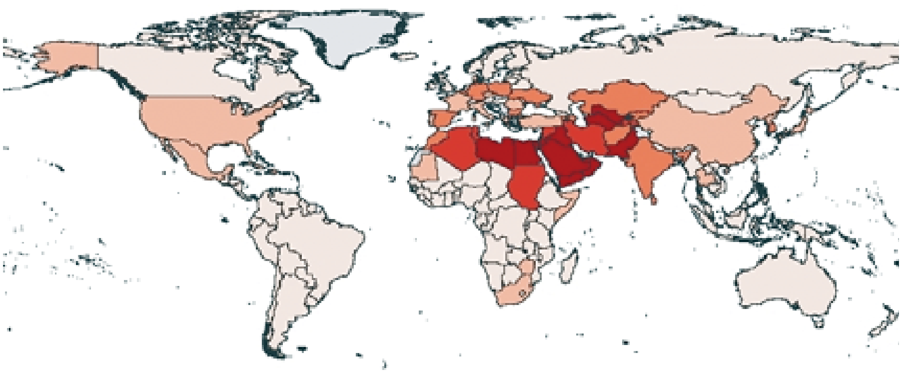
FIGURE 1.1
Actual renewable water and groundwater resources per inhabitant in 2005 (m³/year)



No data | Less than 500 | 500-1000
1000-1700 | 1700-5000 | Greater than 5000

Source: Food and Agricultural Organizatin of the United Nations (2008)

FIGURE 1.2
Water intensity use index by country (around 2001)



Legend
No data | <10 | 10-25 | 25-50 | 50-75 | > 75%

Source: Food and Agricultural Organizatin of the United Nations (2008)

As water demands approach the limits of available resources, or the capacity of existing systems for water supply, competition between water sectors can arise. Urban areas with a sizeable industrial base often have greater economic capacity or political power to fund the infrastructure to develop new water supplies or reallocate existing supplies from agricultural to urban areas. In the competition for water, human needs often prevail over aquatic needs to sustain ecosystems and fisheries. Some of the factors or impacts related to water use sectors are summarised in Table 1.2.

Competition for water resources is often at the expense of agriculture and the traditional economies dependent on it. Water traditionally has been considered a common public good. Without government controls however, this public good can be abused and access to water lost to sectors with political and economic power. Upstream users can both diminish and pollute the water reaching downstream users.

In addition to social inequities, civil and even physical conflict can result from the competition for water. Where there is no established legal framework, or where this is violated, conflicts can result within regions or even between nations when one entity extracts water to the detriment of another (Trondalen, 2004; McCann, 2005; Tamas, 2003). Some legal systems establish priorities in the rights to use water, often giving domestic and urban use a higher priority than industrial or agricultural use. Thus, it

TABLE 1.2

Competition for conventional water resources in agricultural areas

Location	User sector	Potential competitive factors and impacts
Areas with arid or semiarid climate conditions	Agriculture	Optimal temperatures for crops but irrigation necessary to sustain agriculture; over-extraction or illegal extraction of water, especially for high-revenue agriculture
	Industry	Economic advantage over agriculture to purchase needed water, may pollute water resources
	Urban/domestic	Bad water quality and scarcity of water, especially in the lowest part of basins
Industrial areas	Agriculture	Tends to be marginal because industrial jobs are better paid and agriculture is often a secondary occupation, though with exceptions, such as where the agrofood industry is important
	Industry	Has economic or political priority in obtaining water it needs
	Urban/domestic	Usually in exponential growth as jobs congregate around industry; has economic or political leverage in getting water, increased pressure on existing water resources
Coastline	Agriculture in hot climates	Vulnerable, unless protected; uncompetitive for jobs and water
	Leisure activities/tourism in hot climates	Increasing uses of water for people and activities (e.g., golf or water parks)
	Industry	Growth in areas of good transportation infrastructure (harbours, motorways, railways)
Small islands in arid and semiarid climates (e.g., Mediterranean)	Agriculture	Uncompetitive against tourism for jobs or water
	Leisure activities/tourism	High revenue activity, economically dominant for jobs, water and land
River basins	Ecosystems	Damaged without regulatory protection due to reduced flows from human activities
	Urban	Economic and political advantage to obtain needed water (even overexploiting water in a non-sustainable way)
	Agriculture/livestock	Source of water pollution
	Industry	Water demands are usually not consumptive, temperature pollution from discharges by power generation facilities; source of persistent organic chemicals
Groundwater dominant regions	All sectors	Frequently groundwater overdraft, seawater intrusion and contamination
	Agriculture	Soil permeability reduced
	Urban	Reduced natural recharge due to impermeable surfaces

Source: Author's compilation

may be legal for one sector to deprive another sector of its traditional water supply. It is common, for example, for municipal and agricultural uses to be at the expense of the conservation and preservation of natural systems (streams, wetlands, groundwater and associated ecosystems).

The relationship between available water resources and their utilization can be established using the water scarcity index (Smakhtin et al., 2004; Kumar and Singh, 2005). When this index signals potential water scarcity, the country concerned would need to take measures to alleviate the situation, involving either or both of demand management and supply augmentation. The resources to be developed could be conventional (surface or groundwater) or non-conventional. Increasingly, the development of new conventional resources is not feasible on grounds of cost, or faces opposition from conservationists or others who prefer the *status quo.* On the other hand, some non-conventional resources are also questionable on grounds of sustainability problems (*e.g.* desalination in terms of brine disposal and high energy costs). Problems such as these increase the relative attractiveness of reclaimed water, though this has problems of its own. Environmentalists are concerned that reuse in the upper part of basins can reduce the availability of water for ecosystems further downstream. There are also public health risks from the use of reclaimed water, and its prolonged use could impact soil salinity depending on treatment level, though it may also enhance soil fertility and organic matter content. However, there are ways of mitigating any harmful impact on agriculture, *e.g.* using good quality water in the initial growing period and poorer quality water later - this practice can even increase the quality of certain fruits (Oron, 1987; Hamdy, 2004).

Communities reliant on direct precipitation and natural surface water supplies are at the mercy of the availability of these supplies over time and space. They are also susceptible to flooding and drought. Groundwater is less affected by short term weather conditions but is vulnerable to long-term overdraft, resulting in increased pumping costs, salinization from seawater intrusion and long residence time in contact with minerals, and subsidence.

The growth of urbanization and irrigated agriculture weakens the bond between naturally available water supplies and the timing and geography of demands. This has necessitated an infrastructure of canals or pipes to transport water and dams to capture river flows for later release when the demands occur. In developing countries the costs of such infrastructure can be prohibitive. In developed countries, the most cost-effective locations of dams and other schemes of water development have already been taken. Further water development not only is more costly but also competes with the needs for environmental protection of water quality, fisheries, and wetlands. In some cases, limitations have been placed on historic extractions of ground and surface waters to prevent further environmental damage or to restore the sustainable yield of groundwater.

As the development of conventional surface and ground water resources become increasingly expensive and difficult, the use of nonconventional resources or demand management are receiving increasing attention. One such source, seawater desalination, remains a relatively expensive option for irrigated agriculture despite progress in membrane technology. Achieving more efficient water use amongst urban and agricultural users through the various forms of *demand management* has great potential and remains one of the lowest cost alternatives to align supply and demand. The use of better technology to reduce leaks in urban water distribution networks and localized irrigation can also improve the Water Intensity Use Index.

To characterise reclaimed water use as “nonconventional” is not to imply that wastewater is uncommon or unproven as an effective water supply source. Domestic wastewater has been used for centuries in agriculture, and the use of *treated* wastewater is at least a century old. Its nonconventional status reflects the fact that it is only in the last 30 years that the use of reclaimed water has become prominent in water resources planning. With adequate treatment, wastewater is suitable for many urban, industrial and agricultural uses. Though still not approved in many countries, reclaimed water is used for drinking in some locations, such as Namibia (Lahnsteiner and Lempert, 2007).

1.4 THE CASE FOR REUSING WASTEWATER

Reusing wastewater is an important option for Integrated Water Resources Management (IWRM) which is concerned with managing all aspects of the water cycle, and with optimizing the use of water in all its aspects. The World Summit on Sustainable Development in 2002 called for all countries to develop IWRM and water efficiency plans. This approach includes the following elements, amongst others:

- assessment of water needs in collaboration with end users;
- examination of all the water sources available; and
- matching water supplies to needs based on the quantity, quality and reliability required for the various purposes and the costs of supply relative to the benefits in each case.

The reclamation of wastewater and its reuse in agriculture is gaining wider acceptance in many parts of the world. In many water-scarce countries, wastewater has become important in bridging the demand and supply of water in different uses. The drivers of wastewater reuse are somewhat different in developed and developing countries, but there are common problems of increasing population and food demand, water shortages, and concern about environmental pollution. All these forces make reclaimed water a potentially valuable resource.

Water reuse does, however, entail changes in the traditional frameworks for water allocation, funding structures, fixing of water-quality standards, regulatory frameworks, and institutional mandates. It involves good governance at all levels in order to develop a holistic approach and sets of consistent policies for water allocation meeting multiple user needs.

Economic values of water in different uses

Fundamental to reuse is the insight that water is an *economic good*, as recognised in the Dublin Statement on Water and Sustainable Development of 1992: "Water has an economic value in all its competing uses and should be recognised as an economic good." A distinction needs to be made between the *value, cost and price* of water, which are often very different from each other. The economic *value* of water is particularly apparent in situations of water scarcity. Water has different economic values in its different uses. It has an economic *cost* of supply, which also varies in different situations and for different purposes. Water provided to a particular user, in a specific place, at a certain time has an economic benefit, but also entails an economic cost. The relationship between the specific benefit and the specific cost is the basis of the *economic* justification for supplying that user. Finally, the *price* of water is a financial or fiscal transaction between the provider and the user, which is often closely controlled by public authorities, and often bears little relation either to its value in specific uses, nor its cost of supply.

Allocating water purely on the basis of such economic principles is complicated, and difficult to apply in practice (Turner, 2004; Winpenny, 1997). However, the basic concept of comparing the costs and benefits of supplying water in specific locations and to specific categories of users is fundamental to wastewater reuse projects, and this requires some estimation – however rough – of the benefits of the water to the potential users.

The methods of valuing water are eclectic, and depend on the sector concerned, the type of use, and the information available.

- *Household* consumption is commonly valued using Willingness To Pay (WTP) evidence from direct surveys using structured questionnaires or various kinds of "choice experiments". This "stated value" approach can be supplemented and cross-checked by "revealed preference" evidence, such as inferring users' preferences from their changes in consumption following a tariff change or by estimating what they are actually spending at present.
- *Irrigation* water use can be valued in either of two different ways. The marginal productivity of water (the extra value of output that can be obtained from additional applications of water) can be estimated from changes in yields during crop-water trials. Alternatively, the more common approach (the "net-back" method) is to derive the value of water as the residual from farm budget data, after all other costs have been allowed for. This latter method makes the crude assumption that all the residual, or unexplained, farm surplus is due to water, rather than to other factors.
- Industrial water use valuation poses a greater problem. For most industrial (and commercial) enterprises, water is a tiny part of their total costs. It would therefore be misleading to use the "residual method" as in irrigation, and attribute the whole residual surplus to water. Much industrial bulk water is self-supplied from wells and rivers. Many firms recycle water by treating and reusing waste flows. One valuation device is to regard the cost of recycling as the upper limit on industrial willingness-to-pay, since above this level firms would rationally recycle rather than buy in. A crude short-cut to industrial water valuation is to estimate ratios of gross output or value-added to the volume of water involved in different processes. Whilst these ratios can signal the water-intensity of different industrial sectors, they do not indicate the real productivity of water.

The above uses all involve the abstraction of water.

- Water also has *in-stream values* for waste assimilation and dilution, flushing sediment, the functioning of ecological systems, navigation, and various kinds of recreation (fishing, water sports, sight-seeing, rambling, etc.). There are various valuation options. Often, these natural functions of water (assimilation, dilution, flushing) can be compared with the extra cost of alternatives (dredging, treatment). The value of water for navigation can be imputed from its cost advantage over the next cheapest transport mode (e.g. railways). The value of water for recreation and ecological purposes (the maintenance of low flow regimes and wetlands) is generally estimated by WTP or travel cost[2] surveys. It is increasingly common to use the benefit transfer approach to derive empirical values for these environmental effects – as the term suggests, evidence is transferred from situations where it is available to locations and projects which seem to be broadly comparable[3].
- *Hydropowe*r water usage is normally valued according to the cost advantage of hydro over thermal and other alternative ways of generating electricity. In this, as in other cases, it is important to compare like with like, and to be clear about the basis of the estimate[4].

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[2] The travel cost valuation method infers the valuation that visitors place on a free amenity from the amount of time and expense they incur in getting to the site.

[3] A database exists of such studies (www.evri.ca), and a number of results are reviewed in van Beukering *et al.* (1998) and Turner et al. 2004.

[4] If a *short term* approach is taken, capacity is assumed to be fixed for both alternatives to be compared. In the *long term*, new investment can be made in either. Marginal and average costs will also differ, for both alternatives.

TABLE 1.3
Values of water use in the USA, by sector

1994 US$ acre/foot of water

Sector/Use	Average	Minimum	Maximum
In situ			
Waste disposal	3	0	12
Recreational/habitat	48	0	2 642
Navigation	146	0	483
Hydropower	25	1	113
Withdrawal			
Irrigation	75	0	1 228
Industrial	282	28	802
Thermal power	34	9	63
Domestic	194	37	573

Source: quoted in Turner *et. al.* 2004

There have been several comprehensive studies of the economic values of water in different uses, and a number of more selective exercises. One of the earliest was done for the US National Water Commission in 1972, a subsequent one in 1986 at Resources for the Future, and another, also for the Resources for the Future , in 1997. These all use data from the USA, but more selective studies from other regions broadly endorse their results. Table 1.3 indicates the results of a comparative study.

The sectors of most concern for the current report are agriculture, households, irrigation and the various facets of the environment. The evidence presented here is that the value of water for *agricultural irrigation* of many low-value crops (typically food grains and animal fodder) is very low. By the same token, water values can be high for high-value crops (*e.g.* fruit, vegetables, flowers) where the water is reliable, likewise for supplementary irrigation taken as insurance against drought. These results are supported by the actual prices paid for water where water markets exist. In short, the value attached to irrigation water depends heavily on how reliable it is and on the type of crop being produced. Values tend to be higher for privately-owned groundwater than for publicly supplied surface water schemes.

Household values are relatively high, but this is not a homogeneous category. Water used for truly essential needs such as drinking, cooking and basic hygiene is only a minor part of typical daily use, the rest being used for "lifestyle" or productive purposes. In affluent regions with a warm climate a high proportion of water is used for outdoor purposes such as garden watering and swimming pools. Households tend to place a higher value on indoor than outdoor uses, though this would not apply where water is used for productive purposes. In some societies, much of the water provided for households is used for growing crops and feeding livestock (in other words, it is supplied for *multiple use* purposes).

In practice the valuation of water for household use is commonly taken to be equivalent to the average tariff, which usually underestimates its economic cost of supply, and ignores the *consumer surplus*[5] involved. This is typically the approach used in the case studies presented in this report.

The value of water in its *environmental uses* is not adequately represented in the studies described above – which relate mainly to *use values*, particularly recreation. In fact, recreational values show great variation, depending on the visitation rate, location of the site, quality of water, and type of recreation (with fishing and shooting

[5] The difference between what consumers would be *willing-to-pay*, and what they actually have to pay.

licences attracting high fees in some countries). The various methods of valuing the *non-use* environmental benefits of water are described in Chapter 3[6]. In some cases the environmental value of water is expressed through cities and regions purchasing the rights to water sufficient to meet their environmental needs.

The above discussion of economic values has been in the context of sectors, projects or specific uses. However, exercises are also underway to estimate the value of water at a macroeconomic level. One such is the System of Environmental-Economic Accounting for Water (SEEAW) being developed by the UN Statistics Division (UN, 2008).

SEEAW provides a conceptual framework for organising hydrological and economic information in a coherent and consistent manner. It is an elaboration of the handbook *Integrated Environmental and Economic Accounting 2003* of the United Nations, which describes the interaction between the economy and the environment. Both this document and the SEEAW use the basic framework of the 1993 System of National Accounts, which is the international standard. When fully developed, SEEAW would permit a consistent analysis of the contribution of water to the economy and the impact of the economy on water resources. Because it covers all important environmental-economic interactions, it is ideal for capturing cross-sectional issues such as IWRM as well as a range of other relevant features

The contribution of natural resources such as cropland, forests, pastureland and minerals to economic output is already reflected in national accounts, and estimates have been made of the value of such assets as natural capital[7]. These assets yield a future stream of income/benefits and constitute an important form of wealth for well-endowed countries. Conversely, where they are depleted (through exploitation, deforestation, overgrazing causing desertification, etc.) this represents a loss of capital and wealth, which will reduce future income from these sources. Water is part of natural capital: used sustainably (up to its renewable limit) it provides a recurring bounty to national income, but if its aquifers or surface storage is over-exploited, or if its reserves are contaminated, this is tantamount to capital depletion which will reduce future national income.

1.5 WASTEWATER REUSE IN PRACTICE

The global extent of wastewater reuse

Currently, there are over 3 300 water reclamation facilities worldwide with varying degrees of treatment and for various applications: agricultural irrigation, urban landscaping and recreational uses, industrial cooling and processing, and indirect potable water production such as groundwater recharge (Aquarec, 2006). Most of these were in Japan (over 1 800) and the USA (over 800), but Australia and the EU had 450 and 230 projects, respectively. The Mediterranean and Middle East had around 100 sites, Latin America 50 and Sub-Saharan Africa 20. These numbers are growing rapidly[8].

Figure 1.3 shows the number of municipal water reuse schemes across different regions of the world according to field of reuse application. Applications are arranged in four main categories: agriculture, urban, industrial and mixed (multipurpose).

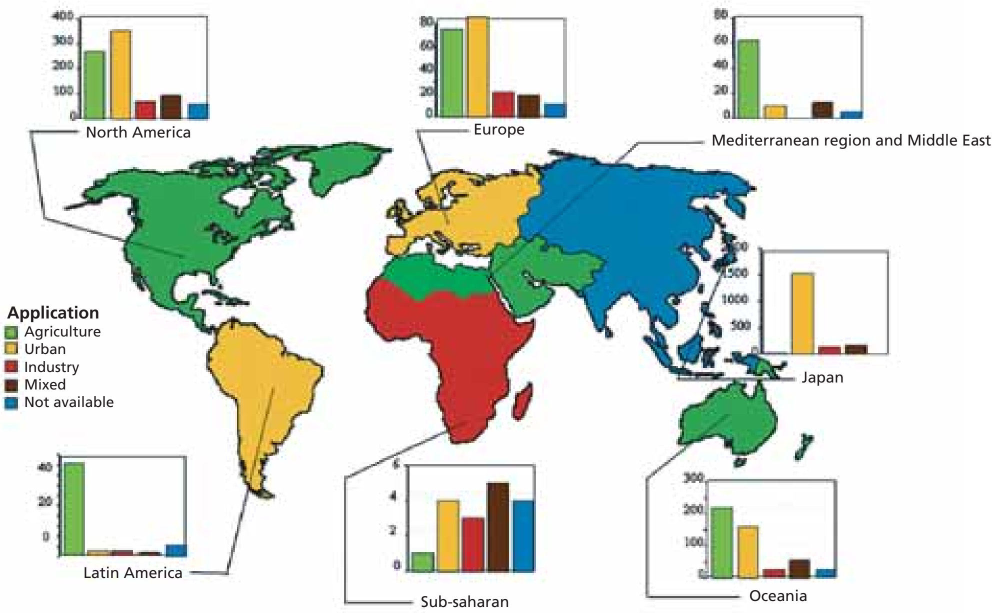
It is estimated that, within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity. Growing competition between the agricultural and urban uses of high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the

[6] And more fully in Turner (2004).

[7] This particular exercise from the World Bank did not include water as one of the types of natural capital.

[8] The monthly journal Global Water Intelligence contains a regular Reuse Tracker with data on all new reuse projects.

FIGURE 1.3
Municipal water reuse schemes, by field of application (AQUAREC, 2006)



BOX 1.1
Integrated wastewater treatment and reuse in Tunisia

Tunisia has a high coverage of sanitation, with 96% in urban areas, 65% in rural areas and 87% overall. Industries also have to comply with national standards for the discharge of wastewater into sewers, and are given subsidies for pre-treatment processes. 78% of wastewater collected is treated, mainly to secondary biological standards.

30-43% of treated wastewater is used for agricultural and landscape irrigation. Reclaimed water is used on 8 100 ha to irrigate industrial and fodder crops, cereals, vineyards, citrus and other fruit trees. Regulations allow the use of secondary-treated effluent on all crops except vegetables, whether eaten raw or cooked. Golf courses are also irrigated with treated effluent.

Tunisia launched its national water reuse programme in the 1980s. Treatment and reuse needs are combined and considered at the planning stage. Some pilot projects have been launched or are under study for industrial use and groundwater recharge, irrigation of forests and highways and wetlands development. The annual volume of reclaimed water is expected to reach 290 Mm^3 in 2020, when it will be equivalent to 18% of groundwater resources and could be used to counter seawater intrusion in coastal aquifers.

Source: Bahri (2009) p. 26

pressure on this ever scarcer resource. Wastewater may be a more reliable year-round source of water than other sources available to farmers, though this is dependent on the primary sources of urban water also being reliable. The value of recycled water has long been recognized by farmers not only as a water resource, but also for the nutrients it contains for plant growth and soil conditioning properties. Currently, the total land irrigated with raw or partially diluted wastewater is estimated at 20 million hectares in fifty countries, which is approximately 10% of total irrigated land (FAO Wastewater Database). Recycling and reuse of wastewater can relieve pressure on water resources due to abstraction from surface water or aquifers, provided that its impact on downstream flows is manageable (Box 1.1).

In Europe, most of the reuse schemes are located in the coastal areas and islands of the semi-arid Mediterranean regions and in highly urbanized areas. Water scarcity is a common constraint in the Mediterranean region with varying precipitation, sometimes below 300 mm to 500 mm per year in southern parts of Spain, Italy, Greece, Malta and Israel. At times, water resources may fall below the chronic water scarcity level of 1 000 m^3 per inhabitant per year. Long distances between water sources and users also create serious regional and local water shortages, and water scarcity may worsen with the influx of peak summer tourists to the Mediterranean coasts and demographic growth, as well as drought and potential climate change-related impacts.

A limited number of European countries have guidelines or regulations on wastewater reclamation and reuse. Article 12 of the European Wastewater Directive 91/271/CEE states: "treated wastewater shall be reused whenever appropriate." The term 'appropriate' still lacks legal definition, and the EU countries themselves have to develop their own national regulations. Nevertheless, water reuse is an option for implementation in the European Water Framework Directive (WFD) that emphasizes

BOX 1.2

Potential impact of EU Water Framework Directive on wastewater reuse

* Requirement for municipal water conservation plans, emphasizing reuse.
* Pressure for development of financial incentives for local governments, developers, and property owners to adopt water conservation and reuse measures and implement public education programs. Incentives can include tax incentives, tax credits, grants and low interest loans. If there is an absence of subsidies, incentives to improve environmental performance by forcing users to innovate or reduce water use might be considered.
* Requirement that, by 2010 water pricing policies be introduced that provide incentives to efficient water uses, aiming to achieve a good ecological status of the water bodies.
* As part of river basin development plans, need to identify the least expensive water supply alternatives that provide the highest level of water sustainability at the river catchment level.
* In pricing conventional and alternative water supplies, need to ensure that the user bears the costs of providing and using water, reflecting its true costs. This implies a stricter application of two major principles: the *polluter-pays principle* and the *full cost-recovery principle*, which means that: "the recovery of the costs of water services including environmental and resource costs associated with damage or negative impact on the environment should be taken into account" when applying the polluter pays principle. This implies that tariffs related to conventional and alternative water sources will have to be reviewed and adjusted. The financial, social and environmental burdens of effluent disposal to the environment should be considered in the economic analysis; thus the true value of reclaimed water would be reflected net of externalities.

Source: Aquarec (2006)

TABLE 1.4
Agricultural crops grown with untreated and treated municipal wastewater

Types	Examples of crops
Field crops	Barley, corn (maize, *Zea mays*), oats, wheat
Fibre and seed crops	Cotton, flower and vegetable seeds
Vegetable crops that can be consumed raw	Broccoli, cabbage, cauliflower, celery, chilli pepper, green tomato (tomatillo), lettuce, pepper, tomato
Vegetable crops that will be processed before consumption	Artichoke, asparagus, beans, onion, peanut, potato, spinach, squash, sugar beet, sunflower
Fodder and forage crops	Alfalfa, barley, clover, cowpea, hay, maize, pasture
Orchards and vineyards	Fruit trees, apple, avocado, citrus, lemon, peach, pistachio, plum, olive, date palms, grapevines
Nurseries	Flowers
Commercial woodlands	Conifers, eucalyptus, poplar, other trees

Sources: Asano *et al.* (2007), Jiménez and Asano (2008), Lazarova and Bahri (2005), Pescod (1992), California State Water Resources Control Board (1990).

the need to integrate health, environmental standards, service provision and financial regulation for the water cycle, in order to achieve overall efficiency and protection of the water cycle (Okun, 2002). The WFD encourages the integration of water reuse options in an integrated water supply and disposal system, in various ways (Box 1.2).

Reclaimed water for agricultural use

There is evidence of the reuse of wastewater in agriculture since ancient Greek and Roman civilisations (Angelakis and Durham, 2008). Because agriculture uses nearly 70 percent of water withdrawals, it is to be expected that in times and regions of water scarcity farmers would turn to domestic or urban wastewater as a water source. While recycled water is a relatively small component of water supply overall, in some countries it has a prominent role, especially for agriculture - as in Kuwait where reused water accounts for up to 35 percent of total water extraction. In agriculture, the UN has estimated that at least 20 million ha in 50 countries are irrigated with raw or partially diluted wastewater, around 10 percent of total irrigated land. About 525 000 ha are irrigated with reclaimed water. Despite progress in the control of water pollution from municipal wastewater, irrigation with untreated wastewater still prevails (Jiménez and Asano, 2008a; Jiménez and Asano, 2008b; Lazarova and Bahri, 2008; Bahri, 2009).

Agriculture is the predominant user of reclaimed water, as it is of freshwater. The use of reclaimed water for agricultural irrigation has been reported in at least 44 countries with a total use of over 15 Mm^3/d (Jiménez and Asano, 2008b). The wide array of crops grown with untreated and treated wastewater is shown in Table 1.4 (this table is not comprehensive, but it illustrates the most common crops). Many more varieties of crops could be grown with reclaimed water under appropriate conditions (Asano *et al.*, 2007; Lazarova and Bahri, 2005; Mujeriego, 1990; Pescod, 1992; Pettygrove and Asano, 1985).

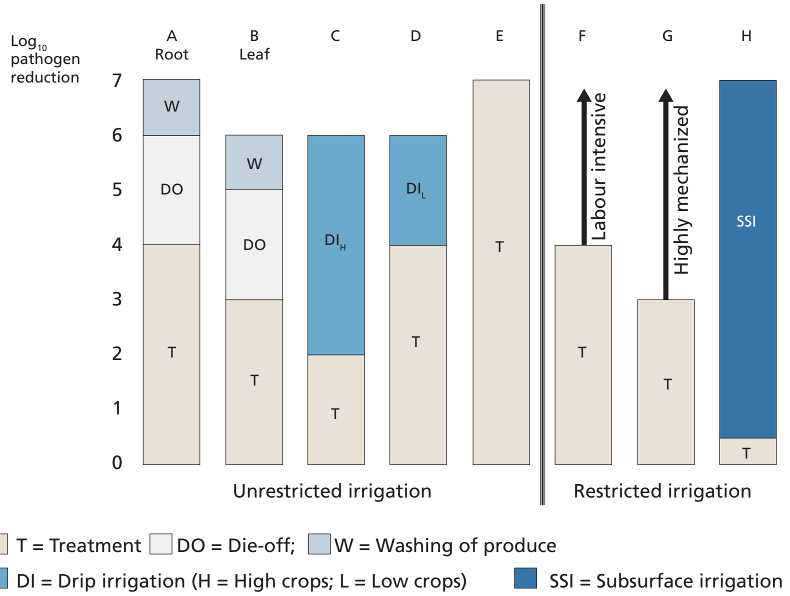
1.6 PUBLIC HEALTH CONCERNS & GUIDELINES

Concern about the risks to public health from the greater use of recycled water is a serious obstacle to the greater spread of this practice.

Many countries base their rules and regulations on this matter on a combination of the California guidelines - the first publications on this topic – and WHO recommendations. For many years, the California standards were the only legally valid reference for reclamation and reuse with the goal of zero risk and with expensive compliance requirements. For example, they stipulate that unrestricted reuse of wastewater requires, after secondary treatment, additionally advanced treatment with a coagulation/filtration step followed by chlorination/de-chlorination to strive for a 0 Fecal Coliform/100 mL limit (Aquarec, 2006) to produce an effluent that is virtually pathogen-free. This technology, referred to as the Title 22 benchmark, is considered

FIGURE 1. 4

Options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALYs per person per year. (WHO, 2006)



the yardstick for unrestricted irrigation, against which all other systems are evaluated because of its long history of successful practice. In Europe, more than half of the tertiary treatment technology is derived from this concept even though full Title 22 treatment is applied only in a few instances (Koo-Oshima, 2009).

In 2006 WHO guidelines for safe use of wastewater apply risk management approaches under the Stockholm Framework and recommend defining realistic health-based targets and assessing and managing risks. The guidelines refer to the level of wastewater treatment, crop restriction, wastewater application methods and human exposure control. The health based targets used by WHO apply a reference level of acceptable risk [*e.g.* 10^{-6} Disability Adjusted Life Years (DALYs)]. The DALY is a quantitative indicator of 'burden of disease' that reflects the total amount of healthy life lost; that is, the quality of life reduced due to a disability, or the lifetime lost due to premature mortality. Depending on circumstances, various health protection measures - barriers - are possible, including waste treatment, crop restriction, adaptation of irrigation technique and application time, and control of human exposure.

Partial treatment to a less demanding standard may be sufficient if combined with other risk reduction measures to achieve the ≤10^{-6} risk (or 1 in 100 000). Figure 1.4 shows the options for risk reduction from pathogens (*i.e.*, viruses, bacteria, protozoa, helminths) in recycled water used for irrigation (WHO, 2006). A major observed risk is from helminths in developing countries where sewage is used with no or minimal treatment. Epidemiological studies from Mexico have reported that children of farmers who live near fields irrigated with untreated wastewater have a higher prevalence of round worm infections than the general population (Peasey et al., 2000). In these studies, infection rates are inversely correlated with the level of sewage treatment.

TABLE 1.5
Water quality categories for different final uses of reclaimed wastewater defined by the Aquarec project (Salgot et al., 2006)

Microbial category	Chemical category	Specific final use
I	1	Residential uses (gardening, toilet flushing, home air conditioning systems, car washing)
	-1	Aquifer recharge by direct injection
II	1	Bathing water
III	1	Urban uses and facilities: irrigation of open access landscape areas (parks, golf courses, sport fields ...); street cleaning, fire-fighting , ornamental impoundments and decorative fountain; greenhouse crops irrigation-Irrigation of raw-consumed food crops. Fruit trees sprinkler irrigated: unrestricted irrigation.
IV	1	Irrigation of pasture for milking or meat animals: Irrigation of industrial crops for canning industry and crops not raw-consumed. Irrigation of fruit trees except by sprinkling; irrigation of industrial crops, nurseries, folder, cereals and oleaginous seeds.
	2	Impoundments, water bodies and streams for recreational use in which the public's contact with the water is permitted (except bathing)
V	1	Irrigation of forested areas, landscape areas and restricted access areas; forestry
	2	Impoundments, water bodies and streams for recreational use in which the public' contact with the water is permitted (except bathing)
	3	Aquifer recharge by localised percolation through the soil
VI	2	Surface water quality, impoundments, water bodies and streams for recreational use, in which the public's contact with the water is not permitted
VII	4	Industrial cooling except for the food industry

Source: Direct aquifer recharge should be drinking water quality, potable water should not be produced from reclaimed wateswater without advanced tertiary treatment like reverse osmosis or percolation through the soil (i.e. indirect aquifer recharge).

Instead of focusing only on the quality of wastewater at its point of use, the WHO-FAO guidelines recommend defining realistic health-based targets and assessing and managing risks along the continuum – from wastewater generation to consumption of produce cultivated with wastewater – to achieve these targets. This allows a regulatory and monitoring system in line with the socio-economic realities of the country or locality.

For the EU, the Aquarec project proposes seven quality categories for different types of reuses (Table 1.5) with microbial and chemical limits for each category (Salgot et al., 2006).

In addition to microbial contaminants in wastewater, chemical contaminants can also be expected from: inorganic salts, nutrients, heavy metals in organic matter, detergents, trace pollutants, pesticides, chlorination by-products such as N-nitroso-dimethyamine (NDMA), chloroform, and endocrine disrupting chemicals and pharmaceuticals. Highly saline irrigation water can severely degrade soils as well as high boron concentrations (>0.4 mg/L) with toxic effects on plants.

Health protection measures

A variety of health protection measures can be used to reduce health risks to consumers, workers and their families and local communities, some of which have already been mentioned. Hazards associated with the consumption of wastewater-irrigated products include excreta-related pathogens and some toxic chemicals. The risk from infectious pathogens is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. The following health protection measures (barriers) have an impact on product consumers:

TABLE 1.6
Examples of Crops Irrigated with Treated Wastewater

Types	Examples of crops	Treatment requirements
Field Crops	Barley, corn, oats	Secondary, disinfection
Fiber and seed crops	Cotton flax	Secondary, disinfection
Vegetable crops that can be consumed raw	Avocado, cabbage, lettuce, strawberry	Secondary,filtration, disinfection
Vegetable crops processed before consumption	Artichoke, sugar beet, sugarcane	Secondary, disinfection
Fodder crops	Alfafa, barley, cowpea	Secondary, disinfection
Orchards and vineyards	Apricot, orange, peach, plum, grapevines	Secondary, disinfection
Nurseries	Flowers	Secondary, disinfection
Commercial woodlands	Timber, poplar	Secondary, disinfection

Adapted from Lazarova and Bahri (eds.) 2005

- wastewater treatment,
- crop restriction,
- wastewater application techniques that minimize contamination (*e.g.* drip irrigation),
- withholding periods to allow pathogen die-off after the last wastewater application,
- hygienic practices at food markets and during food preparation.
- health and hygiene promotion,
- produce washing, disinfection and cooking,
- chemotherapy, immunization and Oral Rehydration Therapy.

The highest quality recycled water is achieved by dual membrane (micro-filtration and reverse osmosis) tertiary treatment processes (Aquarec, 2006). This is, however, expensive, and is best suited for high value cash crops or aquifer recharge. A pragmatic approach is to make wastewater treatment "fit-for-purpose", depending on its intended use and the degree of human contact entailed (*e.g.* whether the produce is eaten raw, peeled, cooked, used for fodder, industry - cotton, biofuels, or whether the water is used for fruit trees, etc.) Various crops can be irrigated with reclaimed water (Table 1.6) and guidance is available on all agronomic aspects of irrigation using reclaimed water.[9]

The FAO and WHO have developed a "Code of Hygienic Practice for Fresh Fruits and Vegetables."[10] This takes a *food chain* approach, assessing risks *from farm to fork*, taking account of all aspects of crops from primary production to consumption. Risks can occur at the primary production stage in the farm environment (through soil, wildlife, proximity to urban or industrial development, waterways, susceptibility to run-off, etc.), in the source of irrigation wastewater, or through manure, soil amendments, pesticides and even the seeds or plants themselves. Risk assessment should also consider the exposure of workers (growers, pickers) and issues arising in transport from the field to the packing/processing houses and the post-harvest handling of fresh produce.

Potential sources of contamination and hazards in the food chain include pathogenic bacteria (*Salmonella*, enterohaemorrhagic *Escherichia coli, Campylobacter, Listeria, Shigella, Yersinia)*, parasites *(Cryptosporidium, Cyclospora, helminths)* and

[9] FAO publishes various reports such as Water Quality for Agriculture as well as studies on the salt tolerance of various crops under the Irrigation and Drainage Report Series. They are available from the website: http://www.fao.org/nr/water/infores_pubs_quality.html.

[10] Expert Group of the Codex Alimentarius Committee on Food Hygiene for Fresh Produce.

viruses (hepatitis A, noroviruses). Recently, problems have emerged with pathogens in fresh produce. Leafy greens pose the greatest concern in respect of microbiological hazards. Leafy greens are grown and exported in large volume and have been linked with multiple outbreaks involving many cases of illness in at least three regions of the world. These crops are grown and processed in diverse and complex ways ranging from in-field packing to pre-cutting and bagging which can amplify foodborne pathogens. International standards such as Codex Alimentarius (WHO, 1993) play a critical role in protecting the health of consumers and facilitating international trade.

1.7 WASTEWATER QUALITY: THE BASIC TREATMENT PROCESSES

Municipal sewage treatment involves the main processes (WELL, undated) illustrated below but extensive definitions are not provided here as they can be found in specific engineering texts. In addition, it is beyond the scope of this report to include discussions on lagoons and extensive treatment systems.

- *Preliminary:* screening and grit removal to remove coarse solid and other large materials often found in raw wastewater. It includes coarse screening and grit removal.
- *Primary:* sedimentation – simple settlement of solid material in a primary settling tank. Solid particles settle at the bottom, and oils and greases rise to the top. This material is removed as sludge, for separate treatment.
- *Secondary:* the further removal of common pollutants, usually by biological processes to remove dissolved organic material. Wastewater from primary treatment flows into an aeration tank, to which micro-organisms are added to consume the remaining organic matter. Following aeration, the mixture is clarified. The residue is removed as sludge, for separate treatment and disposal.
- *Tertiary:* involves the removal of specific pollutants, *e.g.* nitrogen or phosphorus, or specific industrial pollutants. The effluent may then be disinfected to kill harmful micro-organisms by chlorination or ultraviolet disinfection. The residual chlorine is then removed.
- *Processing of solids and sludge:* solids from the primary and secondary processes are sent to a digester which produces by-products including methane and water. The final residue is sent to landfills or incinerators, or used in agriculture for fertilizer or soil beneficiation[11].

Although untreated sewage is quite widely used in agriculture in many locations, the more typical situation involves the reuse of effluent treated to at least secondary levels. As noted in section 1.6 this can meet public health concerns, with appropriate use limitations and safeguards. Effluent treated to secondary levels still contains nutrients of value to farmers, whereas tertiary treatment removes nitrogen and phosphorus which are crucial ingredients for fertilization.

In certain localities (*e.g.* the Llobregat Delta taken as one of the case studies in Chapter 2) the wastewater effluent has an excessively high salt content, which needs to be removed to make it usable by farmers. In this specific case, an Electrodialysis Reversal (EDR) unit is being installed to provide additional treatment for the effluent being sent to farms.

The choice of the degree of wastewater treatment is normally made for reasons of environment, amenity and public health. However, where extra treatment is being considered as part of a reuse project it is desirable to minimize costs by employing technologies that can offer long-term reliable operation, low operating costs, minimize the use of chemicals and be as compact as possible (Sorgini, 2007). Where space permits, the additional facilities can be built inside the existing WWTP premises.

[11] Disposal of sludge at sea is another option, though this is now banned in EU countries, and elsewhere.

1.8 ENVIRONMENTAL, INFRASTRUCTURAL AND LEGAL ISSUES

Environmental

The potential impact of using recycled water on human health was considered in section 1.6. Wastewater contains potential pathogens for plants, animals and humans transmitted through the food-web or the environment: nitrates, *Giardia* and *Cryptosporidium*, endocrine disruptors, other persistent organics, etc., have been matters of recent concern.

Different types and degrees of wastewater treatment can affect the presence of contaminants in the effluent released for recycling. Where this contains heavy metals or other harmful substances there is a risk of their long term build-up in soil. In some cases the contaminant may be present in the source water (as in the Spanish case studies, where salinity is a problem being dealt with through a reverse-osmosis desalination unit).

Discharging inadequately treated wastewater could cause eutrophication of surface waters – hence the environmental directives of the EU and other countries requirement treatment to tertiary levels in specified cases. In these circumstances, farmers confer an environmental *benefit* by using recycled water where nutrients such as phosphorous and nitrogen are absorbed by the crop rather than discharged into other water bodies.

Water reuse may be a means of reducing wastewater discharges. Reclaimed water has also been used to restore wetlands or streams or groundwater aquifers by replenishing flows and water table levels. Reclaimed water may provide a source of water to promote growth in water scarce regions or to increase income of resource-poor urban and peri-urban farmers.

TABLE 1.7

Factors affecting the choice of irrigation method and special measures required for reclaimed water applications

Irrigation Method	Factors affecting choice	Special measures for irrigation with reclaimed water
Flood irrigation	Lowest cost Exact levelling not required Low water use efficiency Low level of health protection	Thorough protection of field workers, crop handlers, and consumers (eg. protective equipment)
Furrow irrigation	Low cost Levelling may be needed Low water use efficiency Medium level of health protection	Protection of field workers, possibly of crop handlers and consumers (eg. protective equipment)
Sprinkler irrigation	Medium to high cost Medium water use efficiency Levelling not required Low level of health protection (due to aerosols)	Minimum distance 50-100 m from houses and roads Water quality restrictions (pathogen removal) Anaerobic wastes should not be used due to odour nuisance Use if mini-sprinklers
Subsurface and drip irrigation	High cost High water use efficiency Higher yields Highest level of health protection	No protection measures required Water quality restrictions (filtration) to prevent emitters from clogging

Source: Lazarova and Bahri (2005, 2008).

Infrastructure and conveyance

In some situations (most of the case studies in chapter 2), treated wastewater of the required quality is available in sufficient quantities, or decisions have been taken to upgrade existing WWTPs to produce such effluent. However, in other cases some upgrading of WWTPs will be required and there may even be a need to add specific processes (*e.g.* desalination) to render the wastewater suitable for farm use.

Local geography is important for the feasibility of recycling schemes. The source of reclaimed water needs to be in reasonable proximity to the intended users, in order to minimise the need for new conveyors and the cost of pumping. If existing conveyors could be used, this would obviously be advantageous. Equally, if not more, importantly, the economics of reuse schemes normally rely on an exchange of fresh water entitlements between farmers and cities: this must be physically and geographically feasible. The freshwater entitlement must be accessible to the city at a reasonable cost, with minimal new conveyance infrastructure and pumping, compared with the alternatives. The case studies in chapter 2 include cases where the transfer is highly feasible in these terms, as well as those where its feasibility is not obvious.

TABLE 1.8
Classification of cultivation practices as a function of the health risk for agricultural workers

Low risk of infection	High risk of infection
Mechanized cultural practices	High dust areas
Mechanized harvesting practices	Hand cultivation
Crop dried prior to harvesting	Hand harvest of food crops
Long dry periods between irrigations	Moving sprinkler equipment
	Direct contact with irrigation water

Source: Lazarova and Bahri (2005)

TABLE 1.9
Levels of risk associated with different types of crops irrigated with reclaimed water

Lowest risk to consumer, but field worker protection still needed	Medium risk to consumer and handler	Highest risk to consumer, field worker, and handler
Agricultural irrigation		
Industrial crops not for human consumption (e.g., cotton, sisal)	Pasture, green fodder crops	Any crops eaten uncooked and grown in close contact with wastewater effluent (e.g., fresh vegetables such as lettuce or carrots, spray-irrigated fruits)
Crops normally processed by heat or drying before human consumption (grains, oilseeds, sugar beets)	Crops for human consumption that do not come into direct contact with wastewater, on condition that none must be picked off the ground and that sprinkler irrigation must not be used (e.g., tree crops, vineyards)	Spray irrigation regardless of type of crop within 100 m of residential areas or places of public access
Vegetables and fruit grown exclusively for canning or other processing that effectively destroys pathogens	Crops for human consumption normally eaten only after cooking (e.g., potatoes, eggplant, beets)	
Fodder crops and other animal feed crops that are sun-dried and harvested before consumption by animals	Crops for human consumption, the peel of which is not eaton (e.g., melons, citrus fruits, bananas, nuts, groundnuts)	
	Any crop not identified as high risk if sprinkler irrigation is used	
Landscape irrigation		
Landscape irrigation in fenced areas without public access (e.g., nurseries, forests, green belts)	Golf courses with automated irrigation scheduling	Golf courses with manual irrigation
		Landscape irrigation with public access (e.g., parks, school playgrounds, lawns)

Source: Lazarova and Bahri (2005)

Irrigation infrastructure and methods

The second aspect is the feasibility of reuse from the viewpoint of irrigation infrastructure. Certain methods of irrigation may reduce the exposure of crops to pathogens, whereas others are not suitable. Sprinklers, for instance, are not advisable for lettuce irrigation, due to the capacity of the crop to hold water between its leaves and thus improve the survival of pathogens. Other crops need specific irrigation methods, *e.g.*, forage grass is usually irrigated with sprinklers and is difficult to do so with drippers unless the soil is heavy.

Some of the general problems of using reclaimed water for irrigation are the likelihood of algal and rooted macrophyte growth in open channels, the formation of biofilms in pipelines, and the re-growth of pathogens along the reclamation and reuse systems. Some of these effects can be mitigated by using chemicals or other means that change the composition of reclaimed water.

Irrigation practices and devices (*e.g.* drip or porous pipes) which limit contact with humans, sensitive parts of the environment, or parts of plants, are less risky to health than those (*e.g.* sprinklers, aerosols) which broadcast reclaimed water in a diffused manner. Some of the factors to consider in the choice of irrigation method, from the viewpoint of the impact on workers and consumers, are illustrated in Tables 1.7, 1.8 and 1.9.

Legal framework & water rights

Wastewater reuse commonly involves a transfer of entitlements to freshwater between farmers and municipalities (or other water users). In principle, both parties should be able to benefit from such an exchange of rights where conditions are favorable. However, unless compulsion is ruled out, a voluntary exchange depends on the farmers having secure and alienable rights to the water that they can transfer – either in water markets or in return for compensation. They must possess such legal rights, and their national legal system must permit the transfer or sale of these rights to others. Many legal systems do not provide these assurances. Consequently, municipalities, which stand to gain (or save) financially, and which could fund reuse projects, may not get sufficient reassurance of their rights to the freshwater "exchanged" for the recycled effluent. Where the water problems of a city or region are sufficiently grave, some compulsion might be required to achieve a solution. Even then, however, questions of rights and compensation are likely to arise.

Formal or informal legal rights may also attach to the use of wastewater (treated or not) by farmers or other groups, who may claim compensation if this is diverted for use elsewhere (Bahri, 2009).

Chapter 2

A regional perspective: introduction to the case studies from Spain & Mexico

This chapter introduces the case studies that provide the real-world context for the consideration of the topic of this report. Following the presentation of the economic methodology in Chapter 3, economic and financial data drawn from these cases studies is used in Chapter 4 to provide a practical illustration of how the analysis can be carried out, with some indicative results.

Case material is drawn from five regions of Spain and Mexico (Table 2.1).
Mexico: Case studies
Mexico City & Tula Valley
Guanajuato City & La Purísima irrigation module.
Durango City & Guadalupe Victoria irrigation module.
The sites were chosen to indicate both the potential and the practical difficulties arising in water recycling, whether of treated (reclaimed) or untreated wastewater. All the sites have the potential for "win-win" outcomes, in the sense that water recycling can benefit two or more of the parties to the transaction, taken to be urban water authorities ("cities"), farmers, and environmental custodians for the sake of this discussion.

Several types of "win-win" projects are represented in the case studies:

- ➢farmers cede their freshwater rights to cities in return for assured supplies of reclaimed water containing nutrients (Sant Feliu, El Prat, Durango);
- ➢farmers accept reclaimed water as a complement or alternative to pumping of depleting aquifers, giving them greater reliability and cost savings, with environmental gains (Tordera Delta);
- ➢the provision of reclaimed water and (untreated) wastewater to agriculture as a solution for urban wastewater treatment and disposal, as well as offering benefits to farmers (Mexico City/Tula, Guanajuato/La Purisima, Gava-Viladecans pre-1986).

Although the principal motives of these various arrangements differ, each offers potential benefits to all three stakeholders mentioned above.

The attraction of these arrangements to the farmers is normally the security of supply of the effluent water, its fertilising properties, and any savings in their own groundwater pumping. The appeal of such projects to cities may be their access to extra fresh water at lower costs than they would otherwise pay, or the opportunity to dispose of wastewater (treated or not) more advantageously than otherwise. The *environment* is also a potential beneficiary where, for example, it is

TABLE 2.1
Case material sites

Spain: Case studies:		
	Llobregat Delta	
		Sant Feliu de Llobregat
		El Prat de Llobregat
		Gavà-Viladecans
	Tordera Delta and Costa Brava	
		Blanes
		Castell-Platja d'Aro
Mexico: Case studies		
	Mexico City & Tula Valley	
	Guanajuato City & La Purísima irrigation module	
	Durango City & Guadalupe Victoria irrigation module	

under pressure from development causing over-exploited aquifers, low river levels, depleted wetlands, or coastal saline intrusion in aquifers. In such cases regional authorities responsible for environmental status (*environmental* custodians) have a direct interest in effluent reuse – either for release into natural water courses (subject to local laws and regulations), or because it allows less abstraction from rivers or aquifers.

2.1 SPAIN: LLOBREGAT DELTA

2.2.1 Site features

The Llobregat River basin is situated in the NE part of Spain adjacent to Barcelona, the capital city of Catalonia (Map 2.1). In recent decades, the river Llobregat has been highly polluted by industrial and urban wastewaters, and by surface runoff from agriculture. This river experiences periodic floods and droughts which lead to frequent morphological variations in the river bed and to modifications in its banks. The river Llobregat has two main tributaries, the Cardener River and Anoia River, and all three receive effluent from various sewage treatment plants and industrial effluent, treated and untreated. Furthermore, the occurrence of natural salt formations which are mined in the basin (at Cardona, Súria and Sallent) have been causing an increase in water salinity.

The delta of Llobregat River lies to the south of Barcelona city and covers about 100 square kilometres. In spite of its close proximity to the city, it is a valuable natural habitat. Its wetlands are of international importance for wildlife and form a critical wintering ground for many migratory birds. The delta aquifer is one of the most important freshwater resources for the Barcelona region, with a groundwater capacity of 100 Mm^3/yr., used by numerous industries, agriculture, and the metropolitan area of Barcelona and surrounding towns. The fertile delta farmland supports intensive agriculture supplying the local market.

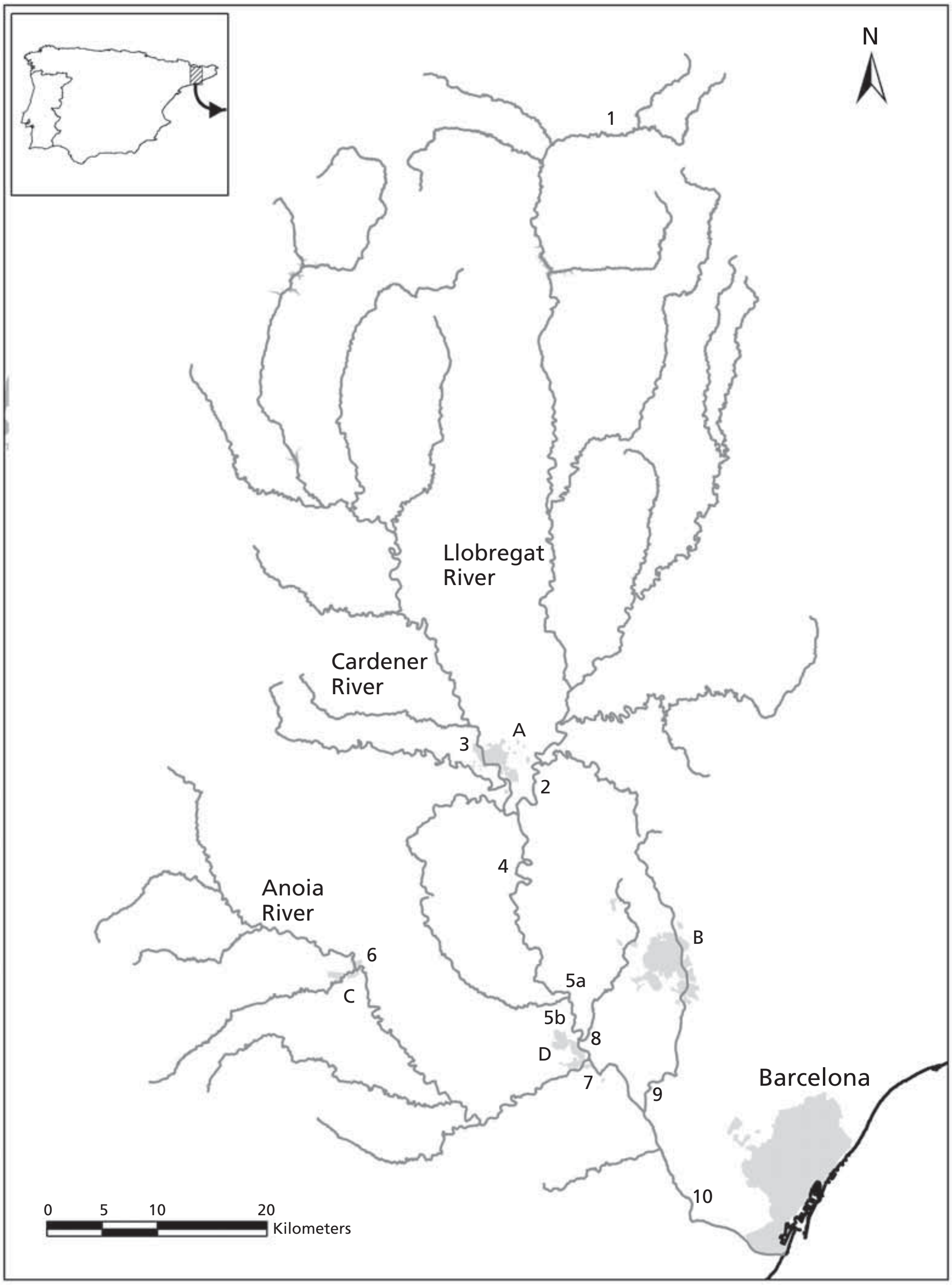
Since the 1960s, the delta's land has been under constant pressure from Barcelona's urban and industrial expansion. Catalonian's most important logistics and transportation facilities - port, airport, motorway network and railways - have gravitated to the area. The recent port extension forced a southward movement of the river entrance to the sea. Less than 5% of the original wetlands in the area now remain and in some municipalities half of agricultural land has been lost in the last decade.

By the end of the 1980s, the Llobregat River was one of the most polluted and degraded in Western Europe. Overexploitation of the underground water had led to salinization of the aquifer, rendering 30% unusable. Since 1991 with the European Directive on Urban Wastewater, a comprehensive programme of wastewater treatment has been implemented along the river and the situation has improved dramatically. New wastewater treatment plants with tertiary facilities have been built, while a water reclamation programme has been planned and implemented to address water shortages and the increasing water demand from all sectors.

The entire watershed, including the metropolitan area of Barcelona, depends on water resources from both local and remote sources that are highly variable. When the flow from the Llobregat River is insufficient, more water has to be conveyed from the Ter River to the Llobregat watershed. Aquifer withdrawals are also affected by the water quality of the Llobregat River - if water quality is poor, surface water has to be mixed with more groundwater in order to be treated for domestic use.

The water supply for the Barcelona Metropolitan area currently comes from three sources: the Ter River supply (c. 50%); the Llobregat River (c. 40%) through 2 water treatment plants (Sant Joan Despí and Abrera); and groundwater from several wells (c. 10%). A new seawater desalination plant will shortly start operating, with a capacity of 60 Mm^3/year.

MAP 2.1
Llobregat river basin



Infrastructure exists to prevent excessive pollution of the river by intercepting specific effluents, such as the channels receiving treated urban wastewater from Rubí and those collecting brine from the salt-mine sites (Figure 2.1). Apart from these, there is a major irrigation channel on the right side of the river, the *Canal de la Dreta*, which provides water extracted from the middle course of the river to horticulture. On the left side of the river the *Infanta Canal* was also built for irrigation purposes, but now its main role is to divert treated wastewater from industries and towns away from the river so as to improve the latter's water quality. The aquifer is used mainly for irrigation, having a lower salinity than the river, except in the areas with seawater intrusion.

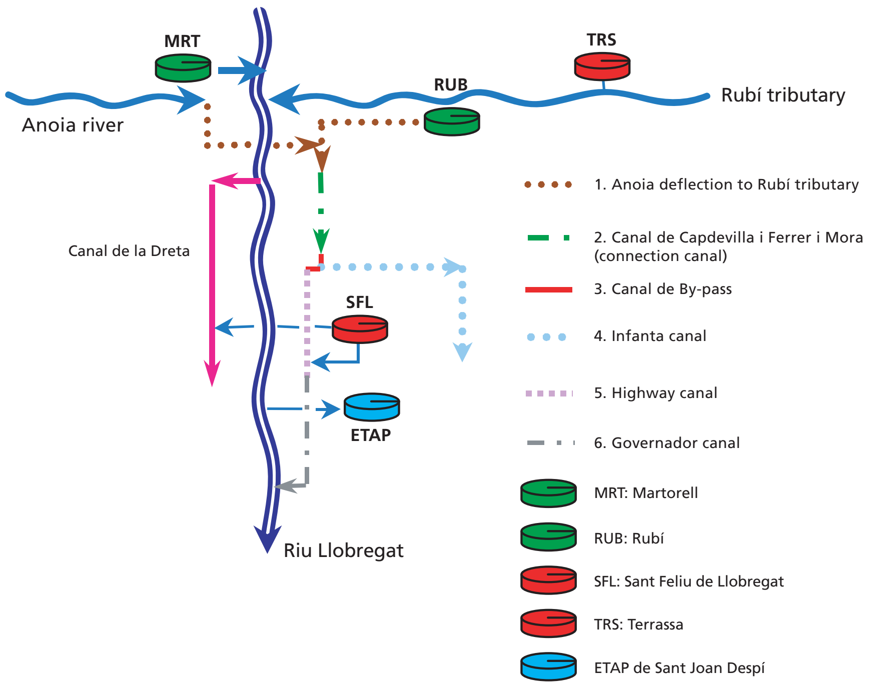
The Llobregat River is the main source of irrigation water, via the Canal de la Dreta, and a small amount via the Canal de la Infanta. At present, in drought conditions, the extraction of the Llobregat aquifers exceeds the natural recharge of 5.6 Mm3/yr. This over-exploitation has led to a new policy aimed at restoring the river basin's natural state based partly on the reclamation and reuse of treated wastewater.

2.1.2 Wastewater treatment

In the study area there are two main wastewater treatment plants (WWTPs): The Sant Feliu de Llobregat WWTP and El Prat de Llobregat WWTP, both with tertiary treatment – see Map 2.2. A third WWTP operates on the western edge of the delta at Gavà-Viladecans, which is discussed below.

Effluent from the ***Sant Feliu de Llobregat*** WWTP is fully treated to tertiary levels and available for use in irrigated agriculture. The effluent volume - around 19 Mm^3/yr – can be transferred to the Canal de la Dreta to be used for irrigation purposes on

FIGURE 2.1
Deflection channels in the lower Llobregat River course



MAP 2.2
Wastewater treatment plants

Source: Food and Agricultural Organizatin of the United Nations (2008)

the right side of the Llobregat delta. The effluent is usually mixed with well water in order to reach an acceptable water quality for irrigation purposes. The irrigated areas are located in Sant Viçenc dels Horts, a village in the north part of the delta. Currently, only a small proportion of the effluent is actually used by farmers (about 0.2 Mm^3/yr), who view it as a last resort to be used in drought periods when sufficient fresh water is not available.

El Prat de Llobregat WWTP, with a wastewater generation of around 120 Mm^3/yr, is one of the biggest treatment plants not only in Spain but in the whole of Europe. The treatment plant, serving more than 2 million inhabitants, generates 4.5 Mm^3/yr of wastewater treated to tertiary levels that can be used to supply the ecological flow of the lower part of the Llobregat river, and to provide water for agricultural irrigation and to supply water to wetlands in the river deltaic areas. An important part of the reclaimed flow will also be used to create a hydraulic barrier to seawater intrusion in the Llobregat lower delta aquifer.

El Prat de Llobregat WWTP can collect the treated wastewater of other facilities located in the medium-upper part of the river. However, the concentration of industrial activity and the salts added by urban uses of water increase the salinity of the effluent and affect its reuse. The treatment facilities of the plant were improved in 2006 in order to obtain the required water quality for reuse. Two different tertiary treatment lines were built, each with its appropriate technology for the expected reuse purposes. Water intended for the coastal seawater intrusion hydraulic barrier is additionally processed with micro filtration and reverse osmosis.

Although the infrastructure exists, the reclaimed water generated by the El Prat de Llobregat WWTP is not currently used in irrigated agriculture. Farmers prefer to use the aquifer as their main water source, supplemented by the Llobregat river water via the Canal de la Dreta. However, extraction from the abovementioned channel by farmers is prohibited in drought periods and, at such times, farmers are obliged to use reclaimed wastewater from the El Prat de Llobregrat WWTP.

Ten kilometers west of El Prat de Llobregat the Gavà-Viladecans agricultural region produces artichokes, tomatoes and other vegetables. Until 1986 the villages of Gavà and Viladecans had no wastewater treatment plant and, before that time, farmers used untreated wastewater distributed via a network of channels. These channels are now used to distribute the output from the WWTP as well as channelling excess water and rainwater. The Llobregat right irrigation channel (Canal de la Dreta) used by the other growers of the delta is too far from this area, so the local farmers accepted the use of effluent treated at the new plant.

The treated effluent from the Gavà-Viladecans WWTP is channeled to local farmers who pump it for their own purposes. This effluent is not used directly for irrigation, but is used for stabilizing the hydrological balance in this area. Some of the effluent is also used to recharge wetlands. Due to potential health risks, there are plans to install a tertiary treatment unit which would enable higher value crops (e.g. tomatoes) to be grown with the treated effluent. However, for the immediate future there is unlikely to be any increase in the agricultural use of reclaimed water since farmers already benefit from it indirectly.

In summary, in Gavà-Viladecans and other parts of the Llobregat Delta, there are at present few direct uses of treated wastewater in agriculture, but the reclaimed water is direct uses of treated wastewater in agriculture, but the reclaimed water is being applied to stabilize the hydrological balance in the area (Map 2.3).

2.1.3 Expansion of effluent reuse in agriculture

At each of the three areas, the Catalonian Water Agency (ACA) plans to expand the use of the treated effluents of the WWTPs for agricultural irrigation and other purposes.

Table 2.2 indicates that rain-fed farming is limited to 15% of the total cultivated land, mainly in the area of Sant Feliu de Llobregat. Farmers use fresh water from the Llobregat River through the *Canal de la Dreta*, with an annual flow of c. 19 Mm^3. The effluent from the tertiary treatment of the Sant Feliu WTTP can be transferred to the *Canal de la Dreta* to be used for irrigation purposes on the right side of the Llobregat delta (Figure 2.1). Normally, the limit for agricultural use of water from the Llobregat river is 1.5 m^3/s, but in periods of water shortage this use is reduced to 0.8 m^3/s. At such times, the farmers are obliged to use treated wastewater from the Sant Feliu de

TABLE 2.2
Wastewater output and re-use in Llobregat delta (2006)

Treated wastewater (Mm^3/yr)	Secondary	120.38	19.10	14.53
	Tertiary	4.50	19.10	14.53
Treated effluent use (Mm^3/yr)	Sea disposal	99.77*	0.0	9.78*
	Aquifer recharge	0.0	0.0	no
	Wetlands	1.5	no	no
	Llobregat river	3.0	19.42	no
	Agriculture irrigation	0.0**	0.225	4.74***
Cultivated area (ha)	Rain fed	58	40	171
	Irrigation	743	235	524
Total water used in agricultural irrigation (Mm^3/yr)****		6.00	1.78	4.20

* Effluent from Secondary treatment

** Potentially via right irrigation channel (Canal de la Dreta)

*** Via delta canals. Ambient reuse, with indirect agricultural use.

**** Does not include unregistered water extraction

no: Option not possible

Llobregat WWTP, which is the only water flow in the *Canal de la Dreta*. Therefore, this effluent is used only in drought periods (currently about 0.2 Mm^3/yr) and, due to its high salinity, the effluent is mixed with well water in order to reach an acceptable water quality for irrigation purposes.

The groundwater used by farmers in this area is estimated to amount to about 5 Mm^3/yr. Farmers actually take a major proportion of their irrigation needs from the aquifers, but this is not fully registered by the authorities and aggregate groundwater use is only estimated from the aquifer balance.

For the foreseeable future, wastewater treatment capacity is not the major constraint in expanding effluent reuse in agriculture. There is currently huge capacity in the Llobregat Delta for generating tertiary treated wastewater which, at present, is hardly used for agricultural irrigation. In the long term, there are options for producing more treated effluent by upgrading existing or building new WWTPs.

2.1.4 Intersectoral water exchange

Assessing the economic efficiency of reclaimed water use cannot be confined to a single sector such as agriculture - a broader perspective at river basin or watershed level is needed. Such an assessment should be informed by the concept of integrated water resource management (IWRM) that considers all water-related issues and their interdependencies, as far as possible.

Box 2.1 provides a summary of the water policy for the Llobregat Delta, involving a mixture of solutions, including desalination, the further use of remote resources (and, conversely, reducing their use when seawater desalination is in operation), further treatment of wastewater, and environmental measures to restore aquifers, replenish wetlands and create a hydrological barrier against seawater intrusion. The recycling of wastewater for irrigated agriculture, both directly and indirectly, through environmental measures and aquifer recharge, fits well with the strategies of IWRM.

The main projects for implementing this policy are listed in Table 2.3.

BOX 2.1

Water policy in the Llobregat Delta

To augment water availability in the metropolitan area of Barcelona, a water treatment plant is under construction to desalinate seawater with a capacity of 60 Mm^3/yr. From 2009, this water will be pumped via a distribution station into the pipeline network supplying Barcelona with drinking water. This will not only increase water availability but will also reduce the conductivity (salinity) of the El Prat WWTP effluent.

The full range of measures being planned by the Catalonian Water Agency (ACA) include the desalination of treated wastewater from WTTPs, deflection of industrial wastewater, desalination for potable water, and greater use of remote resources with lower conductivity from the Ter river. (However, stakeholders from the Ter basin are now claiming the return part of their water concession on the grounds that the new desalination plant makes the use of remote sources unnecessary). Part of the reclaimed water from the El Prat WTTP will be used to recharge the aquifer serving as a hydrological barrier against seawater intrusion. All these measures aim to tackle future water shortages in the Llobregat Delta, as well as improving the water quality and the ecological status of the Llobregat river basin.

The ACA's theme of integrated water management is embedded in a Water Reuse Programme in the context of the overall Catalonian Hydrological Plan for internal basins. The Water Reuse Programme has a planned budget of 180 M€ and a target for reusing 20% of the total treated wastewater.

A further project is the construction of a Reverse Osmosis treatment plant (RO) at the El Prat de Llobregat WWTP as an advanced form of treatment for reclaimed water in order for its use in aquifer recharge for creating a hydrological barrier against seawater intrusion (24 M€).

All these actions will mitigate the current and future water problems at the Llobregat Delta, and they will facilitate directly and indirectly water reclamation. The reduction of the conductivity (salinity) of the El Prat WWTP effluents and upgrading the tertiary treatment at Sant Feliu WWTP will facilitate intersectorial water transfer between agriculture and the city.

It is intended that the reclaimed water from the El Prat and Sant Feliu WWTPs will be used for several purposes (Table 2.4).

As table 2.4 shows, in the near future the reuse of treated wastewater will become increasingly important not only for agricultural irrigation but also for industrial water use and for enhancements of water quality and wetlands (Map 2.3). The conductivity of reclaimed water will need to be reduced to make it more suitable for agricultural irrigation, thus enabling freshwater currently used by farmers to be exchanged for what would otherwise be taken by other users in the Delta.

As noted earlier, both the El Prat and Sant Feliu WWTPs have tertiary treatment.

TABLE 2.3
Action planned in Delta de Llobregat and Barcelona metropolitan area to improve water management

Action	Purpose	Investment Cost M€
Desalination plant El Prat de Llobregat, storage and pipelines	Improve drinking water quality and reduce the salinity of the entire system,	420.0
Desalination (EDR) at Abrera drinking water plant	Reduce conductivity of Sant Feliu WWTP's effluent; improve drinking water quality	65.0
Desalination (RO) of Llobregat River at Sant Joan Despi drinking water plant	Reduce conductivity of El Prat WWTP's effluent; improve drinking water quality (especially for THM)	60.5
Industrial and mining effluent collectors	Reduce salinity of Lobregat river	15.5
Desalination (EDR) at Municipality of Sant Boi **de Llobregat***	Reduce conductivity of reclaimed water from El Prat WWTP for irrigation	14.0
Pipelines for industrial reuse	Reuse of industrial effluent	1.5
New Tertiary treatment in Sant Feliu and pipelines*	Reduce conductivity of reclaimed water for irrigation	1.1
Total		**577.6**

*Actions that facilitate directly the intersectoral water transfer at Llobregat Delta

TABLE 2.4
Projected multi-purpose use of reclaimed water in Llobregat Delta for 2015

	WWTP El Prat de Llobregat	WTTP San Feliu de Llobregat
	Mm³/yr	Mm³/yr
Agriculture	11.83	7.32
Rzver stream flow	10.37	-
Wetlands	6.31	-
Seawater barrier	0.91	-
Municipalities	-	0.11
Recreation	-	0.37
Industry	5.48	-
Total	**34.9**	**7.8**

MAP 2.3
Reclaimed water demand in the Llobregat Delta

Agricultural reuse of effluent dates from the summer of 2007 when a group of farmers started to use reclaimed wastewater mixed with well water. The Catalonian Water Agency (ACA) recommended this mixing in order to avoid long-term soil degradation due to the high salinity of the effluent. Neither of the two WWTPs has sufficient effluent quality to meet farm water requirements, so further measures will be needed including desalination of the effluents and building of new pipelines for water conveyance.

As it happens, the irrigation *Canal de la Dreta* starts upstream of Barcelona's main drinking water treatment plant *Sant Joan Despí*. The use of reclaimed water in agriculture would potentially avoid a diversion of river water in the order of 19 Mm^3/yr that is currently used for irrigation purposes. This amount would become available for domestic water supply, thereby avoiding conveyance of water from remote sources such as the Ter River.

In effect, the reuse scenario would lead to an intersectoral water exchange between agriculture and the metropolitan area of Barcelona. Whether this is economically rational is examined in Chapter 4 within a framework of cost-benefit analysis. A key question is whether farmers would be ready to replace freshwater with the reclaimed water (even it had good quality) and how they can be encouraged to do this. The net impacts on farmers' income would be a crucial consideration.

2.2 SPAIN: TORDERA DELTA & COSTA BRAVA

2.2.1 Site features

The Tordera River Delta, North-East of Barcelona, starts in the point where the Santa Coloma River joins the main flow up to the Mediterranean Sea – Maps 2.4a and b illustrate the Tordera Delta and exploiting well distribution locations.

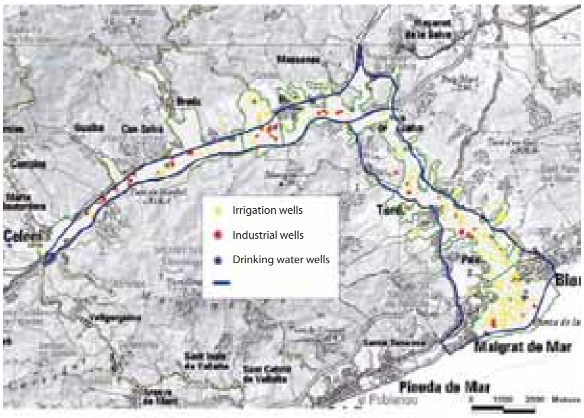
In the study area there are two WWTPs, one in the town of *Blanes* and the other in the town of *Tordera,* both with tertiary treatment. Effluent from the Blanes plant (around 3.5 Mm^3/yr) is used mainly for recharging the aquifer, though a few farmers also use it for irrigation. The Tordera WWTP, producing around 1 Mm^3/yr reclaimed effluent, uses artificial wetlands (purification ponds) for its tertiary treatment. The reclaimed water is currently being discharged into the Tordera River since its pumping facilities (powered by solar energy) are not working (these are needed to convey the wastewater to wetlands for recharging the aquifer). At the moment, none of the Tordera reclaimed water is used by farmers, despite the existence of an irrigation channel.

The Catalonian Water Agency has undertaken several measures to address the growing regional water shortage and pressures on the local aquifers:

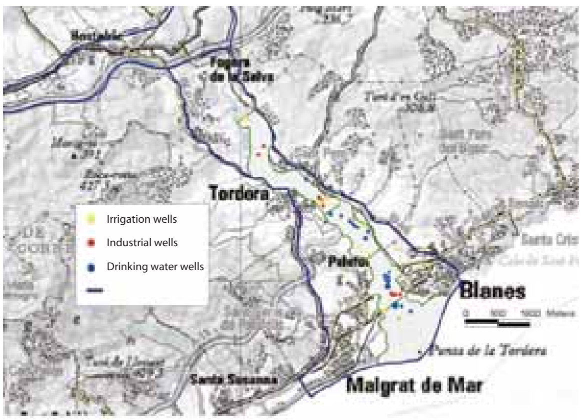
- Construction of a seawater *desalination plant* in 2004 at Blanes. This plant provides almost 10 Mm^3/yr to three drinking water treatment plants (including Tossa-Lloret de Mar, Blanes and Palafolls and North Maresme towns). See Map 2.9. The extraction of groundwater totalling 40 Mm^3/yr from the Tordera River aquifer could be reduced by about 10 Mm^3/yr.
- Upgrading the Blanes WWTP to tertiary treatment in order to reduce the discharge of secondary effluent into the sea through a submarine outfall, and to produce effluent of a quality suitable for recharging the Tordera aquifer.
- Drawing up a plan to regulate extractions from the aquifer.
- Providing farmers with reclaimed water for agricultural irrigation.

The farm areas around *Blanes WWTP* are in three municipalities - Blanes, Malgrat de Mar and Palafolls – with a total cultivated land of around 774 ha, of which 608 ha grow horticultural crops. Irrigation water is taken entirely from groundwater, with no recourse to surface supply (the Tordera River bed is completely dry during summer months at the time when the water demand from crops is highest).

MAP 2.4 a
Well distribution locations in the Tordera Delta



MAP 2.4 b
Wastewater treatment plants



The Blanes WWTP, having tertiary treatment with nutrient removal, produces reclaimed water of a quality suitable to recharge the overdrawn Tordera aquifer. Currently, almost all the effluent is used for groundwater recharge through the river bed, with only a minimum percentage diverted to the outfall and only a few farmers using the reclaimed water. Until 2006 in fact, no farmers used reclaimed water from the WWTP, but the overexploitation of the aquifer caused some of them to ask for a concession to use reclaimed water since their wells had run dry. Two farmers formed a community of irrigation users called *Mas Rabassa* and undertook to build pipelines, a pumping station and a water reservoir to take the effluent. The Catalonian Government funded 70% of the project capital cost; the remaining part being paid by the farmers. This scheme started operating in 2007, and it is likely that more farmers will soon be in the same situation.

A future scenario could be for more use of the Blanes WWTP recycled water in irrigated agriculture, and the complete replacement of groundwater by reclaimed water. This option would save farmers the cost of groundwater pumping, though they would be unlikely to receive fertilization benefits due to the removal of nutrients at the tertiary WWTP. There would be additional benefits to the local environment, and for other water users through the exchange of freshwater rights for the effluent. This option is appraised in Chapter 4.

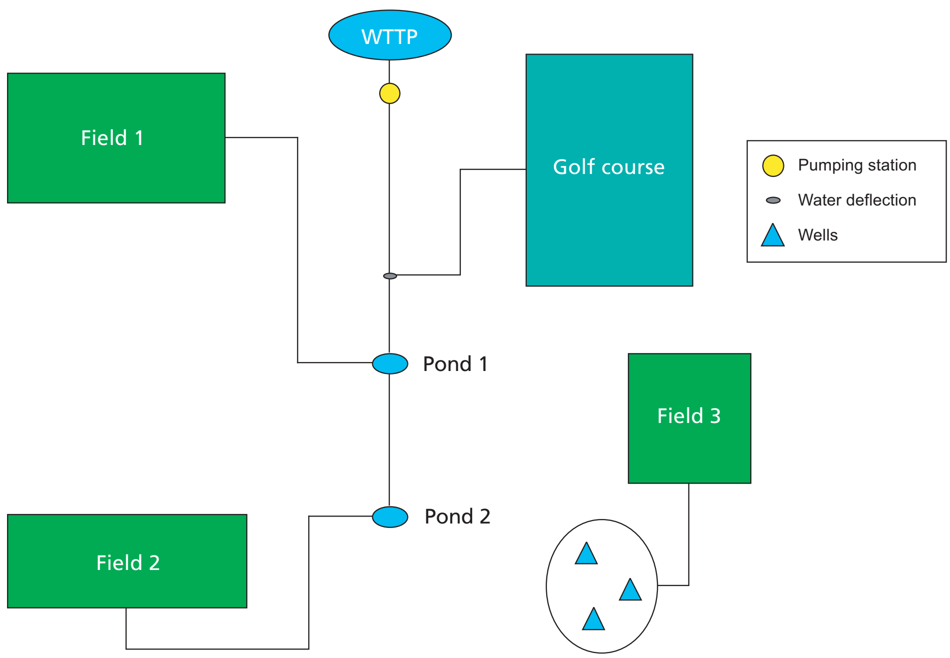
To the west of Blanes, another WWTP providing reclaimed water is located at the area of Mid-Costa Brava – Map 2.5. The *Castell-Platja d'Aro WWTP*, built in 1983, started to supply reclaimed water to farmers around its plant in 2003. This WWTP generates 5.50 Mm^3/yr of effluent, of which 0.98 Mm^3/yr is treated to tertiary level. The latter is used for agricultural irrigation (0.216 Mm^3/yr), golf course watering (0.510 Mm^3/yr) and groundwater recharge (0.263 Mm^3/yr). The remainder (3.54 Mm^3/yr) of secondary treated effluent is discharged into the sea. Farmers are mainly milk producers growing their own fodder, along with winter cereals and summer corn. The effluent from the Platja d'Aro WWTP is rich in nutrients, mainly nitrogen, which is particulary suitable for high nutrient demanding crops like corn. (Map 2.5)

2.2.2 The Mas Pijoan Farm – a microcosm of effluent reuse

The following is one example (Box 2.2 and Figure 2.2) of reclaimed water use in this area.

The farmer concerned no longer has to compete for groundwater with nearby residential and agricultural users, which caused difficulties at previous periods of high groundwater pumping rates. Reliability of water is an obvious benefit, and other farmers in the vicinity have shown interest in using reclaimed water (Muñoz and Sala 2007). Only 30-50% of total effluent from the Castell-Platja d'Aro WWTP is reused, indicating its potential to relieve situations such as that in the *municipality of Llagostera*, where groundwater is extracted from even greater depths - 80-120 metres - resulting in even greater pumping costs than in the Solius area.

FIGURE 2.2
Mas Pijoan irrigatin pipeline scheme (2006)



BOX 2.2

The Mas Pijoan Ranch

The Mas Pijoan Farm uses 0.137 Mm^3/yr of reclaimed water. The farm is located in Solius, a community belonging to Santa Cristina d'Aro municipality. The farm has 300 cattle on 150 ha, 40 ha of which are irrigated for barley, rye, oats and corn for fodder. Until 2003, the farm worked on 35 ha irrigated from the local aquifer. The yield of wells at the beginning of the summer could reach 150 m3/h, but would decrease during the season to 20m3/h, thus water could not be guaranteed at crucial crop growing stages.

Competition for water in the area was always high. Managers of the nearby golf courses shifted in 1998 to the use of reclaimed water due to recurrent shortages in their groundwater supplies and the prohibition on the use of groundwater for irrigation. The Mas Pijoan Farm found that connecting to the reclaimed water pipeline of the Costa Brava Golf Course was a reasonable solution – Figure 2.2. The Golf Course irrigation is in operation from 9 pm to 7 am, and the water is supplied to agriculture during the rest of the day. The agreement between the golf course and the farmer includes the operation of a reversible pumping station to ensure that the golf course can be supplied from the storage pond of Mas Pijoan using well water if necessary. The arrangement has provided mutual reliability and flexibility to both users.

The cost of connecting the existing pipeline to the storage pond was 70% funded by the European Agricultural Fund for Rural Development (EAFRD). Total private investment was 80,000 €. The farmer signed a 25 year service contract to share the use and associated operation and maintenance cost of the reclaimed water pipeline from the Golf course.

The cost of connecting the existing pipeline to the storage pond was 70% funded by the European Agricultural Fund for Rural Development (EAFRD). Total private investment was 80,000 €. The farmer signed a 25 year service contract to share the use and associated operation and maintenance cost of the reclaimed water pipeline from the Golf course.

Between 2003 and 2006 this arrangement enabled the farmer to increase total irrigated land from 35 ha to 41.6 ha, due to the reliability of the reclaimed water, amounting to 136,000 m3/yr in 2006, or 65% of his water needs. The balance of water used by the farm is drawn from groundwater supplies. Overall, the ranch is irrigated partly with reclaimed water, partly with well water and partly with a mixture of the two.

In areas such as these, where treated effluent is potentially part of the solution for irrigation needs, future plans for building or upgrading WWTPs should carefully weigh the optimal degree of treatment (*i.e.*, nutrient removal) since higher nutrient concentrations can make the reuse of treated wastewater more attractive from the viewpoint of fertilization, while it may *ipso facto* give rise to limitations on the water's use.

2.2.3 Options for the future

In the next two years ACA foresees an enlargement of the tertiary treatment capacity of the Platja d'Aro WWTP by 30%, reaching a flow rate of 20,000 m^3/day design capacity. Although reclaimed water has been used in this district since 1989, when the golf course started to irrigate with effluent, still only 22% of the total treated water in the plant is reused. Despite interest among potentially new users, the main limitation is the current tertiary treatment capacity. The greater availability of treated effluent would be of great interest to two municipalities (Castell-Platja d'Aro, Santa Cristina d'Aro), farmers in Llagostera and local golf courses.

ACA has been considering how to adjust the quantity and quality of wastewater treatment to satisfy potential demand. One option is to produce two different types of reclaimed water: one without nutrients for golf courses and municipalities and another one with nutrients for agricultural irrigation. The second option is producing only one denitrified effluent for all users. The first option is, however, uneconomic due to the high cost of running two treatment lines in the same plant which would not be justified in terms of chemical fertilizers saved by farmers.

A more realistic strategy for Platja d'Aro is an increase in the reclaimed water production with a single effluent quality, with the construction of new pumping stations, pipelines and water reservoirs. If the construction costs of these facilities were shared with each of the potential effluent users in proportion to their expected use, the situation would be as depicted in Table 2.5.

Of the total investment cost of around 7.7 M€, 16% would be required for the enlargement of tertiary treatment, 48% for the pipelines and 3^{3}% for storage facilities.

As part of the above scenario it has been decided to install a nutrient removal system at the Platja d'Aro WWTP. The reduction of the nutrient content of the reclaimed water by approximately 70% will diminish its value as fertilizer, but farmers would

MAP 2.5
Castell-Platja D'Aro WWTP

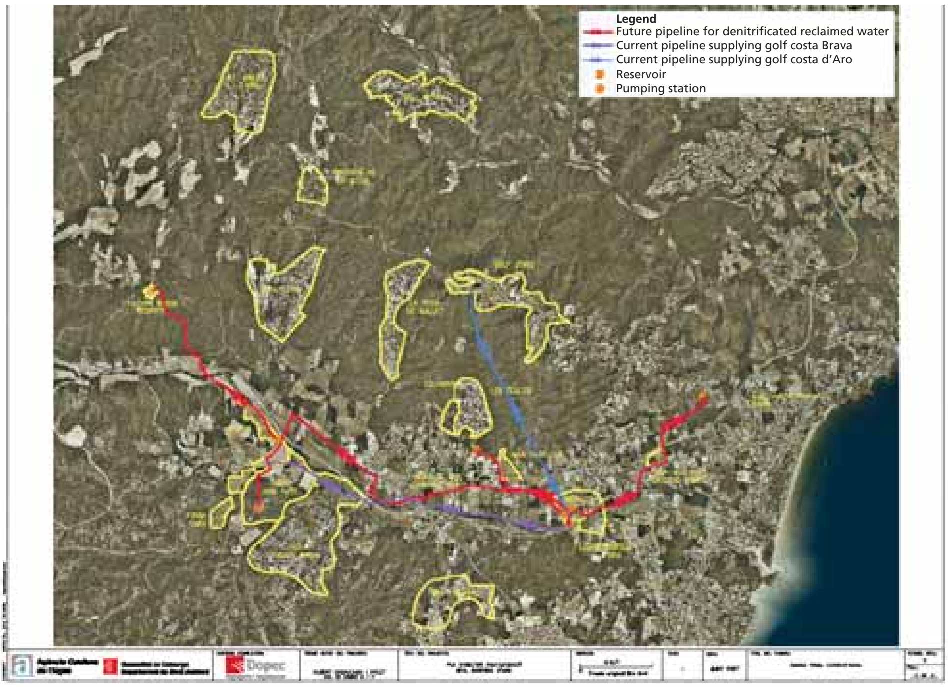


TABLE 2.5
Investment cost of expansion of reclaimed water use at Platja d'Aro area

	Requested reclaimed water Mm³/yr	Investment cost** M€
Agriculture	1.263	4.3
Municipalities	0.288	1.5
Golf courses	0.658	0.7
ACA*	1.0	1.2
Total	**3.209**	**7.7**

* Dedicated for improving the ecologic water flow of Ridaura river

** Rounded values

expect to raise income through the greater availability and reliability of the water. The shift from groundwater to reclaimed water for irrigation would avoid (or defer) the construction of a new pipeline to convey water from the Ter River to meet the increasing water demand in this area of Costa Brava. These benefits and cost savings are further discussed and quantified in Chapter 4.

2.3 MEXICO: MEXICO CITY & TULA VALLEY

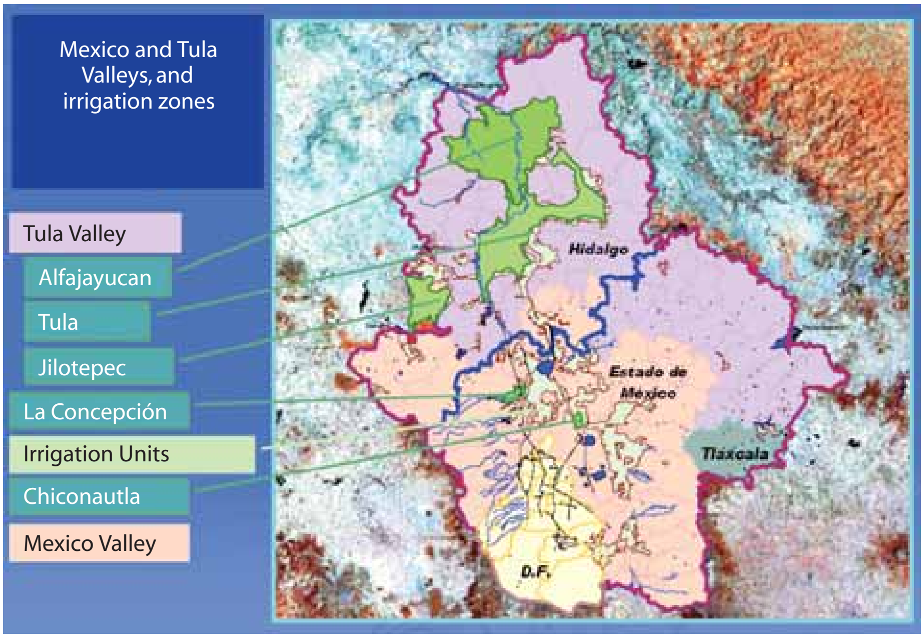
2.3.1. Site features

The Tula, Ajacuba and Alfajayucan irrigation districts are the product of raw wastewater from Mexico City. Almost 90 000 ha of irrigated land, previously with very poor soils, now depend on nearly 1 500 Mm^3/yr of Mexico City's untreated wastewater. Their other water sources are part of the Tula River's flow, a small amount of groundwater, and the reuse of irrigation returns (which in turn contain untreated wastewater). In effect, Mexico City uses these areas for the natural treatment and disposal of its wastewater (Map 2.6).

The transfer of Mexico City's untreated wastewater to the Tula Valley has grown over more than a century. This wastewater has stimulated agricultural production in the Mezquital Valley, the central part of the Tula River basin, where the Tula, Ajacuba and Alfajayucan irrigation districts are located.

During its flow from Mexico City to the Tula Valley the quality of the wastewater improves due to the processes of biological degradation, photo-dissociation, adsorption, absorption, oxydation, precipitation and dilution. These processes explain the *self-purifying capacity* of water when it flows in streams and through the soil, as well as when it is stored in impoundments. Notwithstanding this, health problems can arise: workers who shun sensible precautions and consumers of maize and alfalfa grown[1] with untreated wastewater are at risk of infection. With these risks in view, Mexico

Map 2.6
Mexico City and Tula Valley Irrigation Districts



[1] Against official advice and in contravention of regulations.

City is planning to build six treatment plants with a total capacity of 40 m^3/s, equivalent to 1 261 Mm^3/yr, covering almost all its wastewater.

The system of water use rights in the form of water dowries, assignments, and concessions does not stipulate any specific water *quality.* As a result, no irrigation district can legally complain about the quality of water they receive. Quite the contrary, since farmers prefer to have residual waters because of the organic matter they contain, which allows them to increase soil productivity without using fertilizers or soil enhancers.

Nevertheless, all wastewater discharges must comply with the Mexican Official Norm NOM-001-ECOL-1996 that establishes the maximum limits of contaminants that residual waters may discharge into national water bodies. The Federal Law of Rights contains a provision whereby wastewater dischargers who exceed the permitted contaminant concentrations pay charges, according to the Polluter Pays Principle.

Most of the cultivation in the Mexico and Tula Valleys involves long stalk and industrial crops. In the Mexico Valley the crop pattern is usually 58% corn, 30% green alfalfa, 5% oat forage, 2% grass, 2% barley, and the rest various other crops. In the Tula Valley the typical crop pattern is 42% green alfalfa, 39% corn, 7% grass, 3% oat forage, 2% barley, and the remainder miscellaneous crops. Furrow irrigation is the main method used in these two valleys.

The synergy between Mexico City and the Tula Valley evolved from the need to drain the renewable runoff in the closed basin where the city is located. Initially, centuries ago, this was confined to freshwater discharged from the city's streamflows, but over time untreated wastewater became part of the flow. By this means the city saved money in the treatment cost of urban residual water and meanwhile farmers benefited by applying it to land (wastewater *natural treatment*).

There are benefits to both parties. Mexico City saves the water treatment cost, but also gets rid of the excess water volumes it cannot store and reuse within its area. The Tula Valley, for its part, obtains an economic benefit from economizing in fertilizers from the use of nutrient-loaded waters, and also improves its soils, increases water infiltration to its aquifers, augments the baseflow in surface streamflows, and improves the yield of springs. On the debit side, the Tula region has experienced (in 1991) public health problems from farm workers who failed to use gloves and boots, domestic water users who were not connected to water supplies from a municipal water utility, and farmers that planted and sold unauthorized "restricted" crops.

It may be possible to recycle water for use in certain industrial processes and municipal uses able to take water of the quality concerned. Such measures would also diminish the abstraction of surface and ground waters. Water reuse is facilitated in those municipal areas which have separate water distribution networks: one for potable water and another for treated wastewater, to overcome the cost of distributing it through cistern trucks. Some Municipalities specify a certain order of preference for the reuse of treated wastewaters, which may override the economic incentives to use this source.

2.3.2 Impacts of water reclamation on agriculture

Table 2.6 indicates the additional volume of reclaimed, untreated wastewaters flowing into the Tula Valley from Mexico City. The recharge is partly due to infiltration while water is being conveyed by unlined rivers and channels at Tula Valley, and partly to leaching through the soil. In this region groundwater is mainly used for municipal purposes, while surface water goes to irrigated agriculture.

The total net water used in agriculture is around 749 Mm^3/yr, as delivered at the entrance of the irrigation district.

Wastewater has been used for irrigated agriculture in the Tula Valley for more than a century (since 1890) and there is no empirical basis for a "before and after" or "with and without" comparison. Moreover, the volume of wastewater used and the irrigated surface have changed continuously over this period. The economic benefits resulting

TABLE 2.6
Additional water availability in Tula Valley due to reclaimed wastewaters

Origin	Water availability Mm^3/yr	
	Surface water	Ground water
Natural streamflow	400.5	—
Natural recharge	—	268.5
Import of waste waters	1 368.7	—
Incidental recharge	—	788.0
Total	**1 769.2**	**1 056.5**

from using untreated wastewater instead of freshwater under the special conditions prevailing at Tula Valley would have to be assessed under hypothetical conditions. An assessment on this basis is made in Chapter 4.

A proposal has been made for returning groundwater to Mexico City from Tula Valley aquifers (Jiménez et al., 2004a). This would be water which would have undergone river aeration, reservoir sedimentation and solid aquifer treatment due to land application in irrigated agriculture. However, proposals such as this for the intersectoral exchange of water entitlements are not feasible for hydrological and legal reasons in Mexico at yet.

Firstly, Tula Valley is downstream of Mexico City and there would be a prohibitive cost in pumping water up to the city. Secondly, Tula Valley farmers lack the legal powers to trade local groundwater entitlements in return for treated wastewater or any other benefits. At the point where water reaches a national watercourse, its jurisdiction reverts to the Federal Government which has the power to concede (and in practice has conceded) the water to third parties with valid water use rights. A case in point is the downstream Zimapán hydroelectric project with a concession of 839 Mm^3/yr (Mexico, 2004b) of untreated wastewaters, comprising all the irrigation returns plus the streamflow from local rainfall. Other rights are held further downstream in Tampico City and beyond. Thirdly, Tula Valley farmers have legal entitlements to receive the wastewater, treated or untreated, so it is difficult to see what the *quid pro quo* for the exchange of groundwater would be.

In comparison with the Durango site (see below) where farmers can potentially replace their use of freshwater with reclaimed water, at Tula Valley wastewater is already the dominant resource for irrigation. While at the Durango site it is possible to demonstrate significant economic net benefits from intersectoral water transfer (see Chapter 4), at Tula Valley options for exchanging freshwater entitlements for wastewater from Mexico-City are so far lacking.

2.4 MEXICO: GUANAJUATO CITY & LA PURISIMA IRRIGATION PROJECT

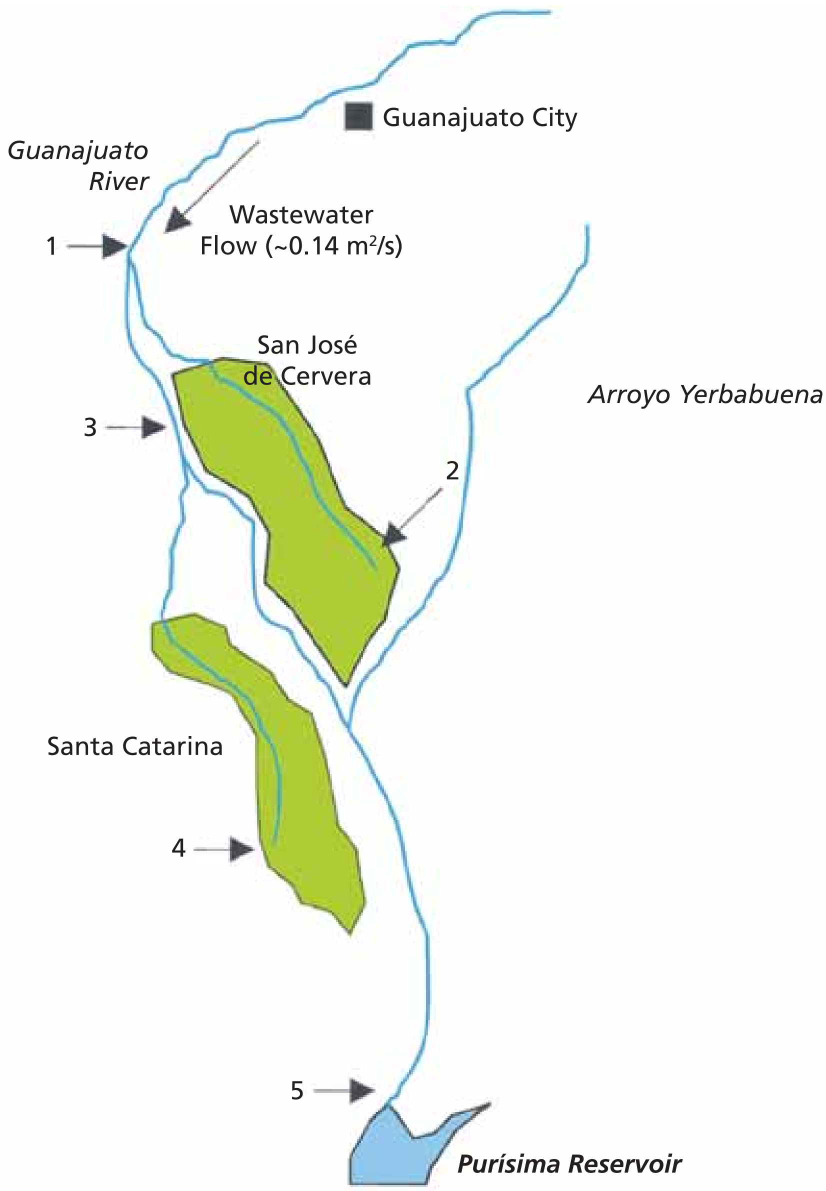
2.4.1 Site features

Guanajuato city lies 300 km North-West of the federal capital. Its agreement with the La Purísima Irrigation Module started as a flood prevention scheme (Map 2.7). La Purísima irrigation module is part of Irrigation District 011 Alto Río Lerma, and is located downstrean of the reservoir La Purísima reservoir was built to protect the downstream city of Irapuato, ten years after it suffered a flooding and five years after the establishment of the irrigation module.

The cropping pattern in the irrigation project has not changed since the time when farmers diverted water directly from the Guanajuato River. Initially the reservoir received both the rainfed streamflows from the upper catchment and the untreated wastewaters from the city of Guanjuato. Recently it has been impounding partially treated effluent from Guanajuato City. Presently, about 43% of this effluent is treated and this was planned to rise to 90% by 2009.

The WWTP built in 2002 treats Guanajuato City wastewater and the residual waters of metropolitan areas located upstream. The plant discharges around 4.3 Mm^3/yr to the Guanajuato River. The first phase of a second treatment plant is due for completion imminently, which will have a treatment capacity of 3.15 Mm^3/yr. Plans for the second phase of this plant would add another 3.15 Mm^3/yr of treated discharges. With the completion of the whole project, the volume of treated effluent would amount to about 10.7 Mm^3/yr, more than 90% of the wastewater of Guanajuato city and metropolitan areas projected for 2010.

MAP 2.7
Irrigation Units Downstream Guanajuato City



This volume of water would support about 1 070 ha of grain farming using furrow irrigation. The La Purísima irrigation module has water rights for 25.2 Mm^3/yr to service an area of around 4 000 hectares. From La Purisima reservoir's total capacity of 195.7 Mm^3, 85.7 Mm^3 is reserved for flood control, and its active capacity is limited to 110 Mm^3. From this storage volume, 25 Mm^3 is reserved for sediments (dead capacity), leaving only 85 Mm^3 for irrigation purposes. The water source for La Purísima irrigation module is the water stored at La Purísima reservoir, whether it comes from rainfed streamflows, agricultural return flows or municipal wastewater, treated or untreated.

At La Purísima Module the main crops are wheat (83%), barley (11%) and tomatillo (4%). However, there is a trend to reduce wheat in favour of barley, which needs less water. The main irrigation channel has enough potential energy to enable sprinkler irrigation or even to produce hydropower with minicentrals. All the water used at La Purísima Module is from surface sources.

In this case, as in the Tula Valley situation, the "win-win" potential consists of the benefits to farmers from the use of nutrient-laden wastewater, and the benefit to the city from being able to dispose of its wastewater in this way. Recycling water for use by farmers does not and would not affect the overall volume of water they receive. Their main concern will be the impact on their operations of receiving a mixture of water with a much higher content of treated effluent from the new WWTP, which would limit any benefits from fertilization. In theory, farmers could receive offsetting gains from the freedom to grow a wider range of crops, with fewer public health hazards. The recent progressive increase in the proportion of wastewater treated in the city is actually reducing the "win-win" range, since the city has decided to incur the cost of treating wastewater however it is disposed, while farmers receive a mixture which could be worth less to them than previously.

As in the Tula Valley, the conditions for a water/wastewater exchange between Guanajuato city and the farmers in La Purisima are absent, for several reasons. Firstly, farmers have no rights to freshwater to exchange with the city – their water comes from the reservoir which contains a mixture of untreated and treated wastewater and water from other sources. Secondly, they have rights to water in the reservoir, whatever its origin and whether the wastewater in it is treated or not. Thirdly, the City has no alternative to returning its wastewater, treated as now required by law, to the river, and cannot deny its use to downstream irrigators.

2.5 DURANGO CITY & GUADELUPE VICTORIA IRRIGATION MODULE

2.5.1 Background

Negotiations between Durango City (around 800 km north-west of the federal capital) and the Left Margin of the Guadalupe Victoria Irrigation Module (part of Irrigation District 052 in the State of Durango, see Map 2.8) began in response to recurrent droughts, and it has evolved into an arrangement beneficial to both parties. (Map 2.8)

The left margin of the Guadalupe Victoria Irrigation Module, which is adjacent to the city of Durango, had been seeking more water resources by increasing the active capacity of the Guadalupe Victoria reservoir. This was finally accomplished in 2006 with an increase in the height of the spillway crest, allowing storage of an additional 10 Mm^3 of water. Prior to that, the irrigators had an arrangement to use the city's treated wastewater from a WWTP that started operations in 1995. In 2000 an inter-connector pipe was built from the aerated lagoons of the WWTP to the left margin main channel flowing from Guadalupe Victoria reservoir.

At the present time, consideration is being given to the possibility of Durango city acquiring rights to the clear surface waters originally granted as a concession to irrigated agriculture in exchange for reclaimed water to be used by the farmers. Such an exchange of water use rights would have several benefits: the aquifer would cease to be overexploited; the municipality would get water of a good quality at a smaller cost; energy would be saved in reduced pumping of the aquifer; and the irrigators would receive some biodegradable nutrient loads for their crops.

2.5.2 Site features

Irrigation District 052 in the State of Durango has a command area of 18 504 ha and water use rights for 134 383 Mm^3/yr. The Guadalupe Victoria irrigation module adjacent to Durango City has a command area of 9 399.75 ha, about 2 775 in the *left margin* and 6 625 in the right margin. The left margin, with 504 irrigators, is the closest part of the irrigation module to Durango City. The source of water for the left margin is the Guadalupe Victoria reservoir via the left and right margin channels. In addition, there are 167 farmers on 663 ha with precarious unofficial rights receiving the irrigation service only when there are water surpluses. This study is limited to the left margin side of the irrigation module, as this is the only one using residual water and in a position to exchange its rights with Durango City.

MAP 2.8
Durango City and Guadalupe Victoria Irrigation Module

The left margin has water rights for 63.259 Mm^3/yr, coming from Tunal River streamflows and stored at Guadalupe Victoria reservoir. This reservoir was built in 1962 with a nominal capacity of 80 Mm^3, and an active capacity of 65 Mm^3. In 2006, the total capacity was increased to 93 Mm^3, of which 11.9 Mm^3 is earmarked for flood control, and 4 Mm^3 is dead capacity, leaving 77.1 Mm^3 as active capacity.

The city of Durango has a population of about 526 700, and its drinking water is provided from an assignment of 61.3 Mm^3/yr of groundwater. The city is entitled to discharge 48.25 Mm^3/yr of wastewater effluent to the Sauceda and Durango rivers. Its aquifer is becoming seriously depleted: some decades ago the 76 wells drilled at the Guadiana Valley were pumping at a depth of 30 to 40 meters; whereas, now pumping is at depths of 100 to 120 meters, and at that depth the water has larger salt and mineral concentrations. It is estimated that the aquifer depletion rate is of the order of 30 centimeters per year, and the current overdraft is 34.91 Mm^3/yr.

The main crops produced in the Guadalupe Victoria Irrigation Module are corn, 56%, sorghum, 18%, beans, 13%, alfalfa, 8%, and oats, 5%. Although the 63 Mm^3/yr of surface water concession is enough for about 6 000 ha sown with basic grains using furrow irrigation, there have been some periods of water scarcity which have led farmers to use effluent from the city of Durango.

In January, 1998, Durango City water and wastewater utility started operating an aerated lagoon WWTP with a capacity of 63.1 Mm^3/yr which has been treating on average 48.25 Mm^3/yr. The plant, with six lagoons of 200 x 100 x 4.5 m and one reservoir of 400 x 300 x 1.5 m, has the capacity to give primary treatment to all the water used for municipal purposes in Durango City and to furnish about 76.3% of the water requirements or the adjacent irrigated areas.

In 2000 an inter-connector pipeline was built between the WWTP and the left principal channel from the Guadalupe Victoria reservoir to convey about 10 Mm3/yr of the treated wastewater to the irrigation module. This was the subject of an informal agreement between the municipal utility and the farmers of Guadalupe Victoria irrigation module2. At present, it is estimated that the Guadalupe Victoria irrigation module uses around 14 to 18 Mm^3/yr of the reclaimed water from the city, which is more than the amount stipulated in the agreement.

2.5.3 Scope for intersectoral water exchanges

The Guadalupe Victoria irrigation module currently uses water from various sources: freshwater from the Guadalupe Victoria reservoir, groundwater from the Guadiana Valley aquifer, treated effluent from Durango City, and untreated urban wastewater diverted from the Acequia Grande creek. The water quality both from the WWTP and the Acequia Grande creek exceeds the amount of fecal coliforms allowed by the Mexican Official Norm (NOM-001-ECOL-1996) for the discharge of effluent to freshwater bodies. But they are within the limits allowed by NOM-002-ECOL-1996 applying to forage and long stalk crops, and even for grasses, provided there is an interval between irrigation and grazing of 14 to 20 days. The BOD of the WWTP effluent (between 50 and 90 mg/l) is well within the norm of 150 mg/l. The municipality of Durango is planning the construction of a second WWTP in the southern part of the city.

One possible scenario is to use part of the surface water stored at Guadalupe Victoria reservoir to supply municipal requirements, avoiding the current over-exploitation of the Guadiana Valley aquifer. At present the city's assignment of water for drinking purposes (61.292 Mm^3/yr) accounts for practically the whole of the aquifer's annual

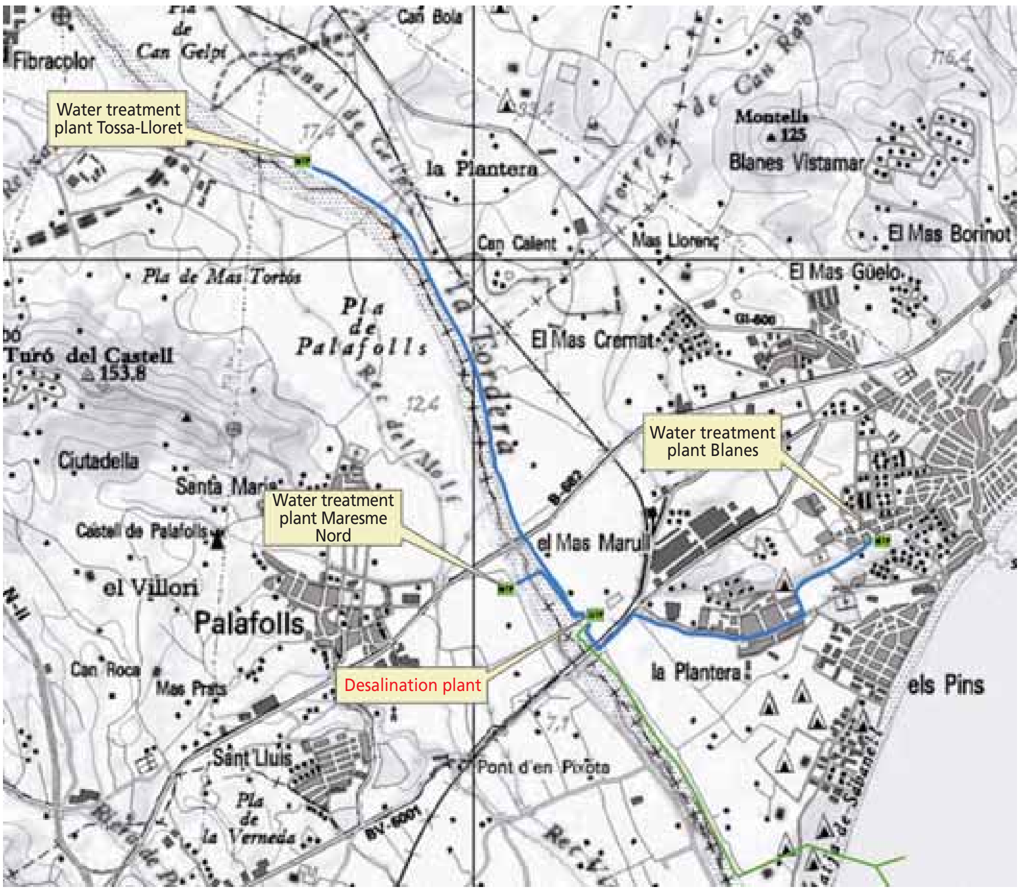
[2] The legal standing of this agreement is unclear: the constitutional powers of the municipality to award a concession of this type is uncertain, and it was done in the absence of approval from the National Water Commission.

recharge. The situation would be eased by an agreement to cover at least 10 Mm^3/yr of drinking water requirements with the surface streamflows stored at the Guadalupe Victoria reservoir, and to supply at least 10 Mm^3/yr of treated urban residual waters to the Guadalupe Victoria irrigation module. The city would keep a small number of wells (10-15) for industrial use.

From the farmers' viewpoint, the use of reclaimed water has enabled increases (up to 30%) in the production of corn, alfalfa and oats compared to the alternative, with a saving of up to 50% in the cost of fertilizer. This indicates the scale of potential farmers' benefits from the arrangement. However, the Durango water utility's attempts to recover its treatment costs from the farmers (estimated to be $320 000/month) have not been agreed. Two difficulties have arisen. Firstly, there is no proper legal basis for charging agriculture users since the city has to treat its wastewaters whether they are used subsequently or not. Secondly, there is no feasible alternative outlet for the effluent since Durango City cannot divert the natural course of the river, nor withhold residual waters nor grant water use rights to anyone anywhere. (In the latter context, an approach to a thermal power plant in the region with a view to its use of the wastewater for cooling purposes has not borne fruit).

MAP 2.9

Network between Blanes desalination plant and water supplier in Tordera Delta



2.5.4 Longer term prospects

The current arrangement described above involves a limited use of effluent by farmers, subject to an informal agreement for 10 Mm^3/yr, though in practice running at more than this. However, in the long run, a feasible arrangement may be to cover practically all the water required by both parties, whereby all municipal water would be supplied from the reservoir and all the reclaimed water would be used in irrigated agriculture. As noted, the full Guadalupe Victoria irrigation module has a surface freshwater concession of 63.259 Mm^3/yr and the city of Durango a ground water assignment of 61.292 Mm^3/yr.

The second WWTP now being planned would increase the available volume of wastewater. The inter-connector pipeline would need to be enlarged and extended to serve the entire command area of the Guadalupe Victoria irrigation module comprising 9 399 ha, and a regulation pond would also be required. The scope for recovering any of these costs from farmers is not expected since the City is legally required to cover the costs of sanitation.

In a longer term perspective, there is scope to increase the efficiency of water use in irrigation through drip irrigation, sprinklers, the use of centre- pivot or lateral-move systems and other methods. The greater use of greenhouses and changes in the cropping pattern would bring benefits to farmers and ease their adjustment to growing food under water scarcity conditions and competition for water use.

2.6 CONCLUDING OVERVIEW OF CASE STUDIES

Table 2.7 offers an overview of the five case studies, with a preliminary assessment of their potential for the reuse of treated effluent in agriculture, and the likelihood of farmers trading their existing rights for freshwater in exchange for recycled water.

Motives and concerns. Growing water scarcity is a concern in three of the sites, pollution of rivers in three and aquifer stress in four. Public health issues have not, however, been prominent, apart from an isolated episode in the Tula Valley in 1991.

Current usage of recycled water. In the Spanish cases, effluent is only used in agriculture during drought years, diluted with groundwater. However, it is used indirectly through aquifer recharge. In the Mexican cases, untreated effluent is used on a large scale in the Tula Valley, and treated wastewater is used (in one case diluted) in the other two sites.

Availability of recycled water for further reuse. All the sites are increasing their capacity for recycling water. Some have recently added capacity, others have new capacity either actively planned or under implementation.

Degree of wastewater treatment. Both the Spanish sites treat to tertiary level (with the exception of one WWTP which treats to secondary level), in compliance with EU directives. Mexico City's current programme of investment in WWTPs is based on tertiary treatment,[3] whereas Durango currently treats to primary and Guanaguato to secondary levels.

Feasibility of effluent reuse in agriculture.[4] This refers to any technical, legal, or public health reasons affecting effluent reuse including the availability of infrastructure to convey effluent to the targeted users. Effluent reuse in agriculture seems to be feasible in all the sites subject to any produce restrictions of operational conditions required for public health and environmental reasons.

[3] used indirectly in Gava Viladecans for aquifer recharge

[4] At present about 12% of the collected wastewater is treated (139Mm^3/yr), of which 31 is re-used in aquifer recharge, 26 in watering green areas, 25 for filling lakes, 23 for irrigation within city boundaries, 11 in industry, 7 in commerce and 16 is lost to leakage.

Potential for the intersectoral exchange of freshwater rights for recycled water. All [6]the sites have the potential (in some cases already realised) for "win-win" arrangements between cities, farmers and the environment involving the use of reclaimed water. Concerning the specific issue of the exchange of farmers' freshwater rights for reclaimed water from the cities, the situation sketched in this chapter is highly varied. In the Spanish cases, recycled water reuse has stronger prospects for environmental purposes than directly for agriculture, although there is some scope for the latter. In Mexico the potential for an exchange is clearest in Durango. In the other two cases, farmers already make extensive use of recycled water, in one case mixed with water from other sources. This arrangement will continue to be part of the two cities' wastewater treatment and disposal plans, which they are legally obliged to do, and which confers continuing benefits to farmers.

TABLE 2.7
Overview of case studies

	Llobregat	**Tordera Delta**	**Mexico City/ Tula V.**	**Guanajuato**	**Durango**
Motives & concerns:					
water shortages	Yes	Yes	No	Yes-	Yes
pollution of rivers	Yes	-	Yes	Yes	-
aquifer stress	Yes	Yes	Yes	-	Yes
public health	-	-	No	-	-
Current usage of effluent for:					
agriculture	Emergency only[4]	Minimal	High	High (diluted)	Some
environment/aquifer	High	Some	Some	-	-
other (e.g. golf)	-	Some	-	-	-
Availability of effluent (high, low, none)	High	(planned) High	High	Rising	Rising
Degree of wastewater treatment (untreated=0, primary = 1, secondary =2, tertiary =3)	3 (2 in G-V)	3	0* (but heavy investment in treatment planned)	2	1
Feasibility (technical, legal, health) of effluent reuse in agriculture.	High	High	High	High	High
Potential for inter-sectoral exchange of water rights between cities and:					
agriculture	Some	Some	Some	Low	High
environment	High	High	Some	Low	Some
other	-	-	Some	Low	-

n.b.further explanation of categories and entries in text

* 12% is 3

Chapter 3

An economic methodology for assessing the feasibility of using recycled water in agriculture

It is assumed that readers of this Chapter have some familiarity with elementary cost-benefit analysis (CBA), as used by applied economists, municipal and civil engineers, agronomists, public health specialists, and professionals from other disciplines relevant to the topic of this report. It may also be used by such readers better to understand or assess the technical merit of studies that are done by others, rather than actually carrying out such studies themselves.

The Chapter does not start from scratch, but explains those specific features of CBA relevant to the topic of this report, and some potentially difficult issues in its application. To the maximum extent possible, the text uses simple and clear language, avoids jargon and all unnecessary mathematical notation.

Further guidance on specific aspects of CBA can be found in the Appendix to this chapter, to which references are made in brackets (e.g. 3A3) in the main text.

3.1 INTRODUCTION: A THREE-FOLD APPROACH

Proposals to use recycled water in agriculture or for other purposes need to be *economically justified, cost-effective* and *financially feasible*. This chapter explains how these three criteria can be applied in practice.

The economic justification will be carried out using a framework of cost-benefit analysis from the standpoint of an agency acting in the overall public interest and applying the principles of Integrated Water Resource Management (IWRM). Such a hypothetical agency could be a national Ministry of Planning or a regional water authority[1], concerned whether the project was "worth doing" on national cost-benefit grounds. In many key respects this perspective coincides with a watershed viewpoint, since it considers the water cycle in its entirety and aims to optimise the use of water for all major purposes – human household needs, agricultural irrigation, navigation, flood control, industrial use, hydropower, wildlife and the various other environmental demands, consistent with IWRM.

The report takes a particular segment of this spectrum, namely, wastewater generated by urban users which is available for treatment and recycling to farmers, or for releasing into the natural environment (for aquifer recharge, river and wetland replenishment, creating a hydraulic barrier to coastal saline intrusion, etc.). The principles explained in this chapter could equally be used in the analysis of projects at other points or other users in the water cycle, such as recycling irrigation effluent back into agriculture, or reusing urban wastewater for further urban or industrial purposes, etc.

1 Sub-national institutions may be "captured" by local, regional, sectoral or other sectional interests and hence may not fully embody the "national interest". In both the countries represented by the case studies – Spain and Mexico – the regions are autonomous and have considerable powers vis-a-vis other regions and central government. In both countries water is an issue guaranteed to arouse strong regional feelings. This will be an important consideration for the assessment of financial feasibility, but the assumption of "national interest" remains a crucial part of the economic justification, especially where central government or external funding is involved.

Once a scheme can be demonstrated to be worth doing, on the grounds that its benefits exceed its costs, the next step is to establish that it is ***cost-effective*** – that it achieves its objectives at minimum costs[2]. This entails an analysis of the preferred project in comparison with other, alternative, methods of meeting the objectives. A number of the case studies examined in this report (Chapters 2 and 4) demonstrate the cost superiority of the preferred project in relation to the next best alternative, and present the result as an *avoided cost* of the preferred project.[3]

The final hurdle for the preferred project, once it can be shown to be worth doing and cost-effective, is to considering its financial feasibility. This takes the analysis into a different realm, in which the narrower sectional interests of various stakeholder groups are considered. Its main elements are:

- Assessment of the project's impact on the financial status of key stakeholders: central government, regional water boards, municipal utilities, farmers etc., including identification of the main gainers and losers, with estimates of their gain/loss. It should include an estimation of the financial implications of the project for public capital and recurrent budgets. This part of the analysis provides a basis for understanding the incentives of crucial stakeholders – especially farmers - to support, or resist, the project.
- Proposals for financial instruments and transfers to create equitable conditions to make the project acceptable, and to provide suitable incentives for its major stakeholders. This would include an assessment of the scope and modalities for water charges, other financial levies or, conversely, subsidies, and innovative financial mechanisms such as payments for environmental services for farmers or other stakeholders.
- Finally, considering the above, proposals should be made for funding the project, considering the various sources available, and the most appropriate solution for the case in question.

3.2 ECONOMIC APPRAISAL: COST-BENEFIT ANALYSIS (CBA)

The economic appraisal (EA) of projects is a tool for making choice in the allocation of scarce resources. It is a method of systematically assessing and comparing proposals[4] using objective and rational criteria. It can apply to a single and well-defined act of investment (*a project*), a group or series of projects (*an investment programme*) or even a *policy* or piece of *legislation*. It can also be used to justify specific items of recurrent spending. The pre-conditions for the use of EA are that the proposal should be coherent, have clear boundaries, its effects should be identifiable, and the bulk of costs and benefits should be quantifiable and capable of valuation.

Most kinds of EA use a *cost-benefit* framework. As the name implies, this identifies and compares the costs and benefits expected from the proposal and provides a decision rule – benefits should exceed costs – and a criterion for comparing and ranking proposals – the size of net benefits (*Net Present Value)*. The latter can also be expressed as a Benefit-Cost Ratio.

CBA rests on certain basic concepts:

- There are always *alternatives*. The analyst should ensure that other solutions have been considered and that the proposal under scrutiny is the best available. The proposal should be the most *effective* in achieving the aims of the project, and/or the most *feasible* (*e.g.* practical, timely, acceptable), as well as being

[2] Or costs that are acceptable or affordable to the public

[3] Note in this context that avoided cost is only a valid criterion if the preferred project is worth doing in the first place. If it fails on CBA grounds, avoided cost is irrelevant.

[4] In the remainder of this Guide, the terms proposals, projects and investments can be used interchangeably.

the most *cost-effective* of options available. Ideally, the CBA will analyse the alternative options and produce a ranking based on their respective net benefits. Where this is not feasible – in the common case of a yes/no decision on a single project – some preliminary consideration should have been given to the obvious alternatives (see below).

- *Do nothing* is one option to be considered. The net costs and benefits of the proposal should be carefully compared to the effects of "doing nothing". This may mean literally what it says, but it is more likely to involve some minimum level of activity or a continuation along the current trajectory - "business as usual". The *without project scenario* provides the benchmark against which the project is judged. If this scenario is badly drawn the case for the project will be flawed.
- Resources used in the project normally have alternative uses. They should be valued at their *opportunity cost*, which is their value to society in their best alternative use. Even currently unemployed resources, such as idle land or temporarily unemployed workers, have a positive opportunity cost taking a longer view.
- CBA is a *quantitative* decision tool. Costs and benefits should be quantified as far as is feasible. They should be expressed in common units to achieve rigour, objectivity and consistency. Not all costs and benefits can be quantified or valued, and the presentation of results should be very clear about unquantified items and their importance, which may be decisive. This applies particularly to environmental amenity and public health impacts.
- The treatment of *time* is an integral feature of CBA, especially for assets with long lives, and/or streams of benefits and costs extending well into the future, such as irrigation systems, WWTPs and other items of water infrastructure. The timing of costs and benefits, and how these streams compare, is crucial information. Hence the use of *discounting*, which reflects both society's time preference and what the capital employed in the project could earn in alternative uses.

The standpoint adopted in this report is that of an agency providing integrated water services to a variety of users (including the environment), as opposed to that of an operator of a stand-alone facility. This agency will be concerned with the impact of a new investment on its total operations, rather than on the cash flow of facilities considered in isolation. The total benefit from using recycled water will vary in each situation, but will usually be a mixture of avoided costs and new benefits[5].

In principle, in a situation of static demand, all benefits will consist of *avoided costs*, namely, savings in the cost of supplying a given demand. Where, conversely, demand for water is on an increasing trend, the reuse of treated wastewater enables freshwater to be exchanged for use in new purposes – by municipalities, industry, the expansion of irrigated farming, or for various environmental purposes. These are *new benefits.*

Where there is growing demand for water, aquifer depletion, or growing environmental "water deficits" – typified by all the case studies in this report – it is very likely that fresh water "released" or exchanged by reuse projects will be used for other purposes[6]. Thus the more common situation is where benefits consist of a mixture of avoided cost and new benefits. The balance between types of benefit, and the size of each, depends on the assumptions made about the growth in demand for water in these various uses.

[5] An avoided cost is treated as a benefit

[6] Even if no conscious decision for conservation is made, less abstraction of water from surface bodies or groundwater will increase the retention of water in aquifers, or increase river levels. These effects could create environmental benefits.

3.2.1 Benefits (see also 3A6)7

The major types of benefit that can be expected from the reuse of treated wastewater are:

- **The avoided cost of abstraction, transmission, treatment, and distribution of fresh water**. These avoided costs include both capital and recurrent cost items, divided between public authorities responsible for the delivery of water to irrigators' fields, and the farmers (or their organisations) where they abstract or pump their own supplies. Farmers may avoid the costs of groundwater pumping – where they take recycled water instead – though they may still need some pumping to operate their irrigation devices such as drips. Farmers may also benefit from pumping at shallower depths – where the water is used to recharge the aquifer.
- **Savings in the cost of fertilizer due to the nutrient content of wastewater**. Organic matter, nitrogen and phosphorus left in wastewater has been shown to be beneficial to the productivity of crops, and saves some of the cost of artificial fertilizer[8]. These benefits will be reduced from higher standards of treatment that removes some of these nutrients. Not all the nutrient present may be used by the crop, and there may also be long term detrimental effects related to soil salinity and heavy metals from the presence of certain elements in the effluent, which should be recorded on the cost side of the balance (see below).
- **Savings in the cost of wastewater treatment** if nutrients are left in the effluent. (This benefit depends on the quality of the wastewater and the pre-existing level of treatment: in other situations, it may be necessary to *increase* the level of treatment in order to make it acceptable for reuse).
- **The greater reliability of reused wastewater**, compared to supplies obtained from other sources. This cannot be guaranteed in every case (a shortage of freshwater in a drought will reduce the volume of wastewater available) but where it does arise, a *proxy estimate* for reliability might be the avoided cost of water storage as insurance, or the avoided losses from reduced harvests.
- **Environmental benefits** from reduced abstraction from rivers or aquifers, or from point source pollution of rivers and coastal systems from the effluent of wastewater treatment plants. (In many countries untreated or partially-treated effluent from WWTPs is the largest polluter of downstream waters). If the use of reclaimed water requires treatment to a higher level than would otherwise be done, it is justifiable to credit some environmental benefit to offset the extra cost of treatment. But if the extra treatment merely raises the standard of effluent to that required by national or regional (*e.g.* European Union) legislation, the environmental benefits from higher wastewater treatment cannot legitimately be credited to the project.

3.2.2 Costs (see also 3A5)

The typical costs involved in these projects are:

- **Capital costs entailed in treatment of the wastewater** (either to secondary or tertiary level), involving adjustments to an existing WWTP or the installation of a new unit. Where an existing WWTP which theoretically has the appropriate capacity is not working effectively, repair and restitution may be necessary.
- Recurring **operational or routine maintenance costs of operating treatment facilities** (typically, power, chemicals, labour, raw materials, etc.). It should be recalled that some recent state-of-the-art facilities have a high degree of energy

[7] See also, Hussain *et. al.* (2001 and 2002)

[8] Molden (2007) reports research results in Mexico and Pakistan (pp 438, 439)

recycling (*e.g.* from burning the methane by-product for energy) which has the effect of lowering (and in extreme cases eliminating) the net cost of operating wastewater treatment works.

- Installation of **new infrastructure for distributing the treated effluent** from the WWTP to the irrigation areas (pipes, tanks, reservoirs, pumps, etc.) and recurring costs entailed (power for pumping, cleaning, etc.).
- **Cost of produce restrictions** – farmers' loss of income due to any restrictions on the type of crops they can irrigate with the effluent.
- Any **longer term effect on soil structure and fertility** from elements in the effluent which are not dealt with at the treatment stage (*e.g.* by desalination to control salinity), which diminish farmers' future incomes.
- **Costs of other public health measures** entailed in handling and using treated effluent (*e.g.* public information, and the extra monitoring entailed, which could be onerous in some countries). It is simplest to assume that produce restrictions and public health measures successfully eliminate public health risk. Otherwise, it will be necessary to estimate public health costs directly (see next item).
- **Residual public health costs** from the reuse of effluent, after all other produce restrictions and public health and safety measures. A common approach is to estimate the probable increase in DALYs[9] due to this project and find some means of valuing these (see section 3.2.3. and 3A4 in the appendix to this chapter).
- **Environmental costs,** *e.g.* from reduced dilution of rivers and other water bodies due to the diversion of effluent to irrigators. Although wastewater reuse has a number of environmental benefits, which would predominate over costs in many cases, the interruption of the water cycle that it entails could cause harm to aquatic habitats and the morphology of rivers and coastal waters if the volume is high. These effects are highly site-specific. For guidance on the valuation of these costs see 3.2.3. and 3A3 in the appendix to this chapter.

The analysis should indicate the distribution of the above costs between the main stakeholders - farmers, water utilities, local governments, regional water authorities, etc. In theory, the existence of a net benefit enables the gainers from a project to compensate the losers, though in reality it can be difficult to design and implement compensation mechanisms. Even so, it is important to identify where costs fall in relation to benefits.

3.2.3 Some practical steps for the use of CBA or Cost-Effective Analysis (CEA) in effluent reuse projects

Data for the abovementioned benefits and costs should be compiled and entered in the analysis in the following sequence, depending on whether CBA or CEA is chosen as the decision criterion.

CBA consists of:

- estimating all the costs and benefits attributable to a project, as in sections 3.2.1 and 3.2.2 above, and applying the appropriate valuation method (see below);
- adjusting market values to produce economic values and expressing values in common currency units and constant prices;
- allocating costs and benefits to each year of the project and producing a net sum for each year (positive or negative);
- *discounting* the annual flows by an appropriate discount rate to produce a *net present value* (see also 3A7);
- justifying the project by the appropriate decision rule – positive net present value or Benefit-Cost Ratio.

[9] Disability-Adjusted Life Years

CEA involves:

- defining the objective of the project expressed in quantitative terms (*e.g.* delivering an extra x m^3 per day to farmers, urban households, etc.;
- identifying the possible options for achieving the above objectives and producing a short list of preferred alternatives;
- estimating the costs of the various options using the categories in section 3.2.2.; and
- choosing the one with the least (discounted) total cost of achieving the particular objective. The total cost can be divided by the output or physical quantities involved in the project, where this is feasible (*e.g.* volume of effluent, or freshwater exchanged) to produce a cost per unit.

This section discusses some of the important practical issues involved in conducting CBA and CEA in this sector. A fuller and more detailed account can be found in the appendix to this chapter.

Determining economic values (see also 3A1)

Prices found in markets and actually paid by farmers, households, governments, etc. are often a misleading guide to the underlying economic values of the goods and services involved. In broad terms, the value of an *output* is measured by what buyers are *willing to pay* for it, while the value of an *input* to production is its *opportunity cost* to other members of society. (Its value in the next best alternative use - what other potential users forfeit from its use for the purpose in question).

The prices of outputs and inputs used in effluent reuse projects may be distorted by taxes, subsidies, quotas, monopoly power, controls and other factors which cause actual prices to diverge from their economic levels as defined above. Distortions are common in agriculture, where crop prices can be fixed above or below prevailing free market levels, while inputs of equipment, supplies, irrigation water and electricity (for pumping) may be subsidized in various ways. In these circumstances, farmers' net incomes can be an unreliable indicator of a project's economic justification in national CBA terms. In principle, unsubsidized free-market prices should be applied to all major outputs and inputs of agriculture.

Likewise, for the increased use of water by urban and industrial consumers, the household price of water is typically less than its economic cost of supply. It is often also lower than people's willingness to pay for it, where this has been surveyed. The nominal tariff for water, or alternatively the average revenue received per unit sold10, can be taken as a minimum value of water for urban use. Where this is evidently too low, some upward adjustment can be made for appraisal purposes, using other national or international yardsticks. The same applies to water sold for industrial use, though this is less likely to be subsidized, and is often a source of cross-subsidy to households and institutional users.

Taxes, subsidies & transfer payments (see also 3A2)

Values should exclude taxes, subsidies and other transfer payments on the grounds that, for the nation as a whole, they are merely transfer payments between different groups. These transfers do not represent real scarcity values – on the contrary they may disguise the true opportunity cost of the item. Income and corporate taxes should be excluded from the analysis, as well as major indirect taxes affecting the project (*e.g.* export taxes, import tariffs, excise taxes) and subsidies and other transfers between citizens and the state. Charges and duties that represent payment for actual services (*e.g.* the cost

[10] This will be higher or lower than the nominal tariff, depending on the net effect of illegal connections, inefficient billing, corruption of meter readers, etc.

of recycling projects), as well as benefits corresponding to services rendered, should, on the other hand, be included as costs and benefits, respectively. Pollution taxes (*e.g.* those paid by farmers for non-point pollution, or by municipal wastewater treatment plants for effluent discharge) can be regarded as a proxy for environmental damage, in which case they should be entered as a real cost or (where they are avoided through a reuse scheme) an avoided cost (= benefit).

Inflation and constant prices

The analysis should be conducted in constant prices, normally those of the year in which the study is carried out. Predicting price inflation more than 1-2 years ahead is difficult[11] and errors continued over a period of years would cause the results of the analysis to become seriously distorted. Using constant prices is equivalent to assuming that future inflation will have a neutral impact on the main cost and benefit items concerned (*i.e.* relative values will be unchanged). If, on the contrary, there are good reasons to believe that the relative value of an important item will change (*e.g.* the international price of a key commodity such as oil, or the future cost of desalination due to technical advances) this can be factored in. It would also be prudent to include this in the sensitivity analysis.

Discounting & the choice of discount rate (see also 3A7)

The use of discounting in CBA, especially for long-lived infrastructure projects with major social and environmental impacts, such as effluent reuse projects, has attracted a great deal of discussion and controversy. This is partly an issue of the discount rate chosen, but more fundamentally because the discount rate performs several different, and often incompatible, purposes, which do not necessarily imply the same rate. The difficult issues involved are discussed further in the appendix to this chapter. Briefly, discounting can serve any or all of the following purposes:

- A reflection of the rate of social time preference (STP) expressed by governments for the present over the future. The STP reflects the trade-off between the future benefits from public investments and the present sacrifices necessary to make these investments.
- A reminder of the opportunity cost (OC) of capital used in the project (what it could earn if used for other purposes).
- A capital rationing device to apportion the available capital investment budget over the most attractive bunch of projects. This may be referred to as the "market-clearing" rate.
- A practical measure for comparing projects with different time profiles of costs and benefits. By converting (*i.e.* discounting) the costs and benefits from alternative reuse projects arising at different times in the future into present values the net present value (NPV) of each of the projects can be determined.

Governments have to choose a middle course between setting a rate that is too low, and one that is too high. The dangers of setting the discount rate *too low* (or even at zero) are: encouragement of capital-intensive projects, a particular concern in countries with capital shortages and labour surpluses; encouragement of a higher pace of investment in less productive schemes (those that would not pass a higher threshold rate of return); the risk of a sub-optimal allocation of scarce capital; and failure to reflect the high premium on short-term costs and benefits of poor communities with an uncertain future.

[11] For highly developed financial markets expectations of future inflation can be inferred from the difference between the rate of interest offered by long term bonds and that of bonds indexed to inflation.

On the other hand, the disadvantages of setting rates too high include: possible discouragement of productive investment; minimizing the long term impacts of both costs and benefits of projects12; hastening the rate of exploitation of renewable natural resources; a stimulus to an exploitative rather than conservationist approach; and disregarding the interests of future generations.

Many Governments set their own target discount rates for selecting public investment projects and, where these exist, they should be used in CBA analyses– though with an appreciation of the different purposes they serve, and the compromises that are involved in their estimation[13]. Where standard public sector discount rates are not available, analysts will have to select their own, bearing in mind that discount rates should be in real terms and risk-free, and that rates based on social time preference are likely to give lower rates than those influenced by opportunity cost and market-clearing criteria.

Projects of a type, or in a sector, that would be seriously disadvantaged by the use of the chosen discount rate should be considered for special appraisal (e.g. for environmental projects, using the various ways of reckoning non-market costs and benefits[14]).

Choice of analysis period

The *technical or physical life* of a project is the number of years over which it can go on producing its expected output, with reasonable maintenance and the occasional essential repair. Many water infrastructure assets have a physical life measured in decades (even centuries).

There are two ways of dealing with maintenance in a CBA. The first is to include in annual costs all the maintenance, repairs, minor replacements, etc. needed to keep the project generating its designed level of benefits for an indefinite future. The project should then have a *residual value* at the end of its economic life, which is credited as a future benefit of the project. The residual value may arise either as future net benefit potential, or as scrap value, or as second hand value. The second approach is to build in obsolescence, with minimum recurrent costs, with a scenario involving zero residual value at the end of the project's life.

But the *economic life* is the period relevant to employment of the capital in question, which is often much shorter than the physical life of the asset. The economic life is influenced by the level of the discount rate: at 10%, a benefit or cost stream loses half its value after 7 years, and at this rate there is little point in extending the analysis beyond 15 years because future values are so heavily discounted[15].

Assessing public health impacts: DALYs and QALYs (*see also 3A4*)

The impact of effluent reuse on public health can enter CBA or CEA in several ways, which commonly start with DALYs or QALYs. The Disability Adjusted Life Year

[12] At 10% any impact arising after 15 years would have little effect on the result of a CBA. This would make it difficult to justify projects with long-term benefits, or take adequate account of costs arising in the distant future.

[13] The Spanish and Mexican case studies in Chapter 4 use a discount rate of 6%.

[14] One possible method is equivalent to lowering the discount rate. Where it is judged that environmental values will rise relative to others, such as the amenity value of an unspoiled landscape in the midst of rapid urbanization or agricultural intensification, it may be justifiable to increase a given benefit stream in real terms over time).

[15] If, at the end of the appraisal period, the project's assets are in reasonable condition and capable of generating further benefits, they can be given a *residual value*. If the appraisal period is 20 years, an assessment should be made of how many more years' of physical life the project would have, given adequate maintenance and periodic repairs. The future stream of net benefits, starting in year 21, should be reduced to an NPV (applying the discount factor for year 21), which represents the residual value of the asset. In most cases, discounting will ensure that residual value is not a critical decision factor.

(DALY) attempts to measure the burden of disease and illness by reflecting the total amount of healthy life lost from all causes, whether from premature mortality or from some degree of disability during a period of time. The Quality Adjusted Life Year (QALY) is the measure more commonly used for health service planning in developed countries. As in the case of the DALY, it multiplies each life year gained with a health intervention by a quality-weighting factor that reflects the person's quality of life in the health state for that year.

The burden of disease, expressed in DALYs, measures the present value of the future stream of disability-free life lost as a result of death, disease or injury in a particular year. Public health measures would normally produce positive DALYs, while health hazards such as pathogenic viruses in recycled water would score negative DALYs. This approach avoids the direct valuation of health gains and costs, though the comparative weighting of different health states and physical conditions is still controversial.

Information about DALYs or QALYs can be used in CBA or CEA in various ways:

i. Different projects, involving, for example, various types and levels of effluent treatment and/or use limitations score different DALYs. Minimizing the impact of a project on DALYs could be a selection criterion to complement (or even override) other decision criteria.

ii. In assessing public health policy, DALYs and QALYs can indicate the relative effectiveness of different sanitation measures in producing improvement in health per unit of spending. This metric might be applied to the public health measures that would accompany an effluent reuse project.

iii. Complying with a target level of DALYs might be a mandatory criterion for the project, in which case projects could be ranked according to their cost-effectiveness in meeting the DALY criterion. For instance, WHO/FAO guidelines on the safe use of reclaimed water indicate a reference level of "acceptable risk" of 10^{-6} DALYs.[16] Figure 1.4 in section 1.6 illustrates different options for reducing pathogens to the acceptable risk level, each of which would have its own cost tag.

iv. The DALY could be converted into monetary values using the various economic methods for valuing life and health states. These are all controversial (3A4).

Estimation of environmental costs and benefits[17]

The impact of an effluent reuse project on the natural environment may be difficult to quantify, and even more problematic to express in monetary form. Table 3.1 recaps the various components of the Total Economic Value of a natural resource such as water.

TABLE 3.1
Total Economic Value

Use values	Non-use values	Other values
Consumptive use	Existence value	Option value
Recreational, aesthetic & educational use	Bequest value	Quasi-option value
Distant value use	Philanthropic value	
Indirect use		

*Source: Turner *et. al.* FAO, 2004 (p. 55)

[16] See section 1.6 of this report
[17] further guidance is available in Turner, *et. al.*, (2004), and Hermans *et.al.* 2006

In the category of *use values,* direct use values arise from direct interaction with water resources, as in consumptive uses (*e.g.* irrigation) or non-consumptive (swimming, fishing, enjoyment of view). Distant use values arise through enjoyment via the media, such as TV and magazines. Indirect use values do not entail direct interaction with water, and include flood protection from the presence of wetlands, or the use of aquifer recharge to remove pollutants. *Non-use and other values* depend on ethical and altruistic concerns to preserve the functioning resource or ecosystem.

Depending on which of these elements arises, various possible methods exist for estimating its economic value. Some consumptive uses of water, such as farm irrigation and golf course watering, can be valued using impacts on productivity using market prices (adjusted as necessary, as discussed above). But most other values have to be approached using other methods, including the following:

- *Willingness-to-pay.* People affected by the project are asked, through carefully crafted interviews or questionnaires, how much a particular "state of nature" or a change in this is worth to them – what they would be Willing To Pay (WTP) for this. For a change adversely affecting them, they are asked their Willingness-To-Accept compensation[18]. This method is also known as contingent valuation. In effluent reuse schemes, it can apply to reduced effluent pollution, a higher level of "environmental" river or wetland flows or, conversely, to restrictions on public use of certain land, odours, etc.
- *Discrete choice and choice experiments* are a further development of WTP in which respondents are presented with hypothetical choices between options, some of which are monetised, others not. Their valuation of non-monetised options are inferred from the preferences they express.
- *Defensive expenditure and avertive behaviour*. Values can be inferred by observing what people actually spend in order to shield themselves from the effects of a particular event (*e.g.* what farmers spend on buying and storing water to insure against irregular supply).
- *Hedonic pricing* infers the values people place on environmental quality by observing what they pay for goods, typically properties, incorporating environmental attributes. This could be used by observing changes in, or the differential values of, land and houses affected –positively and negatively – by reuse projects. However, care should be taken to avoid double-counting of benefits: if the change in land values is due to changes in the incomes of farms due to adoption of the scheme, only one of these methods can be used to estimate the effect.
- *Travel cost*. Peoples' valuation of a (free) natural habitat or local amenity is inferred from the amounts they spend (time, transport) on travelling to the site in question. This estimation method could apply to any effects (positive or negative) on land use, recreation or amenity resulting from a reuse project.
- *Replacement cost and shadow projects*. Where a project threatens a valuable site or habitat a budget can be included in the CBA to replace or relocate it. This can be regarded either as a real cost to the project, or as a hypothetical appraisal device to balance against its claimed benefits. A shadow project is one that would fully offset the negative effects of the project under study. (In the USA "wetland banking" requires the sponsor of a project to replace the wetland that will be destroyed by the project by the creation or restoration of another wetland elsewhere).

[18] WTP and WTA measures will give different results.

Decision rules

Following the completion of the CBA various criteria can be used, either singly or in combination, to decide whether to proceed. The main decision rules are as follows:

Net present value (NPV). A positive NPV, expressed in currency units, indicates that the net return on the project exceeds the discount rate used. By applying a discount rate the future costs and benefits are converted to present values. A reuse project is economically feasible if the present value of the benefits exceeds that of the costs. A positive NPV is a necessary, but not a sufficient, condition for proceeding – see below.

Internal rate of return (IRR), sometimes referred to as *the Economic Internal Rate of Return (EIRR).* This is the percent discount rate at which the streams of costs and benefits are equalised. The IRR should be above the discount rate used as a "test" or "cut-off" threshold[19].

Benefit-cost ratio (BCR). This expresses the total discounted benefits as a ratio of the total discounted costs (*e.g.* 1.5:1.0). The difference between the two discounted streams is the same as the NPV, but the BCR has the merit of relating the size of NPV to the scale of resources (costs) being employed on the project. For instance, a large project may have a respectable positive NPV, but three smaller projects might have larger total NPVs and would be a better use of available capital.

The choice of decision rule to use depends on the circumstances of the decision. There are broadly three situations.

- A yes-no decision on a single project, using a predetermined threshold indicator (e.g. a test discount rate). All three decision rules will converge on the same result. A project with a positive NPV at the test discount rate will have an IRR greater than this discount rate and a CR greater than 1.0.
- Choice between mutually exclusive projects (*e.g.* different sites for a WWTP, different routes for a canal or pipeline for distribution of treated effluent.). The decision rule should be to maximise NPV at the chosen discount rate[20].
- Where a number of projects compete for a limited pool of finance a ranking is needed. The best procedure is to rank projects by descending order of their BCRs.

Other common decision rules are:

Least cost option: where the benefits of all alternative projects are the same, the criterion of choice is the smallest NPV of costs. This is the basic decision rule used in CEA.

First Year Rate of Return (FYRR). Where a project satisfies other criteria but where the timing of the investment is an important part of the decision, the FYRR can be used to determine optimal timing. The FYRR is the benefits of the project in its first year of operation as a percent of total costs, both discounted. If the FYRR is below the discount rate used, the project could advantageously be delayed.

Payback period. This is a common financial rule of thumb: the period over which the initial investment outlay is expected to be fully recovered. It answers the question, "how soon before I can expect to get my money back?," which will be a legitimate concern of both farmers and municipal utilities and water companies.

Annualized costs and benefits. By using the capital recovery factor (CRF) all the future costs and benefits of a project are converted into present annual figures. The CRF is a factor by which the capital investment at the beginning of a project's life is multiplied to get an equivalent recovery cost sufficient to repay the present investment

[19] In theory, in certain restrictive conditions a project will not have a unique IRR, hence the NPV is more reliable. However, for those accustomed to thinking of rates of return, the IRR is more intelligible.

[20] Even if the smaller project has a higher BCR than the larger one- which has a higher NPV. This is somewhat counter-intuitive, but is still a rational use of resources.

after the project's life. By this means, the yearly cost of a reuse project can be compared, for example, with the economic benefit of freshwater released by farmers and conveyed to cities per year.

The assessment and management of risk is an important dimension to the appraisal, and the way it is presented to decision makers (see also 3A8).

Economic appraisal with limited availability of information

The data requirements of the appraisal methods described above are potentially considerable, calling for resources, time and budgets that may be unrealistic in all circumstances. In these cases there is a place for appraisal methods and decision rules based on short-cut approaches or the application of benefit transfer.

Short-cut approaches effectively by-pass full appraisal if, as a result of preliminary investigation, it appears that the magnitudes of costs or benefits are such that a decision can be taken without further refinement.

Identification of critical variables. The preliminary analysis may indicate what the critical variables would be, pointing to areas of investigation where attention should be focused if resources were scarce or time constraints were pressing. This kind of analysis can be tailored to the risk preferences of key stakeholders, indicating what further information or action is required on those aspects of the project of specific concern.

Benefit transfer is another method of economising on research and analytical resources, by selecting evidence on the topic in question from comparable situations elsewhere. Information can be sought, for instance, on the scale of benefits from wetland restoration, the value of recreational benefits, willingness-to-pay evidence on the value of cleaner rivers with minimum flow levels, WTP for the avoidance of bad smells, etc. A number of databases are maintained by university institutes, national environment agencies and international agencies which can be accessed by practitioners[21].

3.3 COST-EFFECTIVENESS ANALYSIS (CEA)

CEA is appropriate where the benefits of a project are difficult to value or quantify, and where a number of options are available to achieve the objectives of the project. CEA is also useful where the methodology of benefit estimation is controversial, which is typical of environmental and public health benefits. CEA compares alternative ways of delivering given benefits, such as a specific volume of water demand in municipalities or agriculture.

As noted in the previous section, CEA involves defining the objective of the project in quantitative terms, identifying the options for achieving it, estimating the costs of the various options and choosing the one with the least (discounted) total cost. The total cost can be divided by the output or physical quantities involved in the project, where this is feasible (*e.g.* volume of water in m^3) to produce a cost per unit, which may be more meaningful.[22]

In a CEA the justification for project A is the cost advantage of reuse compared, let us say, to projects B, C, D and E - alternative options to balance supply and projected demand, such as demand management, desalination, conveyance of water from a distant source, re-lining of distribution channels, etc. CEA avoids the difficulty of estimating use values of water23: as the previous section noted, in CBA water tariffs are often used as a proxy for benefits, but this is very imperfect in view of the widespread under-pricing of water, while the estimation of non-use values (e.g. environmental quality) has challenges of its own.

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[21] One of the largest is the Environmental Valuation Reference Inventory (EVRI) on www.evri.ca. Also, van Beukering *et. al.* 1998.

[22] Where both the future financial costs and the water volumes are discounted at an appropriate rate.

[23] See Turner, 2004.

Problems arise with CEA where different options produce uneven results and are not strictly comparable, *e.g.* some will over-achieve on the main target but underachieve on important secondary matters. Some options may produce secondary benefits as a side effect. A common situation in recycling projects might arise when a particular level of wastewater treatment and safe disposal is required by law, but different options for doing this have different levels of benefit associated with them. In cases of this kind, elements of both CBA and CEA would be present in the analysis, and the value of benefits could be netted off the costs of each alternative in the choice of the least-cost option. Where it is impossible to ensure identical achievement, options may need to be weighted according to their different impacts, which complicate the use of a simple CEA metric.

3.4. FINANCIAL FEASIBILITY

3.4.1 Financial impact on key stakeholders

The analysis should start from an assessment of the project's impact on the financial status of key stakeholders: central government, regional water boards, municipal utilities, farmers, *etc.*, including identification of the main gainers and losers, with estimates of their gain/loss. It should include an estimation of the financial implications of the project for public capital and recurrent budgets. This part of the analysis provides a basis for understanding the incentives of crucial stakeholders, especially farmers, to support, or resist, the project.

Central government

Depending on where the national constitutional responsibility falls, the financial implications of major water infrastructure projects may fall to central government. In this case, responsibility for arranging funding, charges and subsidies to farmers, and financial support to local water providers (*e.g.* covering deficits of local utilities) will be governmental issues. Where there are international implications (*e.g.* for the EU, the Common Agricultural Policy or the Water Framework Directive) or transboundary issues (*e.g.* sharing of rivers or aquifers), or where external finance is involved, the central government will also have a financial interest.

Regional water boards

In the common situation where regional water boards or state governments are delegated the responsibility for major water infrastructure and water services they are likely to be involved in the funding, including cost recovery and fiscal transfers, of projects. In many countries, including Spain and Mexico, any effect on the movement of water between different river basins is highly contentious and sensitive, and its impact on the major regional parties involved needs to be very carefully assessed. There may also be adverse impacts of recycling on downstream water users with financial implications (such as compensation payments).

Municipal utilities

Water recycling projects would normally have a major impact on the financial situation of utilities. Where there is an exchange of the freshwater rights of farmers for recycled water, there would be a positive impact on cities from the avoided cost of more expensive solutions, possibly in savings on wastewater treatment (depending on local environmental regulations), and extra sales of urban water. On the other hand, the capital and operating costs of any new treatment facilities and distribution systems would fall on the utility in the first instance. The utility may also avoid some pollution charges on effluent from its WWTPs. Its policy on cost recovery from farmers and urban water consumers would be a critical influence on the utility's finances.

Farmers

Farmers stand to benefit financially from securing a more reliable supply of irrigation water, containing nutrients which enable them to save some fertilizer costs. They may also avoid some abstraction costs, such as groundwater pumping. On the negative side of the balance, they may have limitations placed on what they can use the water for. The critical issue for farmers is how cost recovery is apportioned. Several case studies show that farmers may well benefit financially from effluent reuse if they do not have to bear the cost of any new treatment facility or distribution infrastructure. However, if these costs are passed onto participating farmers, the latter may lose financially. This analysis has to make some assumption about charges for the effluent in comparison with those for fresh water – which would be a crucial influence on farmers' uptake.

Table 3.2 depicts a simple matrix illustrating how the financial impact of effluent reuse on the key parties can be presented.

3.4.2 Financial instruments and transfers

Following on from the above, this part of the analysis should aim to make proposals for financial instruments and transfers to create the equitable conditions for the reuse project to become acceptable, and to provide suitable incentives for its major stakeholders to become fully involved. This would include an assessment of the scope and modalities for water charges, other financial levies, trading schemes, subsidies

TABLE 3.2

Financial impact of effluent re-use on major stakeholders

Impacts should be quantified in US $ or Euros, making a distinction between single one-off payments (e.g. capital investments) and recurrent items occurring annually

Stakeholder	Positive impacts	Negative impacts	Key factors
Central government	Avoided cost of major inter-state freshwater projects or other new major infrastructure	Initial capital cost of project; Net fiscal cost of transfers and compensation paid to other stakeholders	Delineation of fiscal & financial responsibilities between different layers of administration; water pricing policy; Access to external funding; Mandatory health & environmental standards (e.g. EU)
State governments, regional water authorities	Revenues from sale of bulk fresh water to cities; Fiscal Revenues from further development of urban and rural areas due to greater water security	Capital funding of schemes & O&M costs; Purchase(*) of effluent from municipal WWTPs; Any fiscal transfers entailed	Division of financial & fiscal responsibilities between central, regional and local governments; Local environmental & public health regulations
Municipal utilities	Avoided costs of alternative water solutions; Savings in effluent treatment costs; Extra revenues * from urban water sales; reduced pollution charges	Capital and operating costs of new facilities and infrastructure; Costs of public health measures & restrictions on amenity	Tariff policy for effluent and fresh water; Apportionment of costs between users and authorities;** Degree of current and future urban shortages
Farmers	Greater reliability of effluent;Savings in abstraction & pumping; Savings in fertiliser; increase in yields and sales revenue	Cost of produce restrictions; Reduced amenity, reflected in price of land	How much of project cost borne by & recovered from farmers; Alternatives available, e.g. own groundwater; Price charged for effluent, compared to that of fresh water; Ability to sell existing water entitlement *; Severity of produce restrictions

* Note that in most European countries, water cannot be sold but the costs could be recovered.
** According to EU policy, all costs must be included in final price.

and innovative financial mechanisms such as payments for environmental services. In principle, farmers should contribute to the costs of reuse projects if they benefit significantly from increased sales revenue and cost savings in pumping conventional resources and/or fertilizer. But from another point of view, economic incentives should be used if necessary to encourage farmers to join recycling projects.

Charges
If it were decided that the costs of the project would be recovered from farmers, a charge for use of the treated effluent would be the most obvious option. The feasibility of charges would be greater the fewer alternatives farmers have (in some countries peri-urban farmers are accustomed to using effluent for irrigation, and sometimes this is the only option available). A price differential in favour of the effluent would also attract farmers into the scheme.

The feasibility of using irrigation charges for cost recovery is not a straightforward matter, though – in OECD countries at least – rates of cost recovery for O&M are increasing in most countries. The recovery of capital expenditure through tariffs is less common though this is also increasing.[24]

Outside the OECD, there are greater barriers to imposing, or raising, irrigation charges. However, the present – generally low or even zero – level of charges is the result of specific local social, political and economic factors. In most cases, irrigation charges would need to increase to levels that are politically unfeasible in order to have serious effects on demand. Greater cost recovery from farmers, though often a desirable aim, is easier to bring about within a wider and longer term framework of reform in which farmers have more control over their supplies, greater influence over use of revenues, and a higher standard of service.[25]

Trading schemes
Where farmers have customary or contractual entitlements to water, water trading may be an option, where they would sell their rights to other users as part of the agreement to take effluent. There are various preconditions for such water markets: trading must be legally permissible; it should be physically feasible in the sense that the new users are accessible and the infrastructure exists to convey the water; the interest of the environment and third parties should be protected; and the transactions costs of trading should not be excessive.

Subsidies to farmers
Any subsidies paid to farmers taking wastewater effluent can be justified in several ways.

- They can be regarded as a *payment for environmental services (PES).* The services in this case are the reuse of effluent, thereby avoiding the use of fresh surface or ground water, or enabling the recharge of depleted aquifers or restoration of minimum flows in rivers. The precise rationale for the PES, the form it takes, the amount involved, and the source of finance for it, all depend on local factors.[26]
- A separate but related argument for farmers' subsidy rests on grounds of "fairness"- the case for sharing the financial bounty enjoyed by the regional or urban water authority from the effluent reuse scheme, compared to the *without project* scenario. Farmers are crucial to making this kind of project happen.

[24] OECD: *Managing water for all: An OECD perspective on pricing and financing.* 2009. pp 138-139.
[25] F.Molle & J.Berkoff (eds.) *Irrigation water pricing: the gap between theory and practice.* IWMI/CABI 2007.
[26] FAO *The state of food and agriculture 2007: Paying farmers for environmental services.*

- Compensation for the other market distortions that affect farmers, such as "cheap food" policies that depress farm gate prices, or tariffs on imported machinery and chemical products. This is not, however, a good argument for cheap irrigation water which produces distortions of its own.
- Farmers may need compensation for any net costs entailed in their use of effluent, such as produce or land use restrictions, or any long term negative effects on the productivity of their land (*e.g.* from the build up of harmful residues in the soil). These costs need to be offset against the likely fertilization benefits from nutrients present in the effluent. Another factor in some peri-urban farm situations is that competition for fresh water is such that farmers have no alternative to the use of effluent for irrigation.

The simplest form of subsidy would be to provide the effluent free of charge. This would be relatively easy to administer and monitor. Because it would be proportionate to farmers' use of the effluent, it would also be efficient (creating the right incentive) and equitable between farmers with different rates of uptake. If it were desirable or necessary to go further, subsidies could also be applied to the construction of the infrastructure for conveying and distributing the effluent to farmers' fields.

3.4.3. Funding the project

Finally, considering the above, proposals should be made for funding the project, considering the various sources available, and the most appropriate solution for the case in question. The broad choices are the following:

- Cost recovery from users (charges to farmers, tariffs for other uses of the fresh water exchanged for the effluent);
- External grants or loans on concessional terms (*e.g.* from the EU or international environmental funds);
- Subsidies from central, regional, or local governments for capital and/or recurrent expenses (*e.g.* in Spain the regional government of Catalunya announced a wastewater reuse programme in 2009 to be funded entirely by the public sector, though some projects will involve joint-financing with municipalities or local water companies; [27]
- Equity from private users of the effluent (*e.g.* in the Spanish Tordera Delta a golf course paid for pipes and pumps to convey effluent, and a community of irrigation users financed pipelines, a pumping station and a reservoir);
- Stand-alone commercial ventures for treating or otherwise acquiring the effluent and selling it to farmers and other users, funded from equity and commercial finance, typically under a concession form of contract. This may involve sizeable investment in WWTPs (*e.g.* the Mexican Atotonilco WWTP with the aim of treated wastewater for reuse in irrigation. Bids are invited under a Build-Operate-Transfer (BOT) structure, with 49% of costs coming from the National Infrastructure Fund and the remainder from the private concessionaire. The Matahuala and El Morro WWTPs will have similar aims and financing structures -DBOT[28] and BOT, respectively[29];
- Cost savings of municipal water utilities due to avoided expenditures for alternative solutions, such as construction of pipelines to convey distant freshwater or of desalination plants. Where the costs of these alternatives have been provided for in public budgets, recycling projects can take up part of these allocations.

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[27] *Global Water Intelligence (GWI)*, August 2009, p. 14.
[28] Design, Build, Operate, Transfer.
[29] GWI, August 2009, p. 51-52.

Appendix to Chapter 3: Further guidance on the methodology of cost-benefit and cost-effectiveness analysis relevant to the economic appraisal of wastewater reuse projects.

The following topics are included:

3A1. Adjusting for economic distortions
3A2. Taxes, subsidies & transfer payments
3A3. Tradeables, non-tradeables and unquantifiable items
3A4. Value of health and disease
3A5. Costs
3A6. Benefits
3A7. Estimating discount rates
3A8. Risk assessment and appraisal

3 A1. Adjusting for economic distortions

If the price of a project's output is greatly distorted, there is a likelihood of the wrong decision being taken. Much of the early cost-benefit literature favored the use of foreign exchange as the *numeraire* in which costs and benefits should be expressed. More recently, widespread economic liberalization in both developed and developing countries has reduced the need for comprehensive price adjustments.[30]

Distortions in the prices of goods and factors of production such as land and labor may persist, particularly where trade barriers are important and/or the national currency is seriously under- or over-valued. Particular products (*e.g*. energy, water) may also be distorted by subsidies or taxes. In these cases, some adjustment to actual prices may be required.

In these circumstances, the broad options are to use either *domestic prices*, with the worst distortions ironed out by *ad hoc* adjustments, or to use a foreign exchange unit of account by converting domestic values into their equivalent *border prices.* Deriving a set of border values can be an elaborate exercise and will not be feasible in every case.

3 A2. Taxes, subsidies & transfer payments

Values should exclude taxes, subsidies and other transfer payments on the grounds that, for the nation as a whole, they are merely transfer payments between different groups. These transfers do not represent real scarcity values – on the contrary they may disguise the true opportunity cost of the item. Income and corporate taxes should be excluded from the analysis, as well as major indirect taxes affecting the project (*e.g.* export taxes, import tariffs, excise taxes) and subsidies and other transfers between citizens and the state. Charges and duties that represent payment for actual services, as well as benefits corresponding to services rendered, should, on the other hand, be included as costs and benefits, respectively.

3 A3. Tradeables, non-tradeables & unquantifiable items

Tradeable items, such as oil, machinery and pipes, can be valued at their border prices (import or export values, converted at the prevailing exchange rate). Imports should be valued c.i.f. (cost, insurance & freight, which represent resource costs to the economy), and exports f.o.b. (free on board, excluding transport costs overseas). Where the current exchange rate is substantially different from estimated free market equilibrium levels, the latter should be used where it can be accurately inferred (*e.g.* from purchasing

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[30] The UK's Treasury recommends: "Costs and benefits should normally be based on market prices as they usually reflect the best alternative uses that the goods or services could be put to (the opportunity cost)…." (UK Treasury *Green Book*, 2004 version).

power parity estimates). Some goods and services are not actually traded, though they potentially have an overseas market and a border price. Examples relevant to recycling projects include crops produced for the farmer's own consumption, electric power, etc. The valuation principles for these items are the same as for actually traded goods.
Non-tradeables marketed domestically include land, water and some other public utilities, etc. Many goods with a low value-to-bulk ratio may be in practice non-tradeable, *e.g.* bricks, rubble, water, but could be traded in certain circumstances. In principle, they should be valued against the general yardstick of *marginal social benefit to consumers* Certain items, such as land and labor, can be subject to specific valuation principles that are previously discussed.

In summary, items that are actually or potentially tradeable should be valued at border prices. Non-tradeables are more difficult: in many cases market prices can be used where they are a reasonable reflection of marginal social benefit. Specific valuation methods are applicable to certain common non-tradeables in such areas as health & education and environment.

3 A4. Value of health and disease

Section 3.2.3. described how DALYs and QALYs can be used in measuring the public health impact of a recycling project. Cost-effectiveness analysis can then choose the best option for achieving a given public health outcome defined by the DALY/QALY. However, in certain circumstances there is interest in estimating the economic value of health states (DALY/QALY) resulting from these projects.

All such estimation methods are controversial and pose severe methodological problems. Two possible approaches are outlined below:

Inference from policy decisions (Revealed Preference): in this approach the implicit value of health status is inferred from policymakers' choice of particular safety and health measures (*e.g.* a programme to spend $1 million on public health measures calculated to produce 50 QALYs implies a valuation of $20 000 per QALY). Some public health administrations are believed to use threshold values for QALYs in allocating resources between different health interventions in a cost-effective manner. In principle, these threshold values can be used to infer policymakers' valuation of a QALY[31].

The direct valuation of changes in health status due to public health measures can be done by one or both of the following techniques:

- willingness-to-pay; how much individuals would be willing to pay (WTP) to avoid a particular illness, accident or incapacity;
- using the *human capital* approach to measure the benefits in terms of the income an individual would gain from avoiding incapacity due to health.

Although the search for an acceptable and robust estimation method continues, it faces formidable methodological as well as social and political challenges. The conclusion of a recent authoritative review is:

"There is, in fact, no commonly agreed method for valuing QALYs, raising the question of how best to decide on the economic benefit of healthcare programmes or interventions." (Asim & Petrou, 2005).

3 A5. Costs

General points

The notion of opportunity costs should underlie the treatment of costs in CBA. The cost of a project is the loss to the rest of society from using the resources for this purpose. Costs already incurred at the point of decision (*e.g.* a partially built project) should be disregarded for the purpose of the decision. *Sunk costs* should be ignored,

[31] however, public authorities are reluctant to explicitly reveal these threshold values. See Asim & Petrou (2005)

and only *incremental costs* reckoned in. If a project causes a *loss of benefits*, this too is a cost (*e.g.* draining a wetland to build a WWTP).

Costs can be either *tangible* (*e.g.* wages) or *intangible* (*e.g.* loss of amenity, destruction of wildlife habitat). In principle, both should be brought into the analysis: techniques are available for estimating non-market costs as well as benefits (Figure 3.1).

Costs can be *internal* to the project, or *external* to it (*externalities)*. An externality is a project impact which does not directly affect the project sponsor, and which the private sponsor will not normally factor into the decision to proceed. Externalities may be either tangible or intangible. Externalities may be either costs or benefits. Public agencies should ensure that they are reflected in the project decision, by using various possible valuation methods.

Specific cost items

Certain *financial costs* should be excluded from a CBA. These include taxes and transfer values, which have already been discussed, and depreciation *allowances.* Depreciation is an accounting device used to maximise tax advantage by spreading expenditure on a capital asset over its lifetime, and does not correspond to real opportunity cost. C*apital charges* represent the annual financial costs of the investment (interest and capital repayments). Some projects include payments into a *sinking fund*, which is intended to create the funds necessary to replace the project at some future date, or repay the initial debt. In both these cases, a CBA captures the point through discounting. A project that achieves a positive NPV at a discount rate reflecting the cost of capital can by definition recover all its capital costs during its lifetime.

The use of non-renewable natural resources (*e.g*. fossil groundwater) or, the use of renewables in excess of their rate of replenishment (*e.g*. groundwater, or water stored from stream flow), are similar to mining projects. Part of their cost is the *depletion cost* or *user cost* from using up finite resources. Conceptually, this cost arises in the future, when alternative resources have to be developed earlier as a result of the project's consumption now. The depletion or user cost is the value of the extra future spending needed to tap alternative natural sources or, more precisely, the discounted cost of bringing forward by [say, one] year the use of alternatives, where they are available.

Contingencies included in cost budgets are of various kinds. *Physical contingencies* are extra quantities of work, materials, pieces of equipment, etc., included "to be on the safe side", since a shortfall in cost provision for such extra items might have a disproportionate impact on the project. They should, however, be excluded from CBA because the Base Case should be the best possible estimate of the project's contents and costs. *Price contingencies* cover cost increases that may arise over and above the prices used in the Base Case scenario. These may be provisions against general inflation, which should be excluded since the analysis should be conducted in constant prices. In principle, the Base Case should contain the analyst's best estimate of costs, and genuine uncertainty should be dealt with by including an item for contingent liability (see below).

Contingent liabilities are real costs that should be included. These are the cost of commitments that will fall on the sponsor, or government, if certain events happen (e.g. guarantees and performance bonds that may be called, cancellation penalties, redundancy payments). The probability (expected value) of these events, discounted according to the year(s) in which they might arise, are real costs to be included in CBA.

The following cost items are also likely to arise in recycling projects:

- *Land.* The opportunity cost of land is its value in its best alternative use. In a freely functioning and undistorted market, this is reflected in its market price. However, land is often treated as though it were free to the project and useless for anything else, whereas in reality it always has an alternative use, which may be more valuable than the one proposed.

- *Labor*. In most countries labor markets do not properly "clear" in the sense that wages smoothly adjust to price workers in and out of jobs. Unemployment may persist, either of a chronic nature, or seasonal, or structural (*e.g.* immediately after the closure of an important local employer). Using a *shadow wage* below the actual wage paid can correct for this distortion, and may be a better reflection of the true opportunity cost of the labor. While theoretically correct in certain cases, this practice has been widely abused and should be used cautiously and skeptically. Even in the midst of widespread rural underemployment, labor shortages arise at certain times. Except for projects where employment creation is the main objective, labor costs should not be entered as a project benefit.
- *Subsidized raw materials & energy*. Projects may benefit from the presence of plentiful local resources, such as hydropower, oil, water, etc., which are provided at a below-market cost to the project. The CBA should, however, include these items at their opportunity value, which may be their price as an exportable item (net of transport, etc.), their value in other uses, or the future benefit of not using them and preserving them for later (oil, stored water, etc).

3 A6. Benefits

Consumer and producer surpluses

The welfare gain from a project is the sum of the consumer and producer surpluses that it generates. The *consumer surplus* is the difference between what consumers would be willing to pay (or what they were paying previously), and what they actually have to pay with the project. This category of benefit is likely to be important for goods and services that are not priced, or whose prices fail to reflect their true values. Relevant examples include: improvements in household water supply; more reliable irrigation services, etc. The actual amount previously spent (cash, time) is one yardstick against which welfare can be measured. Where this is not available, willingness-to-pay (WTP) surveys can be done, or data from benefit transfers (see below) used.

The *producer surplus* is the difference between the product price obtained and the unit cost of production, normally equivalent to profit. This can arise for producers in various circumstances, whether public or private, serving monopoly or competitive markets. It applies to water utilities and any other suppliers of treated wastewater whose economic and financial situation is changed by a project. The fact that many water utilities, WWTPs and irrigation agencies operate at a financial loss due to their tariff policies does not invalidate this concept (the surplus can be negative, but still become larger or smaller as a result of a recycling project).

Benefit transfer

Growing use is being made of the benefit transfer method of generating values for CBA, where the alternative is to conduct lengthy and complicated original surveys. This applies particularly in environmental and health appraisals. The method is to tap into databases of existing empirical studies in the sector in question and extract data from those whose features seem most relevant to the characteristics of the project being appraised.

Wider social and economic benefits

Water recycling projects may be promoted by invoking a range of positive effects, beyond those quantified in the CBA. These can include job creation, regional multiplier effects, backward and forward linkages into the local and regional economy, etc. The normal convention is to treat projects as *marginal*, in the sense that they do not have substantial impacts on other sectors or projects, and do not greatly affect the price of their major inputs or outputs.

A project may have *forward linkages* benefiting sectors that use its output (*e.g.* irrigation water, extra water for urban or industrial use), or *backward linkages* to those that supplying a project's inputs (*e.g.* pumping services, water treatment equipment, maintenance). In regions of water scarcity, the extra usable water that recycling could provide might have clear forward linkages for water-using sectors.

Multiplier effects arise when an investment project in an area with surplus capacity generates successive rounds of spending as the original injection of funds works through the local economy. In theory, the total eventual increase in income is a multiple of the original investment. In practice, spending from an investment project "leaks" in various ways, e.g. through higher prices of goods and services where there is no spare capacity, and imports from abroad or from other regions. Such effects would weaken the multiplier effect.

3 A7. Estimating discount rates

As noted in the main text of this Chapter, there are various criteria for the choice of discount rates, the two most common being the rate of social time preference (STP), and the opportunity cost of capital (OC).

The STP is derived from estimates of the pure rate of time preference, the marginal utility of income as incomes change, and the expected growth in per capita incomes. (see Box 3.1). The first two of these components cannot be directly observed, and the third is a forecast. Box 3.1 indicates how changing the values of STP for countries at different stages of development affect the overall rate of STP. The results are purely illustrative and should not be taken as guides for a specific country.

Estimates of the OC can be guided by observations of national capital markets, in particular the real long term rate of return on private capital, adjusted for risk. Although this may be feasible for countries with strong and liquid financial and capital markets, many poorer countries have limited capital markets where the rates of return on capital are not sufficiently transparent. In repressed capital markets, governments are able to borrow at artificially low rates, hence this is not always a reliable benchmark for the choice of discount rate. The minimum OC could be regarded as what the recipient government could earn by depositing the funds safely in international financial markets, adjusted for the foreign exchange risk.

BOX 3.1

Estimating social time preference

Social time preference is obtained from the formula:

$S = p + u.g$

Where:

S = social rate of time preference

P = pure rate of time preference, the rate at which utility is discounted

U = rate at which marginal utility declines as consumption increases

G = expected growth in consumption per head.

In developed countries, the following parameters are typical: p = 2%; u = 1.5%; g = 2%, giving a value for s of 5.0%

In a poor developing country with good growth prospects it is plausible to substitute values of p=5% and G= 3% giving s = 6.5%.

For a poor country with poor, or negative growth prospects, the higher value for p would be wholly or partly offset by low or negative values of g.

Source: OECD, (1995) p. 130

3 A8. Risk assessment and appraisal

Risk assessment

During appraisal, analysts should identify the main areas of risk to which the project is exposed. Some of these will be common to all projects, others specific to the project in hand. Examples of *generic risks* would include demand for the good or service, output price, construction costs and implementation period, funding problems, failures of counterparties to live up to commitments, untried technology, failure to get timely planning approval, etc. For large and complex projects it may be useful to compile a *risk register*.

The next step is to judge the importance of the risks identified, which requires a view on:

- the possible range of deviation from the values used in the Base Case, and
- the probabilities of these deviations occurring.

Except for the largest projects, it will not be feasible to carry out this routine for all risks. A more pragmatic approach would be to consult professional opinion and refer to previous experience to identify the most important risks and feasible magnitudes for their possible deviations from Base Case values. The Base Case should incorporate (expected values of) the best available information on the project, while data on the possible deviations should be retained for sensitivity analysis (see below).

Risk mitigation & management

Active risk management involves identifying risks well ahead and installing mechanisms to minimise their occurrence. It requires processes to monitor risks and feed back information, and controls in place to mitigate adverse consequences.

The potential impact of risks on the Base Case can be demonstrated through *sensitivity analysis*. Potential variations in crucial project variables are tested for their impact on Base Case NPV/IRR. For instance, if a 20% shortfall of benefits (*e.g.* uptake of recycled water by farmers) compared to Base Case reduces the IRR to 4%, while an increase of operating costs (of the WWTP and pumping) of the same proportion only reduces IRR to 6%, this would indicate that the project is more sensitive to lower benefits than to higher than expected operating costs. The moral for project planners is to concentrate more on securing demand, than to spend further time on refining costs.

Another way of presenting this same information is through the use of *switching values.* These show, for each important project variable, how much it would need to change to reduce the NPV to zero. Variables which are not very crucial to the project could vary greatly before they affected the NPV, whereas highly sensitive items would only need to vary by a small proportion to plunge the project into difficulties.

The outcome of sensitivity and switching value testing is an opinion on how *robust* the project is to changes in its key variables.

Risk perception, appetite and averseness

The foregoing discussion has been based on the assumption that project sponsors and stakeholders are *risk-neutral* and that the assessment of risks is objective and widely agreed. This is misleading where, as in anything to do with water, there are important subjective perceptions and attitudes to risk.

Many supposedly "objective" risks have a large judgmental component, especially where new and complicated hazards are concerned. Perceptions of risk by "expert opinion" may differ widely from those of the general public, or groups who believe themselves to be at specific risk. The potential risks to public health from the use of effluent to irrigate food crops may objectively be very small, but public opinion may distrust "expert" judgements on this matter.

In the context of this report, a farmer may lose the market for an entire crop if public health incidents can be traced back to his farm. The *risk appetite* of the sponsor and stakeholders cannot be ignored. In theory, differences in risk perception and in risk appetite can be allowed for by attaching *utility* weights (as well as probabilities) to the various possible outcomes to produce an *expected utility*. A more practical solution is to set out the risks in ways comprehensible to the decision-takers and use decision-rules which are tailored to the sponsor's risk preferences (see below).

Irreversibility & special risks
Where future uncertainty is particularly important for a project, there is an *option value* in retaining the freedom to proceed or not. Delaying a decision gives time for new data and evidence to be gathered, while implementing the project immediately closes down the option. This is serious if the project has *irreversible* effects, for instance on the natural environment. Postponement may be justified where there is a good chance of relevant data becoming available (the value of such extra data is referred to as a *quasi-option value*).

One of the most difficult judgements to be made is over zero-infinity problems, namely, risks with a low probability but a very high severity (e.g. the irreversible contamination of an important aquifer, or the extinction of a protected species due to construction of a new WWTP in a wetland area). Using the normal expected value framework (outcomes x probability) is unlikely to give such events the weight they deserve in the decision. The Precautionary Principle[32] is likely to be invoked in such cases, and policymakers may prefer to avoid the risk entirely, or heavily over-insure against its consequences.

Information for managing risk
The results of CBA should be presented to sponsors, decision-makers and other stakeholders in ways, which are informative in the light of their respective risk appetites and preferences. Reducing the results of a CBA to a single indicator (IRR, NPV, BCA, etc.) and nothing else is a waste of information, and will not satisfy the anxieties and needs of sponsors. Which indicators and decision-rules are presented should be decided following consultation with sponsors and examination of their attitudes to risk. Where risks are particularly important, the basic indicators (NPV, etc.) should be accompanied by full data showing the results of sensitivity analysis and switching values, with worst possible scenarios highlighted.

Most projects would benefit from further study. However, this takes time and resources, and delays the start – which itself has costs. The judgement has to be made whether the long term benefits from a better project, with fewer uncertainties and less risk, justify the higher short term cost of studies, piloting, and deferment of benefits. How much better could the decision be by waiting? Is it worth the wait?

Sensitivity analysis can indicate areas of the project where the reduction of uncertainty would pay particular dividends, by reducing a downside variation or improving the prospect of an upside movement. This enables the analyst to focus on the *value of information* - the sum that would be worth spending on extra information, in relation to the potential benefit to project returns that might be expected.

[32] "where there are threats of serious or irreversible damage to the environment, lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation". (Gilpin, 1996, p. 178)

Chapter 4
Results and conclusions from case study analyses

This chapter illustrates how the economic methodology described in chapter 3 can be applied in the choice and appraisal of projects for the reuse of wastewater effluent in agriculture and other purposes. The case material used here is based on the actual situations in Spain and Mexico portrayed in chapter 2.

Although care has been taken in the choice and analysis of the data, the results presented here should not be regarded as a comprehensive and determinate feasibility study of the projects in question. The examples are intended to demonstrate a method of appraisal, the kind of data that needs to be collected, how they can be interpreted by policy makers, and how the projects can be made financially feasible. A full feasibility study would need to be part of the process of planning described more fully in chapter 5.

4.1 SPAIN: LLOBREGAT DELTA

4.1.1 Overall situation

The Llobregat River Delta covers c. 100 square kilometers of land situated in the North Eastern part of Spain adjacent to the major city of Barcelona. It is a valuable natural habitat, but also under relentless pressure from the city's urban and industrial growth. The river has become highly polluted and degraded, and the important groundwater aquifer, widely used by all sectors, is suffering seawater intrusion. The flow of the river is highly variable, and the main alternative source lies at some distance. In dry periods farmers compensate for reduced surface water with greater pumping of groundwater, and treated effluent is starting to be used on a small extent, mixed with groundwater. Effluent is also used for groundwater recharge and other environmental purposes.

Against this background, the regional water authority is considering bringing effluent reuse into its future water strategies. There is ample effluent available, treated to secondary and tertiary levels, and the existing WWTPs are being modified to reduce the salinity of the present effluent. There are plans to reuse the effluent in agriculture, for various environmental purposes, and in industry, which would exchange freshwater for metropolitan use and reduce the further depletion of the aquifer.

4.1.2 Specification of preferred options

Following preliminary screening, a preferred option has been selected for further appraisal at each of the two main WWTPs in the Delta, Sant Feliu de Llobregat (Sant Feliu) and El Prat de Llobregat (El Prat) (Box 4.1).

The reclaimed water from the Sant Feliu WWTP could be used on farms on the left side of the Llobregat River. The reclaimed water would be conveyed via the Infanta Canal to the farmlands and the freshwater released would be available to augment the Llobregat River and local aquifers.

For the El Prat WWTP, the concept is to pump effluent upstream to a regulatory pond from which water will flow into the Canal de la Dreta. Currently, freshwater with an average conductivity of 1.5 dS/m from the Llobregat River is conveyed via this channel to irrigate farm lands. The use of effluent in irrigation would require the desalination of the WWTP effluent by EDR and facilities to pump it to the Canal de la Dreta and a storage pond. The average salinity of the irrigation water would be reduced from 2.9 to 1.2 dS/m. The existing distribution network could be used to convey effluent to the fields.

BOX 4.1

Preferred options at Sant Feliu and El Prat WWTPs

Sant Feliu: project specification

Construction of a new tertiary treatment unit at the WWTP, involving increase in treated water volume & nutrient reduction;
Installation of a pipeline network to convey reclaimed water formunicipal, recreational and agricultural uses;
Extension of use of reclaimed water in farm irrigation via the Infanta Canal on the left side of the Llobregat River;
Release of freshwater by farmers currently extracted from Infanta Canal.

Expected project impacts

Replaces pumping of surface water (from Llobregat River);
Replaces pumping of groundwater by farmers (3 Mm^3/yr), saving pumping costs;
Increased water availability, quality and reliability;
Farmers cease rain-fed agriculture and irrigate the whole cultivated area (+ 14.5%) with increases in their net sales revenues;
Reduction of fertilizer use.

El Prat: project specification

Construction of EDR (electrodyalisis reversal) unit to reduce salinity of effluent at Sant Boi;
Pumping desalinated effluent to irrigation Canal de la Dreta;
Distributing the effluent to farmers;
Using the freshwater released by farmers for urban domestic water supply.

Expected project impacts

Surface and groundwater use for agriculture avoided;
Farmers save groundwater pumping costs;
Increase in water availability, quality & reliability;
Reduction of fertilizer use;
Avoided costs of groundwater extraction for domestic water use.

TABLE 4.1

Costs and benefits of projects

Euros (million)	**El Prat:** Irrigated area 801 ha Effluent vol. 13.0 Mm^3/yr	**Sant Feliu:** Irrigated area 275 ha Effluent vol. 7.3 Mm^3/yr
Capital cost of new treatment units:	(EDR unit) 14.00	(tertiary unit) 1.12
O&M cost of treatment p.a.	2.6	0.51
Cost of conveying effluent p.a.	0.12	0.20
Cost of conveying water released for urban use p.a.	1.43	0.81
Net new benefits to agriculture p.a.	0.35	0.46
Value of water exchanged for city use p.a.	14.43	8.12

Salinity is a crucial limiting factor for agricultural irrigation. Seawater intrusion into the aquifer limits its use by some farmers. However, farmers are more reluctant to use effluent from the El Prat WWTP because of its high salinity (average is 2 944 dS/cm), due partly to the presence of potash mines in the northern part of the watershed.

Cost-benefit analysis: results

The basic building blocks for the CBA are contained in Table 4.1 which indicates the capital and annual costs incurred by the proposed new facilities, and the aggregate benefits expected from the reuse of effluent and the redeployment of freshwater to the city.

For this exercise, no adjustment is made to the nominal market values of the cost and benefit items. For simplicity it is assumed that the whole capital cost is incurred at the end of year one, and that the recurrent costs and benefits arise, unchanged, in years 2-25 (extending the analysis beyond a 25 year period would make no substantial difference to the results).

For ***El Prat***, the steps are as follows (values in million Euros):

Net benefits (benefits less costs). Year 1: minus 14.00. Years 2-25: plus 10.63. Applying a 6% discount factor to this stream of net benefits gives a **Net Present Value** of 114.54. [1] The corresponding **Benefit-Cost Ratio** is obtained by comparing the Present Values of the benefit and cost streams separately, in this case 188.88 to 66.19, or 2.85 to 1.0.

For Sant Feliu the corresponding steps are:

Net benefits. Year 1 minus 1.12. Years 2-25 plus 7.06.

Net Present Value = 69.49

Benefit-Cost Ratio = 109.65 to 20.47, or 5.35 to 1.0.

If the values contained in Table 4.2 are plausible, both projects appear highly attractive in economic terms to the regional water authority. By far the largest benefit of both projects is the value of the extra freshwater made available for the city, whereas the net benefit to farmers, though positive, is much less. If a *sensitivity analysis* were to be done, it would show that the overall NPV would be highly sensitive to the size of urban water benefits that are assumed here. On the other hand, the *switching value* of urban water benefits (the % decline that would reduce the projects' NPV to zero) would also be very large, a sign of robustness in the projects.

Comments on the key variables follow.

- *O&M treatment cost.* 0.2 €/m^3 for desalination by EDR. , 0.07 €/m^3 for the tertiary treatment.
- *Costs of conveyance of effluent and fresh water.* Pumping costs of 0.11 €/m^3. It is reasonable to assume that existing infrastructure would suffice to take the extra fresh water for the city. Water not used for the Canal is conveyed in the river down to the drinking water treatment plant, and the reclaimed water from the tertiary treatment unit crosses the river using a siphon to reach the Canal located nearby. Pumping costs would be very small.
- *Benefits to agriculture.* Assumes reliable supply of reclaimed water at Sant Feliu enables an increase in the irrigated area of 14.5%. The benefit is made up of increased sales revenue (in Euro million) 0.388, savings in the cost of groundwater pumping 0.06, and savings in fertilizer 0.01. At El Prat the benefits consist of savings in groundwater pumping costs 0.32 and savings in fertilizer 0.03. It is assumed there would be no produce restrictions due to the use of effluent. It is also assumed at this stage of the analysis that none of the costs of treatment or conveyance would fall on the farmers.
- *Value of water exchanged for city use.* This is valued at 1.11 €/m^3, based on current tariffs in this region, which is a very conservative estimate of its full economic cost.
- *Choice of discount rate.* The rate used is 6%, as used by the regional consultants.

4.1.3 Implications of the CBA

The cost of water reclamation (extra treatment and conveyance) will not be offset by the value added in agriculture due to savings in fertilizer, groundwater pumping and the benefits from farming larger irrigated areas. This implies that neither of the preferred schemes makes economic sense as an agricultural cost-saving measure without considering the schemes in the broader regional context.

[1] The present value (PV) of 1.0 per annum over 25 years at 6% is 12.78. Multiplied by the actual annual net benefit this gives PV of 135.85. Since this only starts in year 2 a discount factor of 0.94 is applied to produce an NPV of 127.70 . Deducting the capital cost in year 1 (discounting by the first year rate at 6%) gives an NPV of 114.54.

However, taking a broader view of the projects in the context of growing urban demand for water, there are sizeable net benefits from releasing river water for urban use. Water shortages in the Barcelona region may have been factors in the relocation of several firms out of the area, and the drought of the last five years has severely constrained household and municipal use. In this perspective, the potential value of the extra freshwater for the city strongly justifies for the projects.

Apart from this, the infrastructure for conveying water from one place to another has been built, and it is relatively cheap to exchange the water since all the key sites are close together. Sufficient storage is also available since the river is well regulated for most of the time, except in a few occasions of heavy rains in the mountains.

Though both the projects appraised here appear economically attractive in drawing up a regional water strategy, they would need to be compared with other means of providing (including conserving) urban water to test whether the benefits they provide can be delivered *cost effectively*, in other words, more cheaply than the alternatives. This evidence is not available for the purpose of this report, hence no *Cost-effectiveness Analysis* is presented here.

FIGURE 4.1 a
Project infrastructure

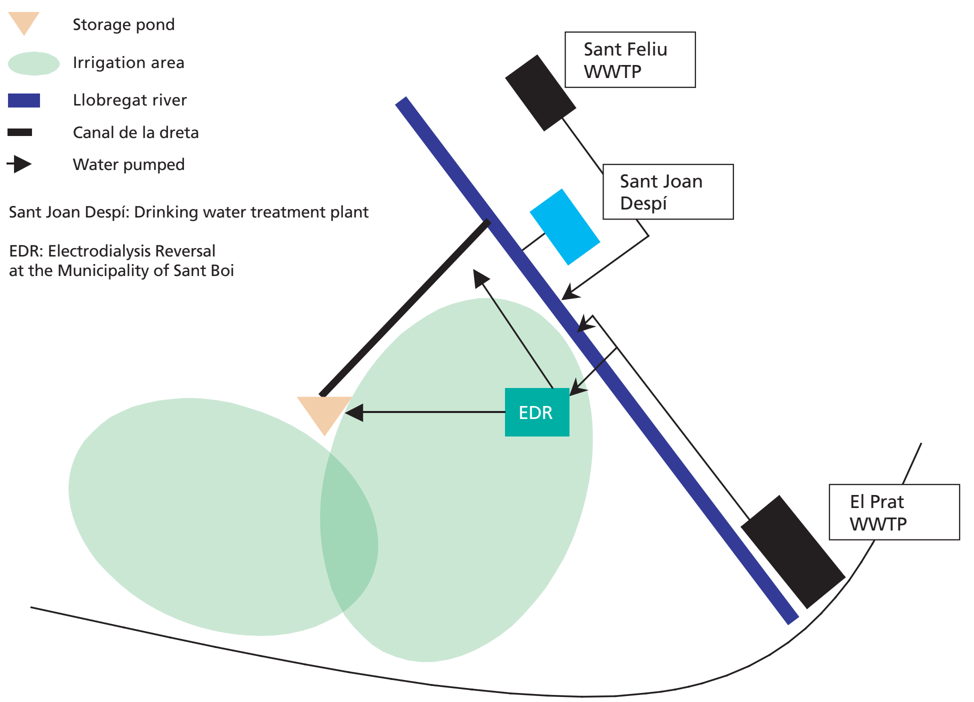
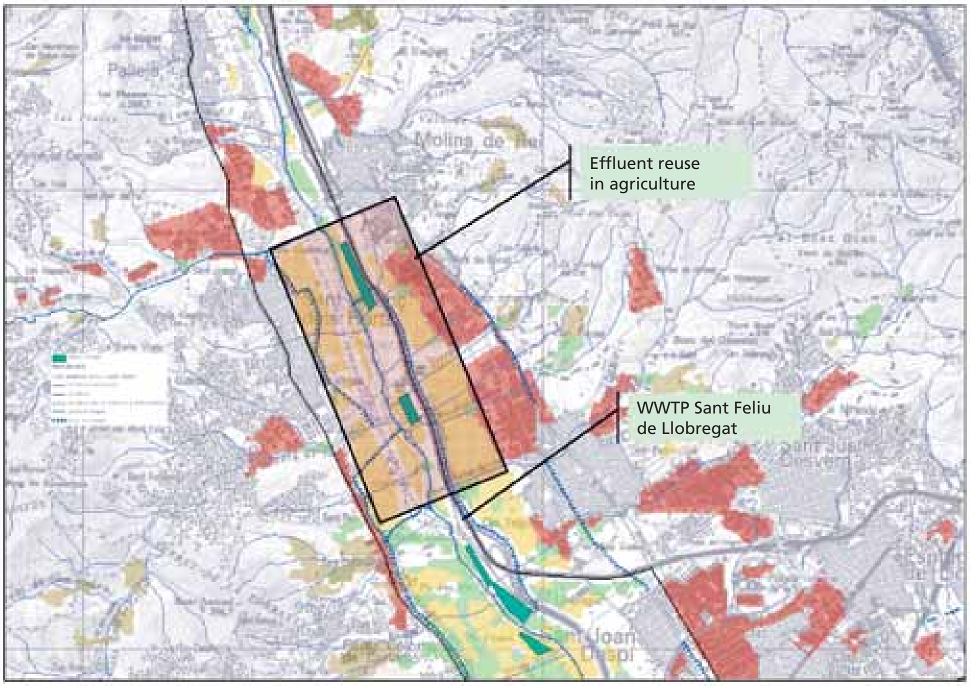


FIGURE 4.1 b
Map of WWTP and reclaimed water. Irrigated agriculture area



The crucial variable in the CBA is the amount of freshwater that would genuinely be released by farmers for exchange to the city. Farmers would need to be convinced of the value of the exchange for themselves – that the benefits from greater reliability of the water, the savings of groundwater pumping, and the nutrient in the effluent are sufficiently firm to offset the possible health hazard, impact on local amenity, and risk of produce restrictions. The analysis takes an *optimistic* view of this factor.

On the other hand, the analysis contains two sources of *underestimation* of the likely project benefits:

i. Underestimation of the value of urban water. This value is equated with the prevailing water tariff, which is less than its economic cost of supply. This is true even allowing for the fact that an environmental tax is incorporated in the water price, levied by the Catalonian Water Agency (ACA) in order to guarantee the long-term water supply of cities and to improve the present quality of both surface and groundwater. In practice, only 23% of the current cost of water and sanitation services is recovered from the tariff (Agència Catalania de l'Aigua 2007).

ii. The schemes have other benefits, not quantified in the analysis - improvement of river flow, wetland conservation, creation of a hydraulic barrier against seawater intrusion and potentially providing water for industrial use (see Table 2.4 in Chapter 2).

4.1.4 Financial feasibility

i) financial impact on key stakeholders

Farmers

In the Sant Feliu area, the project would have a relatively modest impact on farmers' costs through savings in pumping and fertilization, and the greater benefit would be the extra sales revenue expected from an expansion in the irrigated portion of land[2]. Farmers in the El Prat area would only enjoy the cost savings from pumping and fertilization. Up to the present farmers have resisted the use of reclaimed water due to its high salinity, compared with river water, but with the new desalination unit at the treatment works this factor would disappear.

Municipality

Given the tightly constrained demand for water at present, the City should be able to sell all the newly released amounts of freshwater at least at the prevailing water tariff. The city's water company is restricted in charging the full economic tariff, and may be unable to benefit fully from the extra sales revenue, or benefits to costs from economies of scale. Hence it is difficult to predict the final impact of the projects on municipal finances in this specific instance.

Nevertheless, the *potential* for fiscal gain is there. Revenues from the extra water sales would exceed the capital costs and incremental O&M cost of the exchange. If both WWTP projects and their associated works were implemented, on the evidence of Table 4.1 the city utility would make an *annual* financial gain of €16.88[3] million, in exchange for the initial capital outlays of €15.12 million. Any decision to raise tariffs in real terms would improve the project's financial appeal even more. In other circumstances, the city would also save Pollution Charges payable on wastewater released from the WWTPs, but in this instance the treated wastewater goes directly into the sea and no Pollution Charge arises.

A full dossier on this project would, of course, have to include a comparison of this scheme with the cost of other options for delivering the same volumes of fresh water, which is not available for this report.

ii) financial instruments and transfers

The analysis would support the view that most, if not all, of the cost of this project would have to be recovered from outside agriculture. On this evidence, there is little basis for charging farmers a cost-recovering level of tariffs for use of the effluent, which would have to be c. 0.40 €/m^3 for El Prat and 0.22 €/m^3 at Sant Feliu.[4] These are greatly in excess of anything considered realistic in Spanish agriculture at present. On the other hand, the levels of urban tariffs (1.1 €/m^3) are already considered to be well below the economic cost-recovering levels, and there may be scope to raise these, particularly in the context of demand management at times of scarcity. In the absence of compulsion or other kinds of administrative coercion, the voluntary participation of farmers in freshwater/effluent exchange may depend on subsidies, since the offer of free effluent may not be enough. Negotiations with farmers together with agricultural advisors may result in co-operative agreements with the commitments made by each of the parties laid down in contracts.

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2 The assumption in this analysis is that such an expansion in irrigated area would only be possible through the use of reclaimed water. Otherwise, these benefits could also be obtained in the without-project case.

3 The sum of the annual value of fresh water exchanged for city use, minus the total of annual costs (excluding initial capital costs).

4 Calculated as follows: El Prat: present value of cost stream over 25 years Euro 66.19, divided by annual volume of effluent 13 Mm^3 for 25 years discounted at 6% = 0.398 €/m^3. Sant Feliu: PV costs Eur 20.47 divided by volume of effluent over 25 years, discounted at 6% = 0.219 €/m^3.

The option of developing markets for the sale and purchase of water rights is a long term theoretical possibility which would substitute for a subsidy scheme. Farmers would then be able to sell their fresh water rights to the city, in exchange for cash and/or effluent. Such a scheme would depend on farmers having secure legal entitlement to a given amount of fresh water (from surface sources or aquifers), and the existence of a national legal framework for such exchanges.

iii) funding the project
In the Llobregat Delta, the investment cost of water development projects is financed in part from EU programmes and the Catalonian Water Agency. In 2009 the regional government of Catalunya announced a programme of wastewater reuse to be funded entirely by the public sector, though some projects would involve co-financing with municipalities or local water companies.[5] In the neighbouring region of Aragon the regional government has started implementing a major programme of wastewater treatment funded by a public-private partnership model.[6] In various other countries[7] effluent reuse projects have been funded under private Build-Operate-Transfer and similar types of concession. Such concessions require the creation of a project structure with a Special Project Vehicle whereby the concessionaire receives revenues from the public sponsor (off taker), since in many cases the recovery of costs directly from farmers is unlikely to be feasible.

4.2 TORDERA DELTA & COSTA BRAVA

4.2.1 Overall situation

The Delta of the River Tordera lies half in the Southern boundary of the Costa Brava (Girona Province coastline) and the other half in the North of Barcelona province, in North-Eastern Spain. It contains two WWTPs, at *Blanes* (Girona) and *Tordera* (Barcelona), both with tertiary treatment. Effluent from Blanes is used mainly for recharging the aquifer through river discharge and subsequent infiltration in a highly permeable river bed, though a few farmers also use it for irrigation. Reclaimed water from Tordera is currently being discharged into the Tordera River but, once its solar-powered pumps are operational, the effluent will also be used to recharge the aquifer. Farmers in the vicinity rely on groundwater since the Tordera River is completely dry during summer months when the water demand from crops is highest. However, several farmers are starting to use reclaimed water to supplement their normal sources.

In the Southern Costa Brava, the *Castell-Platja d'Aro WWTP*, started to supply effluent to farmers around its plant in 2003. Most of this effluent is treated to secondary levels, but around 20% is treated to tertiary levels and this is used for golf course watering and groundwater recharge, with the residue discharged into the sea. Plans are imminent for upgrading the tertiary treatment capacity of the WWTP, which would have a mixed impact on agriculture, reducing its nutrient content while broadening its applicability to other crops, and also making the effluent more usable by municipalities and golf courses. An important choice to be made is whether to produce effluent of a single quality, or of two qualities, aimed at different users.

This section outlines the analysis required for the economic justification for the projects at Blanes and Platja d'Aro. The former is brief, since data is lacking on certain key points, but the latter is more complete.

5 *Global Water Intelligence (GWI)*, Aug 2009, p. 14.
6 OECD, *Strategic financial planning for water supply and sanitation,* 2009.
7 *GWI* "Reuse tracker" (a regular feature of the journal)

4.2.2. Project specification

At **Blanes** the proposal is to reuse the tertiary effluent from the WWTP (currently 3.15 Mm^3/yr, to be increased to 5.05 Mm^3/yr) for agriculture, which would replace all use of groundwater by farmers.

At **Platja d'Aro** the regional water authority ACA foresees an enlargement of the tertiary treatment capacity of the WWTP by 30% to a 20 000 m^3/day design capacity flow rate. Currently only 22% of the total treated water in the plant is reclaimed. The upgrade would respond to the potential demand from new users (*e.g.* the municipalities of Castell-Platja d'Aro and Santa Cristina d'Aro, farmers in Llagostera – a neighbouring municipality - and golf courses).

Following consideration of the option of differential effluent treatment standards for different users, it has been decided on grounds of cost to produce a single effluent quality. The project also includes new pumping stations, pipelines and water reservoirs. The total investment cost would be around 7.7 M€, 16% for the enlargement of tertiary treatment, 48% for the pipelines and 33% for storage facilities.

The extra reclaimed water would be allocated between uses as in Table 4.2.

4.2.3 Assessment of project impact

Blanes

Table 4.3 indicates the principal cost and benefit items that would constitute the CBA, with data filled where available. Certain key values that are not available for the purpose of this report are indicated.

The information provided in Table 4.3 does not permit an economic judgement on this proposal, but it does indicate where further data searches should concentrate. The cost of enlarging the existing tertiary wastewater capacity is unknown, though the cost of the distribution infrastructure seems substantial relative to the known benefits to farmers. It is assumed farmers will get no benefit from the fertilization properties of the effluent since most nutrients will have been removed. They will benefit from savings in the relatively heavy pumping costs (which are likely to grow in the future since pumping depths are large and increasing).

The two key potential benefits, which along with the incremental capital cost of treatment would largely determine the feasibility of the project, are unknown at present. The effluent would provide greater security of supply and economic benefit to farmers (for instance, enabling them to plant more valuable crops needing greater certainty of water[8]). The experience of the Mas Pijoan farm discussed below is relevant.

The other crucial benefit, the value of groundwater left in the aquifer, depends on regional policy – whether to keep the water in the ground, or to allow other users to exploit it. In the former case, the values would be environmental, in the latter case the value of the water to future users, whose identities are currently unknown.

TABLE 4.2
Proposed allocation of extra reclaimed water in Platja d'Aro area

	Requested reclaimed water Mm^3/yr
Agriculture (plots adjacent to WWTP, and farmers in Soilius & Llogostera)	1.263
Municipalities (Platja d'Aro & Santa Cristina d'Aro)	0.288
Golf and Pitch & Putt courses (6)	0.658
Improving water flow in Ridaura River for ecological purposes	1.0
Total	**3.209**

[8] though produce restrictions might apply to the use of effluent, compared with groundwater

Platja d'Aro

The enlarged tertiary treatment at the WWTP would reduce the nutrient content in the effluent by about 70%, which would diminish the potential savings in farmers' fertilizer costs. Thus, the main benefits to *agriculture* from the project would be the following:

i. The increase in crop production due to enhanced water availability. The use of reclaimed water will ensure less variable yields and sales revenues per ha as they are less reliant on uncertain water supplies.
ii. The avoided cost of groundwater pumping.
iii. A small reduction in fertilizer costs would still remain.

Benefits for *municipalities* would consist of the value of extra water available for domestic use. This would come from the release of 3.2 Mm^3/yr of groundwater currently extracted for agriculture. The benefits from use of the water for golf courses or other tourism purposes are not estimated, though are likely to be positive.

The project could benefit the *environment* through aquifer recharge: one possible estimate for this benefit is the savings in the cost of groundwater pumping because of the shallower aquifer level.

The balance sheet of costs and benefits is set out in Table 4.4.

TABLE 4.3
Blanes project: cost and benefit categories (€ M)

1	Capital cost of tertiary treatment	Not available [Incremental cost of raising tertiary output from 3.15 to 5.05 Mm^3/yr]
2	Capital cost of pipelines, pumps, etc. to convey effluent to fields	5.05
3	Annual O&M costs (mainly pumping) for conveyance of effluent to farms (0.02/m^3 x 5.05 Mm^3)	0.10
4	Savings in groundwater pumping costs (0.11 x 5.05 Mm^3)	0.55
5	Savings in fertilization	zero
6	Avoided losses in farm revenues due to water shortages in drought years	unquantified
7	Value of groundwater left in aquifer	unknown

Items 1 and 2 are initial one-off costs, other items are annual flows

TABLE 4.4
Costs and benefits of Platja d'Aro WWTP upgrade (Euro million)

1	Capital investment cost: <u>total</u>	<u>7.70</u>
	tertiary effluent treatment;	1.20
	pipelines;	3.68
	pumping;	0.25
	storage;	2.55
2	Incremental annual O&M costs of treatment (0.05 €/m^3), pumping, conveyance, etc (0.10 €/m^3)	Treatment: 0.16 Conveyance: 0.32 <u>Total 0.48</u>
3	Increased farm sales revenue (net):From future expansion from 41.6 to 291 ha	[0.874]
4	Savings in groundwater pumping	0.007
5	Savings in fertiliser cost	0.004
6	Value of groundwater released for urban and other potential use: 3.2 Mm^3 @ 1.1 €/m^3	[3.52]
7	Sales of effluent to municipalities 0.28 Mm^3 @ 1.1 €/m^3	0.30
8	Sales of effluent to golf & pitch & putt courses: 0.65 Mm^3 @ 1.1 €/m^3	0.71

The broad picture from Table 4.4 is that, for an investment of € 7.7 million and annual O&M costs of € 0.48 million, existing farmers will receive very modest savings in pumping and fertiliser costs (€ 0.011 million). Some of the effluent would be sold to municipalities and recreational establishments for €1.01/m^3. The costs and benefits mentioned so far are reasonably robust.

The reuse of effluent would relieve pressure on the groundwater aquifer of up to 3.2 Mm^3/yr if it is assumed that all the users stated in Table 4.2 would otherwise draw their water from the groundwater. This would create an environmental benefit, since the aquifer is diminishing and suffering from saline intrusion. If it is public policy to arrest the diminution of the aquifer, then this is purely an environmental benefit, which can be valued appropriately. If there is no such policy to stabilise the aquifer, the groundwater "saved" by the reuse of effluent would be available for other users. Since this benefit is uncertain, it is omitted from the Base Case CBA calculation below.

Another uncertain feature of the CBA arises from the possibility that part of the effluent from the upgraded WWTP would be available for a major expansion of agriculture in the Llagostera area, currently constrained by the availability of suitable water. This could be a major future benefit (which preliminary studies have estimated to be € 0.874 M/yr) but is somewhat speculative at present, and is also omitted from the Base Case CBA below.

Cost-benefit analysis - Base Case

As in the Llobregat case, no adjustment is made to the nominal values of the cost and benefit streams. It is assumed for simplicity that the whole capital cost is incurred at the end of year 1 and that the annual streams continue at a constant level for 25 years. The results are as follows (in Euro million):

i. Present Value of costs (1 + 2, discounted at 6%): 12.99
ii. Present Value of benefits (4, 5, 7, 8, at 6%): 12.26
iii. Net Present Value (ii minus i) minus 0.73
iv. Benefit-Cost Ratio (ii: i) 0.94 to 1.0

The result of this Base Case analysis is that there is a small negative NPV when only the "basic" benefits are reckoned. This may be considered a pessimistic rendering, for several reasons:

- The value of the groundwater "saved" is omitted due to its uncertainty. The main problem is a lack of the capacity of the aquifer to supply enough water. Several years ago, Platja d'Aro and other neighbouring municipalities started to be supplied by the El Pasteral dam.
- No account is taken of the potential value of the effluent to new irrigated land to be developed in Llagostera.
- The benefits for non-agricultural users (such as golf courses and other municipal purposes) are partly considered.
- There is no reckoning of the environmental benefits of reduced pollution of seawater, nor of the benefits from enhanced flow of the River Ridaura, which is practically dry for most of the year.

Clearly, either of the first two factors above would swing the NPV into a sizeable positive amount. Likewise, inclusion of a relatively small environmental value under the third category would make the project economically justifiable. The project is sensitive to the size of revenues from the sale of effluent, and highly sensitive to inclusion of the value of groundwater saved or released, and to its benefits for irrigation yet to be developed.

The preliminary analysis above indicates that further investigation could fruitfully focus on the potential use of the effluent by farmers in the Llagostera area, who hold the key to this project's feasibility.

Cost-effectiveness Analysis

If the project is only marginal at best, the *avoided cost* of the next best ("next worse") project is irrelevant since the project is not worth doing. However, if the omitted benefits above were reinstated, the project would become worthwhile. Then question arises, would there be more cost-effective ways of achieving its objectives?

While a comprehensive review of alternatives is not available, some estimation has been made of the cost of providing the water volume by desalination and, alternatively, the conveyance of water from the Ter River through a newly constructed pipeline. The reference costs for sea water desalination have been taken as 0.45-1.00 €/m^3. For comparison, the unit cost of the Platja d'Aro WWTP project based on Table 4.5 values is 0.33[9] €/m^3, which would give it a cost advantage, though the quality of effluent would differ in the two cases.

A simple estimation has also been made of the cost of bringing freshwater from the Ter River through the new pipeline. Based on capital costs of € 27 M and annual O&M of € 0.54 M the unit cost of this solution for a comparable volume (though of freshwater) would be 0.82 €/m^3 [10], more expensive than the Platja d'Aro WWTP but in the range of competitiveness with sea water desalination.

The significance of Mas Pijoan Farm

The account of the Mas Pijoan case in Chapter 2 is indicative of the gains that farmers can make from using reliable supplies of treated effluent, compared to pumping groundwater. The evolution of farm operations between 2003 and 2006, before and after use of the effluent, is shown in Table 4.5. In short, the farm was able to expand its irrigated area, reduce its reliance on groundwater and increase its crop yield by 40%. These results are being watched with interest by the farmers in the neighbouring area of Llagostera, where groundwater is extracted from depths ranging from 80-120 metres, even greater than in the Solius area used in the Base Case.

TABLE 4.5
Comparison between past and present situation at Mas Pijoan Farm

	Situation in 2003	Situation in 2006	Change compared to 2003 (%)
Total irrigated land (ha)	35	41.6	+18.9
Land irrigated with reclaimed water (ha)	0	25	-
Land irrigated with mixed water (ha)	0	7.6	-
Land irrigated with well water (ha)	35	9	-74.3
Well water used (m^3/yr)	175 000	71 240	-59.3
Reclaimed water used (m^3/yr)	0	136 760	-
Crop yield (kg/ha)	50 000	70 000	+40

9 The NPV of the initial capital cost (€ 7.7M) and the annual operating costs (€ 0.48 M)of the new facility are discounted by 0.94 to obtain their PV at the beginning of year 2. This is divided by the volume of the extra water (3.2 M/yr) for 25 years beginning in year 2 discounted at 6%. (The present value (NPV) of 1.0 per annum over 25 years at 6% is 12.78. Since the flows of water and costs are assumed to only start in year 2 a discount factor of 0.94 is applied.)

10 By the same process as that described in the above footnote

Financial feasibility

i) Financial impact on key stakeholders

In Blanes farmers would directly benefit from savings in pumping costs and from the greater reliability of effluent compared with existing sources. On the other hand, there may be produce restrictions. The immediate financial impact on the municipality is likely to be negative since there is no obvious possibility of "exchanging" the reused effluent for freshwater rights that can be sold elsewhere. The only current outlet for the effluent is agriculture which is unlikely to be able to pay for the whole capital cost of extra treatment, distribution and pumping. Any environmental benefits would need to be compensated by the regional or national authorities. In this case example, the aquifer has been declared "overexploited" which would allow the authorities to use some degree of compulsion. Although the formal trading of rights is illegal, some negotiation is possible.

The situation in the Platja d'Aro has similarities to that in Blanes but with two principal differences. Firstly, there are potential non-agricultural off-takers for the effluent in the shape of municipal and recreational users who can defray part of the cost through tariff revenues. Secondly, there is a promising agricultural demand for the effluent in Llagostera with the possibility of a contract with farmers developing new irrigable land. As in Blanes, the value of water left in the aquifer is difficult to determine without having regional authoritative policy on this issue.

ii). Financial instruments and transfers

In both areas, there are limited opportunities for exchanging reclaimed water for freshwater rights, hence most of the cost of the projects would have to be recovered either from farmers or from environmental custodians. The illustrative economic cost of the treated effluent in the Platja d'Aro scheme (0.31 €/m^3) is much higher than the cost of pumping groundwater (0.11 €/m^3) and the price of reclaimed water set by the *Consorci de Costa Brava* of 0.08 €/m^3. There is no present source of cross-subsidy from farmers – even in Platja d'Aro, where urban and recreational users could in principle afford the economic tariff. They only account for a minor part of consumption. The option of developing water markets is not much more promising since farmers have only rights over groundwater which is difficult to trade for both legal and cost reasons.

There remains a justification of subsidies to farmers on the grounds of environmental service providers, as compensation for maintaining the aquifer level, though the aquifer is no longer used as a source of water.

iii). Funding the projects

The initial investment costs of these projects could attract capital grants and soft loans from regional and central government and from EU schemes. In the Mas Pijoan scheme, 70% of the cost of connecting to the existing pipeline was provided by the European Agricultural Fund for Rural Development. It would also be reasonable to look to participating farmers for a contribution to the capital cost of distributing reclaimed water to their fields, where water from other sources is becoming scarce and unreliable. An agricultural water charge equivalent to the average cost of pumping groundwater (~ 0.11 €/m^3) would cover a minor part (in Platja d'Aro around one quarter) of the recurrent costs of supply.

Prospects of funding these projects from private concessions are not promising, except if the concessionaires are remunerated directly by municipalities through off-taker agreements for the effluent. Cost recovery from the users (mainly farmers) is unlikely, so long as they can pump groundwater at less than the tariff.

4.3. MEXICO

4.3.1.Mexico City & Tula Valley

Overall situation

Farmers in the Tula Valley irrigate their fields with free untreated wastewater from Mexico City, supplemented by other local water sources. The relationship between the City and Tula Valley is synergistic: the arrangement benefits both sides – providing the City with a downstream outlet for large volumes of untreated wastewater, and the farmers with ample nutrient-laden water to irrigate their crops. It would be possible to estimate the cumulative benefits to the City from the possibility of delaying its investment in advanced wastewater treatment until now, as well as the benefits to farmers of using wastewater in comparison with other possible water sources, of less fertility. Such an exercise would be interesting to countries and regions at an earlier stage of considering wastewater strategies, but in the present case it would be academic since decisions have been taken and alternatives for both parties seem few.

As a result of the City's on-going programme of investment in WWTPs, most of the wastewater will soon be treated to tertiary level. In theory this will widen the applicability of the reclaimed water for other crops, and further reduce any public health hazards, but will require farmers to apply fertilizer to offset the reduction in the nutrient content of the recycled water. Rough estimates done by the case study authors suggest that farm productivity could be 18% higher with the use of wastewater, compared with using freshwater.

The situation as described above is likely to continue: neither party has any strong reason to change it, nor the means to do so. There is little scope for an intersectoral exchange – of farmers' freshwater rights in return for continued supply of reclaimed water – such as was discussed above in the Spanish cases. A proposal has, for example, been made (Jimenez Cisneros, 2004a) for the City to take some of the aquifer water in the Tula Valley that has been recharged with the wastewater effluent and other sources. This would be part of an exchange for the continued supply of (treated) wastewater. However, there are physical and other obstacles to an exchange of water use rights between the farmers and the City – explained in chapter 2 that could limit exchanges of this nature, even if either party wished to do so – which is not obvious.

Cost-benefit and cost-effectiveness analysis only has traction where policymakers have choices, and these are severely limited in the Mexico City-Tula situation by the decision to implement the WWTP investment programme, by hydrological realities, by farmers' use rights, and the rights of users even further downstream.

4.3.2 Guanajuato City & La Purísima

Overall situation

This case has some similarities with the previous one. The farmers in La Purisima irrigation scheme draw water from a reservoir fed partly by fresh river water and partly from treated wastewater from the City's WWTP, which is upgrading its secondary treatment capacity. Their rights to water do not take account of the quality of the water concerned.

In this case farmers already use recycled water contained in the river feeding the reservoir, and upgrading the level of treatment would make little effective difference to the volume of water they received out of the reservoir. Farmers' main concern would be the impact on their operations of receiving a mixture of water with a much higher content of treated effluent from the new WWTP, which would reduce the previous benefits from fertilization. Farmers could, however, receive offsetting gains from the freedom to grow a wider range of crops. Rough estimates conducted by the case study authors suggest that farm productivity could be 10% higher compared with the (hypothetical) use of wholly freshwater.

As in the Tula Valley, there does not appear to be scope for an exchange of water use rights between farmers and the city, for reasons explained in chapter 2. Farmers would appear to be the passive recipients of any change in effluent quality decided by the city and – so long as they depend exclusively on the reservoir – they have no means of reducing their exposure to such changes.

4.3.3 Durango City & Guadalupe Victoria irrigation module

Overall situation

Consideration is being given to the scope for Durango city acquiring rights to the clear surface waters originally granted as a concession to irrigation farmers in the Guadalupe Victoria area adjacent to the city. This would be in exchange for providing reclaimed water to be used by the farmers.

Such an exchange of water use rights would have several benefits: the aquifer would cease to be overexploited; the municipality would get water of a good quality at a lower cost; energy would be saved in reduced pumping of the aquifer; and the irrigators would receive some biodegradable nutrient loads for their crops.

There is a precedent for the agricultural reuse of effluent. Between 2000 and 2006 the irrigators had an arrangement to use the city's treated wastewater to supplement their regular supply of reservoir water. This was mainly motivated by their need to secure supply in drought periods. In 2000 an inter-connector pipe was built from the aerated lagoons of the WWTP to the left margin main channel flowing from Guadalupe Victoria reservoir. Since 2006 effluent supplied under this arrangement has diminished, since the spillway crest of the reservoir has been raised, providing additional storage of 10 Mm^3 of water.

Project specification: the basis of a possible agreement

The situation has an arithmetical symmetry which makes an agreement between the city and the farmers appealing: the full Guadalupe Victoria irrigation module has a surface freshwater concession of 63 259 Mm^3/yr, while the city of Durango has a ground water assignment of 61 292 Mm^3/yr. The latter accounts for practically the whole of the aquifer's annual recharge. An arrangement for all municipal water to be supplied from the reservoir and all the reclaimed water would be used in irrigated agriculture would cover practically all the water required by both parties for the foreseeable future. This would avoid the current over-exploitation of the Guadiana Valley aquifer.

Such a long term agreement would require irrigators to formally cede their rights to surface water in exchange for treated urban wastewaters. More investment in infrastructure would also be required to make the outcome feasible. The second WWTP now being planned would increase the available volume of wastewater, and the existing inter-connecting pipeline would need to be enlarged and extended to serve the entire 9 399 ha command area of the Guadalupe Victoria irrigation module, and a regulation pond would also be required.

In the short term, a more limited arrangement might be envisaged, whereby farmers would relinquish their rights to 10 Mm^3/yr of surface streamflows stored at the Guadalupe Victoria reservoir, in return for receiving 10 Mm^3/yr of treated urban residual waters delivered to the Guadalupe Victoria irrigation module. The city would keep a small number of wells (10-15) for industrial use.

For illustrative purposes, a cost-benefit framework for the development of such an intersectoral agreement is sketched in (Table 4.6). In principle, the agreement could cover any level of water exchange, but for the purpose of exposition the full amount of the irrigation freshwater concession (63 Mm^3/yr) is taken as the Base Case.

Table 4.6 indicates that all the data necessary for a proper CBA are not yet available. The crucial items in any decision are likely to be:

- The value placed on keeping water in the aquifer and avoiding further groundwater depletion (this was estimated by the case study authors to be c. $0.88/m^3). This is mainly an environmental benefit, which will affect local streams and wetlands, and therefore wildlife and amenity. But there would also be gains to users who continue to pump the aquifer (*e.g.* local industry), and the aquifer would also have monetary value as water storage as protection of future drought (insurance value).
- The city's savings in the cost of pumping groundwater from increasing depths. This has not been estimated, but is likely to be sizeable.

The assumption above is that the reuse agreement would enable the city to satisfy its municipal water need by replacing groundwater with surface water from the reservoir. This is, of course, a simplification of what is likely to happen, but insofar as it is valid, it indicates that the benefit of the agreement to the city would be as an *avoided cost* rather than creating any *new benefits***.** The economic value of the water sold in the city would, *ex hypothesis,* be the same as before (though its financial value would probably be less, since the basis of charges has to be the actual cost of supply, which would be lower for surface water than groundwater). The *city* thus has to weigh the incremental cost of the project (enlarging the inter-connector, pumping effluent to farmers) against the benefits of savings in groundwater pumping and avoiding further aquifer depletion.

Farmers benefit from the nutrient value of the effluent, but may face produce restrictions due to their use of effluent rather than clear surface water.

Both parties, the city and farmers, would have to consider the *cost-effectiveness* of the arrangement compared with alternative ways of meeting their needs. Although the detailed alternatives are not available to this report, the options for the City might include further enlarging freshwater storage, transmitting water from more distant sources, and demand management including the reduction of losses in distribution. Alternatives for farmers to improve their own water security might be increasing water efficiency by changes to their irrigation techniques and the system for delivering water to their plots.

The *financial* impact on the city is likely to be positive, through savings in recurrent costs of obtaining water. For farmers the benefit seems more marginal, and – depending on their legal rights to the reservoir water – there may be a basis for compensation for the forfeit of such rights.

TABLE 4.6
A cost-benefit framework for an intersectoral agreement in Durango City
Values in millions of Mexican Pesos

1	Capital cost of wastewater treatment	It is assumed that the cost of the second WWTP is required anyway to conform with national environmental regulations, hence should not be attributed to the reuse project
2	Capital cost of the inter-connector pipeline from the WWTP(s) to the irrigation areas	Cost of original inter-connector ($9.5M) is a sunk cost. Cost of enlarging this is ~ $1M/km]
3	Net difference in annual O&M for conveying effluent from WWTPs to farmers, compared with farmers' original cost of conveying fresh water from reservoir to fields.	n.a.. [local convention is to assume this is 2% of capital cost of item 2 above. O&M cost of treatment should not be attributed to this project]
4	Farmers' avoided cost of fertilizer	17.17
5	Durango City: avoided cost of groundwater pumping	n.a.
6	Environmental benefits to aquifer	n.a. [Difficult to quantify, and dependent on public policies towards aquifer use]
7	Cost of produce restrictions: net loss of farm income	n.a.

n.a. = not available

4.4 ISSUES ARISING FROM THE USE OF THE ECONOMIC METHODOLOGY

The variety of case material presented from Spain and Mexico provides a good field testing for the approach presented in Chapter 3, and demonstrates that this is an appropriate framework of analysis for projects involving the reuse of effluent. In general, the framework presented, consisting of the three-fold approach – *Cost-Benefit Analysis*, *Cost-Effectiveness Analysis*, and finally *Financial Feasibility* – has proved its merits as a method of justifying the projects concerned.

The viewpoint adopted by the hypothetical CBA analyst in this report is that of the national or regional water or environmental authority. Such an agency takes an "IWRM" stance on water management, taking account of the interests of all relevant stakeholders. Although the two that are most prominent in this report are municipalities and farmers, there is an important third part at the table – the environment – which needs a champion and a custodian. Reflecting the needs of the environment, valuing its assets and services and ensuring that its financing needs are met, is a challenge to analysts in this area. The case studies confirm that effluent reuse is an area ripe for the application and refinement of the tools of environmental cost-benefit analysis.

The case material demonstrates that certain items of costs and benefits are more robust than others. On the cost side, the capital costs of treatment units, pumps and canals can be estimated with some confidence, and their operating costs (pumping, chemicals, labor, etc.) are also fairly evident. The technology of wastewater treatment (including desalination) is, however, evolving, and it is difficult to make firm assumptions about future unit costs. Turning to benefits, most of the case studies rely on the perceived benefits to farmers from the nutrient properties of effluent, savings in groundwater pumping, and the greater reliability of effluent compared with other sources in arid climates. While pumping costs are reasonably firm, the benefits of fertilization depend on local empirical evidence ("with and without project"), which is patchy and will need to be reinforced, for instance through agronomic trials. The benefits of reliability also need to be demonstrated more convincingly, possibly by closer study of farmers' response behavior (insurance, aversive actions, etc.).

From the viewpoint of urban water demand, the case studies reflect the widespread view that water supply tariffs are too low, hence there is a pervasive underestimation of the benefits created by developing new solutions to growing demand (*e.g.* Llobregat). However, some of the cases (*e.g.* Durango) illustrate the importance (stressed in chapter 3) of distinguishing genuinely new benefits, on the one hand, from the avoided costs of meeting existing demand in a different way.

In several cases the data were missing or incomplete, and a comprehensive CBA was not feasible. In these and all other cases, however, the use of sensitivity analysis (including *switching value* estimation) provides a good guide to the "value of information" approach – where scarce research time should be focused in cases where data is weak across the board. The following is a list of other items where information proved to be problematic:

- Market prices were typically used, without adjustment to reflect economic scarcity values or transfer payments;
- Calibration of the potential public health risk from using effluent, and information on the impact of produce restrictions;
- The downstream impact (on other users, the environment, etc.) of recycling water;
- The appropriate rate of discount for projects of this nature (justification of the rate employed, typically 6%);
- The difficulty in some cases of carrying out cost-effectiveness analysis because of the wide variety of alternative options available, and the need to place the project in the context of regional strategies (*e.g.* that of the regional Government of Catalunya);

- Environmental impacts, which are difficult to value at any time, crucially depend on government policies and regulations. The value of restoring groundwater levels is a recurring issue in the case studies, another is the impact of higher effluent quality on receptor water bodies. Where official regulations on these matters apply, a CEA approach is more appropriate for project decisions. None of the case studies appeared to involve protected species, which is a complicating issue in many water resource projects elsewhere. In several case studies, the result hinges on how environmental impacts are valued, which emphasize the importance of developing the methodologies and experience in this area[11].

4.5. POLICY IMPLICATIONS OF RESULTS OF CASE STUDIES

There are several ways of viewing the purpose of effluent reuse projects:

- *as a feasible and cost-effective means of meeting the growing demands of agriculture for water in regions of growing water scarcity and competition for its use.* This motive also applies in situations where demand is not necessarily rising, but where periodic water scarcity is a problem for farmers planning their annual crop patterns. The case studies contain evidence (*revealed preferences*) of farmers responding positively to the use of effluent in these situations, as a temporary expedient or long term solution. However, effluent reuse is one amongst a number of options at farm level to minimizing exposure to water risk. Moreover, the creation of expensive distribution and storage facilities, with a high recurrent cost, in order to furnish water for low value farm purposes, is not always warranted – unless there are benefits to other sectors (see below).
- *as an environmental solution to the growing volume of wastewater effluent and its potential for downstream pollution*. The Mexico City-Tula case is the clearest example of the mutual benefit for the City and farmers from disposing of urban sewage and effluent to agriculture – and allowing natural processes to carry out some of the purification *en route*. Reuse schemes allow the dispersion of effluent and its assimilation across a wide area, as compared to the *point source pollution* from WWTPs. The reuse of effluent nutrients in crop production, rather than their removal and effective destruction during advanced processes of wastewater treatment also has a strong appeal to many Greens. The case studies confirm these environmental benefits of using reclaimed water.
- *as a "win-win" project that is a solution to urban water demand, while also delivering the agricultural and environmental benefits stated above*. The Llobregat sites and Durango City are clear-cut examples of potential win-win propositions since in both cases it is physically and geographically feasible for farmers to exchange their current entitlements to freshwater for effluent, and for the cities to gain access to the freshwater rights that are thus "released". (Whether or not this actually happens depends on legal and other barriers being overcome, as well as successful negotiation over the financial arrangements between the parties to the deal. It must not be assumed that farmers will readily give up rights – as a general observation on the cases, the assent of farmers is presumed too readily, without further consideration of their operational situations. Most farmers prefer to have several water sources as insurance).

Much of this report, and all the case studies, are concerned with producing "win-win" outcomes of the third kind above. In two of the cases (Mexico City-Tula and Guanajuato) the scope for a win-win outcome is not fully apparent, since crucial

[11] Turner *et. al.* (2004), Hermans *et. al.*(2006)

elements of feasibility are either absent or yet to be determined. In other cases (Blanes, Platja d'Aro) the freshwater rights "released" by farmers are from groundwater – which could be a potential source of urban water, or may be better left in the aquifer for environmental reasons. The basis of a win-win exchange in such situations is tenuous.

Needless to say, a "win-win" outcome only happens when farmers really do relinquish their freshwater rights in favor of urban users. This currently only happens in a minority of cases (Box 4.2).

A CBA approach helps to set the parameters for agreements between the main stakeholders, which in this report are assumed to be farmers, cities and the natural environment. It helps to define the interests of the parties in moving towards, or resisting, agreements that change the *status quo.* Where the balance between costs and benefits for one party (*e.g.* farmers) is very fine, the existence of a large potential net benefit to another (*e.g.* city or environment) can provide "headroom" for agreement by indicating the economic or financial bounty available to lubricate a deal.

BOX 4.2

Global water Intellignece quote

"At the moment, reused water is mainly supplied to low-value applications such as agricultural irrigation, with pretty much no ceiling on demand. Around a third of all reused water is given away for free, and two-thirds is sold at an extremely low price, which means that although investment into facilities is relatively high, there is very little return. There is little more than environmental concern to motivate reuse projects, and reused water is failing to offer much-needed relief to the pressures of urban potable supply. "

Global Water Intelligence, October 2009, p. 6.

Chapter 5
A planning framework for wastewater reuse

The economic framework for wastewater reuse presented in chapters 3 and 4 should fit within a comprehensive planning framework. A sound and methodical planning approach will assist in identifying all the relevant factors necessary for the decision to proceed with a project. This final chapter presents such a planning framework, relating back to the key issues introduced in chapter 1 and fitting them into a comprehensive approach, which incorporates the economic and financial methodology expounded in this report.

The contents of this chapter are set out in Box 5.1

5.1 THE PROCESS OF PROJECT PLANNING

The typical stages of project planning are shown in Fig. 5.1. The process may be iterative. Reconnaissance level planning may occur initially for the analysis of project concepts based on limited data. If this preliminary analysis is favorable, the planning stages may be repeated with more detailed data gathering, definition of project alternatives, and analysis of each alternative.

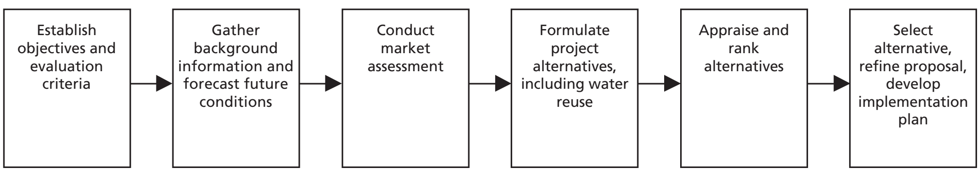
The assumptions, data, and analyses should be documented in a *facilities planning report* to provide a basis for public review and for decision-makers to decide whether to proceed to implement the project. A suggested outline of such a report is shown in Table 5.1. This outline can also serve as a checklist of topics to evaluate during planning.

The interrelatedness of water supply, wastewater management and environmental protection lends greater importance to Integrated Water Resources Planning. Wastewater reclamation and reuse is a bridge

BOX 5.1
The planning framework

Project planning process	5.1
Identification of problem & project objectives	5.2
Definition of study area & background information	5.3
Market assessment & market assurances	5.4
Identification of project alternatives	5.5
Appraisal & ranking of project alternatives	5.6
Implementation	5.7
Specific technical issues:	5.8
Facilities & infrastructure	
Balancing supply and demand	
Wastewater quality	
Public health risks & safeguards	
On-farm issues	

FIGURE 5.1
Project planning process



Source: Adapted from Mills and Asano (1998) between water supply and wastewater management and is able to address a broader set of goals than is typical of single-purpose projects. Ideally, regional planning involving a broad spectrum of water supply and water quality goals would precede detailed planning for a wastewater reuse project. When such master planning has not taken place, it will be more important to address the larger water supply and wastewater management context in a facilities plan for water reuse.

The successful implementation of a project depends on its acceptance by the general public and the relevant body of public administration. Using reclaimed water as a water source raises concerns about public health, water availability, and costs. Farmers have concerns about their water rights, the availability and quality of reclaimed water, its effects on soils and crops, and its impact on farm operations and income. Water reuse often crosses jurisdictional boundaries of several agencies responsible for regulation, operation, and financing. Thus, participation of the public and stakeholders must be a part of the planning and decision-making (Asano et al., 2007; Wegner-Gwidt, 1998). Stakeholders that should be involved include:

TABLE 5.1
Outline of a wastewater reclamation and reuse facilities plan

1	Study area characteristics: geography, geology, climate, groundwater basins, surface waters, land use, and population growth
2	Water supply characteristics and facilities: agency jurisdictions, sources and qualities of supplies, description of major facilities and existing capacities, water use trends, future facilities needs, groundwater management and problems, present and future freshwater costs, subsidies, and customer prices
3	Wastewater characteristics and facilities: agency jurisdictions, description of major facilities, quantity and quality of treated effluent, seasonal and hourly flow and quality variations, future facilities needs, need for source control of constituents affecting reuse, and description of existing reuse (users, quantities, contractual and pricing agreements)
4	Treatment requirements for discharge and reuse and other restrictions: health- and water quality-related requirements, user-specific water quality requirements, and use-area controls
5	Reclaimed water market assessment: description of market analysis procedures, inventory of potential reclaimed water users and results of user survey
6	Project alternative analysis: planning and design assumptions; evaluation of the full array of alternatives to achieve twhe water supply, pollution control, or other project objectives; preliminary screening of alternatives based on feasibility criteria; selection of limited alternatives for more detailed review, including one or more reclamation alternatives and at least one base alternative that does not involve reclamation for comparison; for each alternative, presentation of capital and operation and maintenance costs, engineering feasibility, economic analyses, financial analyses, energy analysis, water quality effects, public and market acceptance, water rights effects, environmental and social effects; and comparison of alternatives and selection, including consideration of the following alternatives a. water reclamation alternatives: levels of treatment, treatment processes, pipeline route alternatives, alternative markets based on different levels of treatment and service areas, storage alternatives b. freshwater or other water supply alternatives to reclaimed water c. water pollution control alternatives to water reclamation d without- project alternative
7	Recommended plan: description of proposed facilities, preliminary design criteria, projected cost, list of potential users and commitments, quantity and variation of reclaimed water demand in relation to supply, reliability of supply and need for supplemental or backup water supply, implementation plan, and operational plan
8	Construction financing plan and revenue program: sources and timing of funds for design and construction; pricing policy of reclaimed water; cost allocation between water supply benefits and pollution control purpose; projection of future reclaimed water use, freshwater prices, reclamation project costs, unit costs, unit prices, total revenue, subsidies, sunk costs and indebtedness; and analysis of sensitivity to changed conditionsConstruction financing plan and revenue program: sources and timing of funds for design and construction; pricing policy of reclaimed water; cost allocation between water supply benefits and pollution control purpose; projection of future reclaimed water use, freshwater prices, reclamation project costs, unit costs, unit prices, total revenue, subsidies, sunk costs and indebtedness; and analysis of sensitivity to changed conditions

Source: Adapted from Mills and Asano (1998).

- End users of reclaimed water, such as farmers
- Water supply agencies
- Municipal wastewater treatment and management agencies
- Neighbours and passers-by
- Regional water and wastewater authorities
- Customers or consumers of agricultural goods
- Local associations
- Environmental organisations
- Water quality and public health regulatory authorities
- Economic development authorities
- Potential financial assistance organisations
- Agro-food industries
- Other people impacted directly or indirectly with reclaimed water use.

An important decision to be made at the start of planning is the time horizon appropriate for the planning period. There are four time horizons to consider in the planning and design of projects:

1. *Planning period* is the total period for which the need of the facility will be assessed and alternatives evaluated for their cost-effectiveness and long-term implementation.
2. *Design period* is the period over which a component of the facilities is expected to reach full capacity use.
3. *Useful life* is the estimated period during which a facility or component of a facility will be operated before replacement or abandonment.
4. *Financing period* is the period over which debts must be serviced and repaid, and the required return on the investment is achieved.

These four time periods should be kept distinct and applied appropriately in the various analyses of planning (Mills and Asano, 1998).

Many components of water supply and water reuse projects have useful lives of 50 years or more. Some major water developments, such as dams, may have capacities to meet water demands many years into the future. To document the full costs and future benefits of a project, it may be necessary to establish a long planning period, such as 50 years. However, it is difficult to predict economic conditions and future growth trends so far into the future.

Most water, wastewater and water reuse projects can be planned adequately with a time horizon of 20 years. The economic analysis can allow for facilities that have useful lives shorter or longer than 20 years (see chapter 3). In addition, because of the uncertainties in predicting the future, it is often not desirable to construct facilities with capacities to meet a demand period longer than 20 years. Phasing construction to meet future capacities in smaller increments is often the most cost-effective approach. A 20-year planning period can allow for a long-term framework or master plan to anticipate long-term trends and needs while at the same time analysing phased construction in the most cost-effective manner.

5.2 IDENTIFICATION OF PROBLEM & PROJECT OBJECTIVES

Planners should be clear what problems are to be addressed and which objectives are expected to be achieved. The reuse of water is not normally an objective in itself, rather it is a means to a broader and more fundamental social objective, such as:

- A reliable water supply
- Public health protection
- Environmental protection and restoration
- Regional or sectoral economic development
- Finally, for many developing countries, the use of treated or untreated wastewater in agriculture is crucial for ensuring the food supply (WHO-FAO, 2006).

Multi-objective planning in a context of integrated water resources planning (IWRM) can provide greater understanding of the relationships between water sources, demands, recycled water, and agricultural development needs. Through this understanding there is greater opportunity for formulating water reuse projects with a broader group of beneficiaries and thus gaining more public support.

Reliability may be a key issue, in the sense that supply is insufficient to meet existing demands or to prevent expected future shortages. This may be a particularly serious issue for agriculture, because of the shared use of water sources, the supply and demand of water in all sectors in a region should be considered. Agriculture may have adequate water supplies, but there may be opportunities to shift current freshwater use from one area to another within a region or from the agricultural sector to the urban sector by using reclaimed water. This exchange could create a more optimal use of all water resources in a region to meet current and future demands.

Water reuse may be a means of improving public health, at risk from poorly treated or improperly disposed of municipal or domestic wastewater. Reuse may drive an improvement in wastewater treatment, which would benefit the health of farmworkers and consumers of agricultural products currently grown with untreated or partially treated wastewater. However, the use of recycled water introduces a public health concern of its own that must be considered.

Discharging inadequately treated wastewater can cause environmental damage to aquatic resources. Conversely, water reuse may be a means of reducing wastewater discharges. Reclaimed water has also been used to restore wetlands or streams by replenishing flows that have disappeared due to development or to supply newly constructed wetlands to replace wetlands lost to urban and commercial developments.

For economically depressed areas, reclaimed water may provide a source of water to promote economic growth in a region or increase income of farmers. A sustainable water supply may allow farmers to be less vulnerable to weather conditions or to shift to more profitable crops.

The fundamental objectives described above should be considered primary objectives. It is also important to identify secondary objectives in establishing the criteria for evaluating project alternatives. Some examples of secondary objectives might be:

- Sustainability, such as, preventing soil sodicity;
- Public health protection, such as, preventing negative health impacts from use of reclaimed water;
- Crop productivity, such as, maintaining adequate irrigation water quality.

Care should be taken not to let secondary objectives divert attention from the ultimate goals of addressing fundamental social needs.

5.3 DEFINITION OF STUDY AREA AND BACKGROUND INFORMATION

An initial planning task is to establish the geographic scope of analysis. The study area should then be characterised for baseline (existing) and future conditions. This information becomes the factual framework upon which to formulate project alternatives, the sizing of facilities, and the project's costs and benefits.

The study area must be wide enough to include the water sources, demands and wastewater management needs that could be affected by a water reuse project. In some cases where water is imported from outside the region, the analysis will have to address the interrelationship between these sources and the region. The study area must also encompass all potential water reuse opportunities within a reasonable geographic area surrounding the wastewater sources. Where water resources are shared between areas or use sectors, the study area should include an analysis of water sources and needs for all shared areas to identify opportunities for shifting water sources from one area to another, or one sector to another, by using reclaimed water to replace fresh water.

For background information, the general characteristics of the study area should be provided, together with a description of water resources, wastewater management and related facilities. This is an exercise in data and information gathering to provide the basis for the remaining analyses. The types of information that generally must be documented are shown in Table 5.2.

TABLE 5.2
Study area characteristics and baseline information

Category	Information required
Demographics	Current and future population during planning period
	Current land use and future changes
Economic conditions	Major sources of employment
	Major sectors supporting community or regional economy
	Income levels in economic sectors
Climate & soils	Rainfall, seasonal variation
	Frequency and extent of droughts
	Temperature, seasonal variation
	Soil characteristics
Water sources	Surface water sources, existing and potential
	Groundwater sources, existing and potential, overdraft conditions
	Environmental damage from excessive surface water withdrawals
Water supply	Current and future water demands by sector and areas within region
	Currently developed water sources meeting current demands for each use sector
	Description of existing infrastructure of developed supplies, water conveyance, treatment, and distribution to consumers
	Capacities of existing facilities and estimated year that use will reach capacities
	Projection of future gaps between existing supplies or capacities and future demands
	Existing quality of various sources
Wastewater	Existing and projected quantities of wastewater generated and collected in urban areas
	Existing extent of sewered areas and future trends
	Description of existing wastewater collection, treatment, and disposal facilities
	Capacities of existing facilities and estimated year that actual use will reach capacities
	Existing or anticipated water pollution or public health problems associated with wastewater management or inadequate facilities
	Existing quality of wastewater, seasonal or daily variation
Institutions	Identification of relevant government and private sector institutions (water, wastewater, agricultural, financing)
	Public health and water quality regulatory authorities
	Roles and responsibilities of institutions
	Delineation of boundaries of agencies
Water reuse	Description and quantities of existing use of untreated or treated wastewater
	Potential quantity and quality of reclaimed water for future water reuse
	Reclaimed water market assessment (see Sec. 5.4)
Financing	Current sources of revenue in water and wastewater sectors
	Current and projected pricing of fresh water
	Potential sources of financial assistance for capital or operations costs
Regulatory constraints	Mandates to correct existing violations of public health or water quality laws and regulations due to water extraction or wastewater disposal
	Water quality and wastewater treatment requirements to reuse wastewater

5.4 MARKET ASSESSMENT & MARKET ASSURANCES

A particularly important criterion for assessing water reuse projects is the capability and willingness of water users to take reclaimed water in the quantities estimated, and the prices or costs that will be borne by the users. Early in the planning process a market assessment should be performed to determine the potential users of reclaimed water and the conditions that must be met to gain user acceptance. When a decision is made to proceed with implementation of a project, generally some form of market assurance will be needed to ensure users will participate in the project when it is constructed.

Market Assessment

After background information on the study area has been collected, a potential geographic area for the delivery of reclaimed water should be determined. Within this area, a comprehensive assessment of all potential types and areas of use for reclaimed water should be made. This is the *market assessment*. Even if the initial motivation of a study is to look for sources of water for the agricultural sector, the potential for use of reclaimed water in the urban and industrial sectors should not be ignored. Upon full analysis, the best and most economical use of reclaimed water may be in the urban sector, leaving more fresh water for the agricultural sector. Other options, such as desalination of seawater or interregional water transfer, should also be taken into consideration.

There are two aspects to the market assessment: 1) gathering of background data and information related to generic uses and sources of water and 2) gathering of data and information on specific potential customers or users of reclaimed water. The types of background information that is necessary are shown in Table 5.3 in a rough chronological order. Based on this information, individual users, including farmers or their representatives, can be interviewed to determine their existing sources, farming practices, water costs, needs, and expectations, as shown in Table 5.4.

Ultimately, a water reuse project will not be successful without the support of the actual and potential users of the reclaimed water. Farmers will compare the farming practices for using reclaimed water to current practices with respect to suitability for crops, yield, water costs, and the potential problems in marketability of crops due toperceptions of the public or agricultural produce distributors (WHO, 2006). The market assessment should identify all potential concerns of farmers so that they can be addressed at the planning stage. Because intermediate wholesale agricultural produce distributors may play a key role in whether crops grown with reclaimed water can be marketed, the market assessment should also include contacting the distributors to determine their concerns and attitudes.

Market Assurances

Water users are more reluctant to use reclaimed water than freshwater, for many reasons, some of which are shown in Table 5.5. Even potential users expressing a favourable attitude toward reclaimed water during a market assessment interview may reclaimed water when it becomes reality. It is often desirable to obtain some form of legally binding arrangement or contract to assure that farmers or others will actually take the reclaimed water once the project is completed. he success of such contracts depends on the economic incentives they contain for farmer (*e.g.* expected increase in income). Such a contract should include all relevant conditions, technical and financial, of the services to be provided in order to ensure transparency and full understanding of the terms of the agreement. Some governments or water purveyors have the legal authority to mandate the use of reclaimed water (Asano *et al.*, 2007)

TABLE 5.3
Steps in gathering background information for a reclaimed water market assessment

Step	Description
1	Create an inventory of potential users in the study area and locate them on a map. Group the users by types of use. Cooperation of retail water agencies can be very helpful in this task.
2	Determine public health-related requirements by consulting regulatory agencies. Such requirements will determine the levels of treatment for the various types of use and application requirements that will apply on the sites of use; *e.g.* backflow prevention devices to protect the potable water supply, irrigation methods that are acceptable, use-area controls to prevent ponding or runoff of reclaimed water, practices to protect workers or the public having contact with the water.
3	Determine water quality regulatory requirements to prevent nuisance or water quality problems, such as restrictions to protect groundwater quality.
4	Determine water quality needs of various types of use, such as industrial cooling or irrigation of various crops. Government farm advisors or agricultural experts familiar with local area may be helpful in this regard.
5	Identify the wholesale and retail water agencies serving the study area. Collect data from them on current and projected freshwater supply prices (rates) that would be applicable to the reclaimed water users. Also, collect data on the quality of freshwater being provided.
6	Identify the sources of the reclaimed water and estimate the probable quality of the reclaimed water after treatment to the level or levels under evaluation. Determine what types of use would be permitted at the various levels of treatment based on public health requirements and requirements suitable for various usages, such as industrial or agricultural uses.
7	Conduct a survey of the identified potential reclaimed water users to obtain detailed and more accurate data for evaluating each user's capability and willingness to use reclaimed water. The types of data that should be collected on each user are shown in Table 5.4. While most of these data must be obtained directly from the user, some of these data may be assessed from the background information obtained from other sources.
8	Inform potential users of applicable regulatory restrictions, probable quality of reclaimed water at various levels of treatment compared to freshwater sources, reliability of the reclaimed water supply, projected reclaimed water and freshwater rates. Determine on a preliminary basis the willingness of the potential user to accept reclaimed water.

Source: Adapted from Asano *et al.* (2007).

TABLE 5.4
Information required for a reclaimed water market survey of potential users

Item	Description
1	Specific potential uses, including types of crops irrigated, of reclaimed water
2	Location of user
3	Recent historical and future quantity needs (because of fluctuations in water demands, at least three years' of past use data should be collected)
4	Timing of needs (seasonal, daily, and hourly water demand variations)
5	Water quality needs
6	Methods of irrigation and related water pressure needs
7	Reliability needs - the availability and quality of reclaimed water, and susceptibility of user to interruptions in water supply or fluctuations in water quality
8	Needs of the user regarding the disposal of any residual reclaimed water after use
9	Identification of on-site treatment or plumbing retrofit facilities needed to accept reclaimed water
10	Internal capital investment and possible operation and maintenance costs for on-site facilities needed to accept reclaimed water
11	Monetary savings needed by users on reclaimed water to recover on-site costs or desired pay-back period and rate of return on on-site investments
12	Present source of water, present water retailer if the water is purchased, cost of present source of water
13	Date when user would be prepared to begin using reclaimed water
14	Future land use trends that could eliminate reclaimed water use, such as conversion of farm lands to urban development
15	For undeveloped future potential sites, the year in which water demand is expected to begin, current status and schedule of development
16	After informing user of potential project conditions, a preliminary indication of the willingness of user to accept reclaimed water

Source: Adapted from Mills and Asano (1998).

TABLE 5.5
Farmers' potential concerns about reclaimed water

•	Price of reclaimed water relative to freshwater costs
•	Inability to finance on-site conversion costs
•	Concerns over water quality and effects on crops and soil
•	Inability to prevent worker exposure to reclaimed water
•	Possibility of farm field worker objections
•	Lack of reliable reclaimed water supply
•	Water supply costs insignificant relative to inconvenience of reclaimed water
•	Liability to public health or third party claims
•	Restrictions on crop selection, marketability of crops, income
•	Problems selling crops to produce distributors or consumers

Source: Adapted from Mills and Asano (1998).

5.5. IDENTIFICATION OF PROJECT ALTERNATIVES

Based on the objectives of the project, the information available on existing infrastructure and the market assessment, a number of potential alternative water recycling and intersectoral water transfer projects usually become apparent. In the ideal situation, these reuse alternatives would be analysed simultaneously with other water supply and wastewater management options in an integrated water resources context. Even where this is not possible, water reuse must still be analysed in relation to other water supply and wastewater options that meet the same fundamental objectives (*e.g.* construction or upgrading of WWTPs, desalination of seawater, interbasin transfers).

To determine the net impact of a project, it is necessary to compare what the future would look like, respectively with, and without, the project (Asano et al., 2007; Gittinger, 1982; Mills and Asano, 1998). This would reveal the impacts, costs, and benefits of the alternative of doing nothing, or the *without project* alternative. The *without project* alternative depicts the situation that will arise from "business as usual" – the operation of existing infrastructure of water and wastewater facilities.

Since there are opportunities to shift water between areas or use sectors, it may be necessary to identify alternatives for serving individual areas or sectors, as a basis of comparison. While multi-regional or multi-sectoral comparison can greatly add to the complexity of analyses, it can identify multiple beneficiaries, thereby creating political and financial support for a water reuse project.

Examples of potential project alternatives that may be relevant to justification of a water reuse project are provided in Table 5.6. Note that even within a general project concept there may be alternative features to consider, such as alternative treatment technologies.

5.6 APPRAISAL AND RANKING OF PROJECT ALTERNATIVES

This report (chapter 1 and the current chapter) highlights a number of important criteria by which wastewater reuse projects should be judged. Although economic and financial criteria have been given a central place in the report (chapters 3 and 4) in a planning decision they take their place alongside other considerations. Box 5.2 illustrates what a list of criteria for project choice might include (Mills and Asano, 1998; WHO, 2006).

Not all of these criteria are of equal status. Depending on the local situation and public policy, some criteria will be paramount (*e.g.*. reduction of downstream effluent pollution, overcoming a growing scarcity of water for agriculture, minimising the cost of increasing freshwater supply to cities). Other criteria will be permissive (*e.g.* satisfactory public health safeguards, mitigation of environmental damage, legal feasibility). Certain criteria (*e.g.* existence of a satisfactory market demand for the effluent reuse) can be wrapped into others (such as the economic and financial feasibility, which would include sensitivity analysis of the impact of demand variations). Some criteria (economic, financial) can be monetised, some can be quantified in non-monetary terms, others are of a qualitative nature.

TABLE 5.6
Water reuse: examples of project alternatives

Functional category	Example of alternatives or variations
Freshwater supply (single purpose)	No project (existing infrastructure) Surface water storage (dams) Groundwater augmentation and storage (recharge, aquifer storage and recovery) Interbasin transfers Desalination (seawater or brackish water
Water demand management	Urban and agricultural water conservation
Wastewater management (single purpose)	No project (existing infrastructure) More WWTPs Alternative treatment technologies Stream discharge of treated wastewater Land application of treated wastewater with or without beneficial reuse
Water reuse (single or multiple purpose)	No project (existing infrastructure) Alternative uses of reclaimed water Alternative locations for use of reclaimed water Decentralised treatment locations to increase accessibility to more use locations (satellite treatment plants) Alternative treatment technologies Alternative levels of treatment (existing and new, primary, secondary, tertiary, advanced) Alternative routes for distribution pipelines or canals Inter-regional or intersectoral shifts in freshwater entitlements (water rights trading) One or multiple levels of treatment One or multiple wastewater treatment plants

BOX 5.2
Criteria for Project Choice

Economic justification
Financial feasibility
Public health impact
Public acceptability
Environmental impact
Technical feasibility
Market and demand
Legal and institutional feasibility
Etc.

One approach is to accept certain criteria as paramount, and to treat the planning exercise as maximising (or optimising) the primary criterion(a) subject to meeting the constraints imposed by other criteria. For example, the primary objective might be minimising the economic cost of obtaining extra freshwater for cities, subject to satisfactory safeguards for public health, environment, etc., and its feasibility on technical, legal and market demands.

Another approach is through *multi-criteria analysis* (MCA) which involves scaling, scoring and weighting of each criterion (Snell, 1997). This is a formal mathematical optimising method, which can be applied flexibly to accommodate the subjective or explicitly imposed weights of decision makers, regulators or politicians. This flexibility comes from maximizing first a single criterion subject to acceptable levels to the others and then varying the criterion and the weights. MCA may well prove to be a more acceptable and durable method of making planning decisions since it contains information about all the key considerations entailed in each situation, including non-monetary impacts.

MCA is likely to involve *trade-offs* – where a project performs well on one criterion, but poorly on another, compared to another project with the opposite scoring. The more criteria are included, the more difficult and complex this trading-off becomes. Aggregating the results of scoring on different criteria involves an implicit weighting ("all criteria are of equal importance") or priority setting based on arbitrary and subjective factors ("environmental issues are paramount"). However, the systematic variation in weights can produce a set of non-inferior solutions in which no objective can be improved without decreasing the others (the *Pareto optimal* result).

A simple process of multi-criteria analysis would involve the following elements:

For each of the project alternatives identified (section 5.5):

i) list the criteria applicable to the project (Box 5.2);

ii) for each criterion create a scale of judgement (*e.g.* good, satisfactory, poor, unacceptable or a scale of zero to 1) based on the factors appropriate for each (*e.g.* for the economic justification, the NPV or the BCA, for public health risks, acceptable or unacceptable according to the legally mandated standards in place);

iii) score each of the project alternatives according to each of the criteria, *e.g.* tick for one of the boxes (good, poor, etc.). As a refinement, the projects could be scaled numerically from 0-5, 0-10, etc. where 0 = unacceptable, and 10 is excellent.

iv) produce a score for each project, showing the ticks in each box, with the option of producing a single composite score from the scaling. The criteria may need to have different weights, following consultation with the main stakeholders.

v) choose a preferred project based on the above scores. Alternatively, produce a short list by eliminating those with poorer ratings and apply an overriding criterion (*e.g.* economic BCR) to select the final preferred option.

5.7 PROJECT IMPLEMENTATION PLAN

The production of a project implementation plan should precede a final decision to proceed with a water reuse project. Many elements must be put in place for the project to succeed, not least the agreement by the many interested parties. Postponing the resolution of difficult issues until late in the design phase or even until after construction is completed can lead to false expectations and even project failure. All the key activities involved in implementation should be identified. A responsible entity should be identified and a performance schedule produced for each of the following activities:

- Facilities design
- Construction
- Wastewater treatment operation
- Reclaimed water conveyance and delivery to users (farmers or irrigation districts)
- Construction financing
- Revenue or tax collection for project operations and debt payment
- Technical assistance to farmers during project start-up and long-term problem resolution
- Analysis, monitoring and evaluation.

It is likely that more than one agency would need to be involved in all these activities, in which case contractual agreements will be needed between agencies to define their responsibilities and reimbursement for costs incurred. At the conclusion of planning there should be general agreement on the framework for responsibilities and willingness to participate in a project, even though contractual details may still have to be negotiated. Contracts or other legally binding arrangements usually will be needed with farmers, as discussed in Section 5.4. At the conclusion of planning there should be some form of written affirmation by farmers or their representatives and municipalities of willingness to enter into contracts at an early date. In the contracts, the commitments for each of the parties involved are to be specified (*e.g.* volumes and quality of treated wastewater and released freshwater, use of water-saving irrigation technologies, charges on water users, compensation payments, period of validity, etc.).

5.8 TECHNICAL ISSUES

Municipal wastewater consists of domestic, commercial, or industrial waste discharged into a sewage collection system. To this may be added stormwater run-off, unless this is collected separately. This run-off can be highly polluted. The wastewater passes through the following facilities on its way to being transformed into reclaimed water (effluent) and delivered to use sites:

- Sewer collection system
- Wastewater treatment plant (note that a reclaimed water unit could be outside the WWTP and managed separately)
- Reclaimed water distribution system
- On-site facilities at reuse sites.

Figure 5.2 contains a flow chart of the path of wastewater from source to point of use. Various costs are associated with each segment of wastewater management and reuse, as shown in Table 5.7. Reclaimed water may incur special costs that would not be required for freshwater use, for example, worker and public protection, and environmental protection, extra water for leaching soils, or protection of potable water systems, especially in urban areas. Some facilities are necessary for wastewater discharge, regardless of whether wastewater is reused. For the purpose of economic and financial analyses the differential, or incremental, costs of wastewater reuse, compared with "normal" wastewater treatment and disposal, should be identified and estimated.

FIGURE 5.2
Pathway of wastewater from source to points of use or discharge

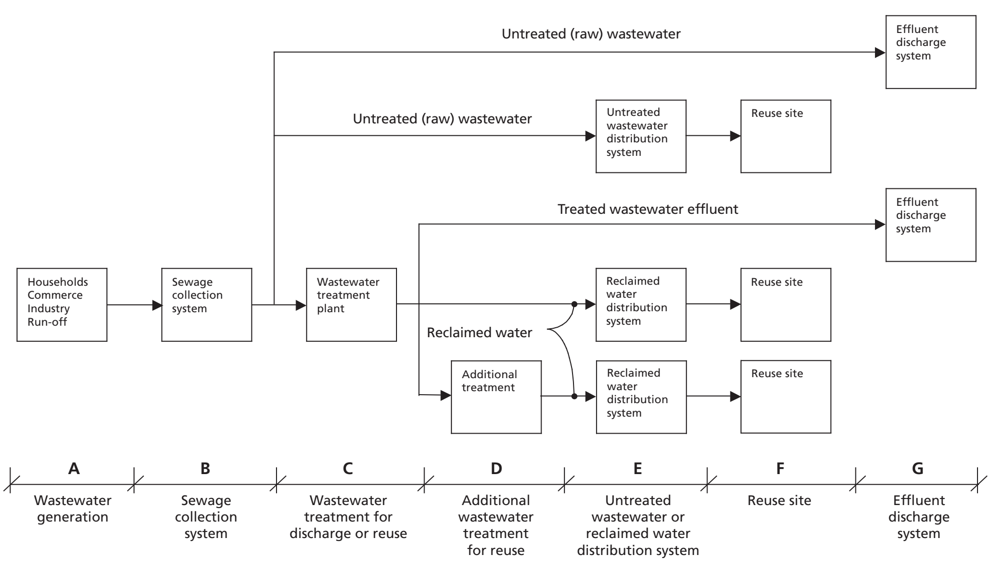


TABLE 5.7
Major cost elements of wastewater reuse systems

	System segment	Major cost elements	
		Physical facilities and associated costs	Other costs
A	Wastewater generation	Pre-treatment (especially by industry) to prevent constituents toxic to humans or crops being discharged into sewers	Source control regulatory system
B	Sewage collection system	Construction, operation and maintenance costs for pipes, pump stations	
C	Wastewater treatment for discharge or reuse	Construction, operation and maintenance costs for treatment facilities	Regulatory system to set treatment or effluent quality standards and to monitor treated water quality, worker protection
D	Additional wastewater treatment for reuse	Construction, operation and maintenance costs for treatment facilities	Regulatory system to set treatment or effluent quality standards and to monitor treated water quality, worker protection
E	Untreated wastewater or reclaimed water distribution system	Construction, operation and maintenance costs for pipes, canals, water storage	
F	Reuse site	Construction, operation and maintenance costs for pipes, canals, meters or water measurement devices, valves, irrigation equipment; re-plumbing of existing sites to separate potable from nonpotable pipes	Additional water purchase to leach salts from soil, worker protection, negative effects on farm production and income, education of local residents, groundwater monitoring, regulatory surveillance
G	Effluent discharge system	Construction, operation and maintenance costs of pipes	Regulatory surveillance

At various points in the water cycle shown in Figure 5.2 the water/wastewater is stored and mixed with water from other sources. The characteristics of water and wastewater can change significantly when held for any period, especially when mixed, hence the importance of controls at the point of end use.

Certain of the specific cost items arising in a water reclamation and reuse system include:

- Supplemental fresh water to maintain supply reliability in the reclaimed water distribution system.
- Backflow prevention devices on potable water lines entering use sites to prevent potable water contaminated on the use site from flowing back into the community drinking water supply.

Some of the other technical issues requiring attention are discussed below (see also Asano, 1998; Asano et al., 2007; Lazarova and Bahri, 2005a; Pescod, 1992; WHO, 2006).

Balance of supply and demand

The reliability of reclaimed and recycled water is dependent on the abstraction and storage of the original freshwater that it is derived from. In certain circumstances, this may make it more reliable than farmers' alternative water sources. In any case, irrigation needs have different seasonal peaks and troughs than household demand. Raw wastewater has its own variable flow characteristics:

i) The quantity of wastewater in most communities varies widely, peaking in daytime and reaching a low during the night.
ii) Rainwater can leak into sewer systems, resulting in higher wastewater flows during storms or during rainfall seasons.
iii) Wastewater flows may have seasonal or other variations due to tourism, seasonal industries, or other conditions.

On the demand side, each water user has its own characteristics. Urban landscaping has its own regular needs, which are different from those of agricultural irrigation. Irrigation serves the transpiration needs of the crops, leaching to maintain soil quality, and in some cases a warming or cooling function for crops in extreme climates. The water demand from agriculture could change as it converts to reclaimed water, possibly resulting in increased water demand to increase crop yields, grow different crops or support more plantings during the growing season. Since reclaimed water may contain elements not present in freshwater, it may be necessary to increase applied water to leach out excess salts from the soil. Commercial and industrial customers can also vary their demand by time of day, days of the week, or season.

There is little or no control on the raw wastewater flows discharging from the sewer system. Whether treated or untreated, the wastewater must either be used directly, applied to land, discharged into a stream or other surface water, or stored until it can be used or safely discharged. Storage is usually required in reclaimed water distribution systems. Long-term or seasonal storage is often used where agricultural use takes place or where the discharge of wastewater is prohibited due to protection measures for surface waters. Short-term storage is most often used in urban settings where seasonal storage is not practical or there is insufficient demand to justify carrying wet weather flows into dry seasons for use.

Short-term storage can match reclaimed water to hourly water demands. For example, urban landscape irrigation is often done at night, when wastewater flows are at their lowest, to avoid human contact with reclaimed water in parks or school yards. Equilibrium storage is often incorporated into wastewater treatment plants to even out hourly flows, allowing downstream treatment processes to operate more efficiently at uniform flow rates. Design considerations and sizing techniques are addressed in several references (Asano et al., 2007; Mills and Asano, 1998).

Water quality

Regardless of its source, the quality of water is a critical concern to agriculture (Ayers and Westcot, 1985). The common uses of potable water in households and commercial and industrial premises contribute salinity and chemicals that are not removed in normal wastewater treatment. Reclaimed water may have higher concentration of some chemicals and additional constituents than are usually found in fresh water, but these can be removed before use (*e.g.* the RO desalination unit in the Llobregat cases in Chapter 2).

Water quality in relation to public health is addressed below and in chapter 1 (see also Asano et al., 2007; Lazarova and Bahri, 2005a; Pescod, 1992; Pettygrove and Aano, 1985). In the agricultural context, elements present in reclaimed water can have beneficial or negative effects. The main categories of water quality constituents and their effects are shown in Table 5.8.

Some of these negative impacts can be mitigated. Certain constituents can be reduced through source control, by preventing chemicals being discharged into sewers. Water softeners used in households replenished by sodium salts contribute to both salinity and sodicity and have been banned in some communities. Industrial sources of boron or other chemicals can be restricted. Another option is restriction on the delivery of reclaimed water during sensitive phases of plant growth, e.g. using good quality water in the initial growing period and worse quality water later on. This practice can even increase the quality of several fruits (Oron, 1987; Hamdy, 2004). The cropping pattern can be changed to favor more tolerant species or varieties. All these effects and mitigation measures have potential impacts on the overall costs and benefits and farm income resulting from use of reclaimed water.

TABLE 5.8
Reclaimed water quality and effects on agricultural use

Category	Example of constituents	Potential effects
Nutrients and trace elements	Nitrogen Phosphorus Potassium Calcium Magnesium Sulfate	**Positive:** Essential for plant growth Reduced need for fertilisers **Negative:** Phytotoxic in excessive concentrations Excessive foliar growth, delayed maturation, poor quality crop (due to excessive nitrogen during flowering/fruiting phase) Toxic to livestock in high concentrations in animal feed Biofilms in pipelines Algal growth in open storage or canals
Suspended solids	Particulates Algae in wastewater or subsequent growth in storage caused by reclaimed water nutrients	Clogging of irrigation infrastructures, particularly in sprinkler and drip irrigation emitters
Salinity	Total dissolved solids (Electrical conductivity)	Plant stress and growth reduction directly from irrigation water or salt accumulation in soil from irrigation water
Sodicity	Sodium (Sodium adsorption ratio)	Soil impermeability
Specific ion toxic elements	Sodium Chloride Boron	Phytotoxicity (leaf damage, dieback, reduced productivity)

Public health (see also chapter 1)

The main sources of pathogens in wastewater are households, hospitals and office buildings. Commercial and industrial uses of potable water can add harmful chemicals to wastewater. The degree of pathogen and chemical removal by wastewater treatment depends on the levels of treatment and technologies used. The risk to health depends on the infectivity of the pathogens, their concentrations in reclaimed water, and the extent of human contact. Acceptable levels of risk can be achieved through levels of wastewater treatment appropriate to the types of uses and the associated human contact as well as practicing multi-barrier risk management strategies in Good Agriculture Practices.

Table 5.9 gives examples of wastewater constituents of concern to public health. Through adequate treatment of wastewater, the proper handling of reclaimed water, and farming practices, the transmission of disease can be prevented or reduced. Table 5.10 shows the populations exposed to risk, and their means of exposure to pathogen or chemicals in reclaimed water.

In addition to their direct exposure to reclaimed water, people are also at risk from pathogens and chemicals passed through the food chain in crops or into groundwater and streams through percolation or farm runoff. The points of exposure (with reference to points in Fig. 5.2) and the groups exposed can be summarised as follows:

- Untreated or treated wastewater discharge to surface waters (downstream of point G): fishermen, swimmers, bathers, downstream users of drinking water
- Wastewater treatment (points C and D): workers
- Irrigation (point F): agricultural field workers, local residents or passers-by
- Crop handling (point F and later): workers, crop consumers
- Excess percolation of irrigation water (point F and later): consumers of groundwater
- Runoff from agricultural fields to streams and canals (point F and later): fishermen, swimmers, bathers, downstream users of drinking water, local residents
- Crop ingestion (after point F): crop consumers.

TABLE 5.9
Waterborne pathogens or chemicals of health concern present in wastewater

Contaminant category	Specific examples	Consequences
Excreta-related pathogens	Bacteria Helminths Protozoa Viruses	Human diseases (direct or indirect infection)
Skin irritants	Undetermined, but likely mixture of chemical and microbial agents	Contact dermatitis
Vector-borne pathogens	*Plasmodium* spp. *Wuchereria bancrofti*	Human diseases
Chemicals	Heavy metals Organic compounds Inorganic compounds	Acute or chronic human illness (direct contact or indirect through food)

Source: Adapted from World Health Organization, 2006.

The health risks that can be encountered are summarised in Table 5.10.
Wastewater treatment is the most fundamental barrier to the transmission of disease, but other precautions are also necessary. The methods of exposure control for the risk groups are as follows (Lazarova and Bahri, 2005b).

1. Wastewater treatment workers, agricultural field workers, and crop handlers:
   * Use adequate wastewater treatment, including disinfection
   * Use of protective clothing, such as boots and gloves
   * Maintenance of high levels of hygiene
   * Immunisation against or chemotherapeutic control of selected infections (if reclaimed water is not well disinfected).
2. Users of streams or canals (fishermen, swimmers, etc.):
   * Adequate wastewater treatment, including disinfection, before discharge
   * Restrictions on stream uses
   * Informing stream users, warning signs.
3. Crop consumers:
   * Adequate wastewater treatment, including disinfection, based on crop and level of exposure
   * Washing and cooking agricultural produce before consumption
   * High standards of food hygiene, which should be emphasised in the health education, appropriate to the type of wastewater treatment and consumer exposure
   * Restrictions on the types of crops grown with reclaimed water.
4. Local residents:
   * Using adequate wastewater treatment appropriate for the potential exposure
   * Informing them of the use of wastewater and the precautions to avoid fields or canals, warning signs
   * Not using sprinklers within 50-100m of houses or roads, depending on the level of wastewater treatment.
5. All groups:
   * Source control on sewer system to prevent toxic chemicals from entering wastewater.

There is a trade-off between the level of wastewater treatment and the degree of restrictions and precautions required for workers and consumers. It may be difficult to control the behaviour of workers, residents, or consumers through hygiene, education, or field practices. Farmers may resist the imposition of restrictions on the type of crops they can grow, such as food crops eaten without cooking.

Health risks from the use of wastewater in agriculture have been investigated in two separate areas of research: quantitative microbial risk analysis (QMRA) applied to irrigation and epidemiology (Mara et al., 2007). In the recent years, there has been a movement to apply the HACCP (Hazard Analysis and Critical Control Points) concept to wastewater reclamation and reuse (Westrell et al., 2003). The HACCP procedures were initially established for foodstuffs and aeronautical and pharmaceutical industries, where the final objective is to generate safe products.

Taking into consideration agricultural practices, hygiene, food processing, and the degree of human exposure, and in the light of the calculated risk for various pathogens, certain use practices and levels of wastewater treatment have been established by regulation (U.S.EPA and U.S.AID, 2004). The third edition of the WHO and FAO guidelines for the safe use of wastewater, excreta and greywater, published in 2006, is an extensive update of two previous editions, expanded to include new scientific evidence and contemporary approaches to risk management (Asano et al., 2007; WHO, 2006). Although it is technically feasible to obtain any required quality of water effluent from a particular type of wastewater, the treatment could be so expensive as to make reclamation non- feasible. In this case, the recommended practice is to use Best Available Technology (BAT) which involves use of the best adapted technology to every specific case, considering all the issues related to end-quality treatment, reclamation and reuse.

TABLE 5.10
Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health risks		
	Helminth infections	**Bacterial/virus infections**	**Protozoal infections**
Consumers	Significant risk of helminth infection for both adults and children with untreated wastewater	Cholera, thyphoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated; increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms /100ml)	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of helmith infection for both adults and children in contact with untreated wastewater; increased risk of hookworm infection for workers who do not wear shoes; risk for helmith infection remains, especially for children, even when wastewater is treated to <1 helminth egg per litre; adults are not at increased risk at this helminth concentration	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated watewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection reported to be insignificant for contact with both untreated and treated wastewater; however, another sutdy in Pakistan has estimated a treefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with irrigation with fresh water; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	Transmission of helminth infections not studied for sprinkler irrigation, but same as above for flood or furrow irrgation with heavy contact	Sprinkler irrigation with poor water quality (10^6-10^8 total coliforms/100ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4-10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

Source: World Health Organisation - FAO Guidelines (2006)

Chapter 6
Conclusions

6.1 CONTEXT AND STARTING POINT

The use of recycled water (treated and untreated) in agriculture is widespread and increasing in regions with water scarcity, growing urban populations and rising demand for irrigation water.

Many regions of the world are experiencing growing water stress, arising from a relentless growth of demand for water in the face of static, or diminishing, supply and periodic droughts. Water stress is aggravated by pollution caused by wastewater from expanding cities, much of it only partially treated, and from the contamination of aquifers from various sources. Such water pollution makes scarcity worse by reducing the amount of freshwater that is safe to use without proper treatment.

Climate change is adding to these pressures: it is estimated that global warming of 2 degrees Celsius could lead to a situation where 1 to 2 billion more people may no longer have enough water to meet their consumption, hygiene and food needs. The evidence of recent prolonged droughts, and the impact on social and economic life of severe seasonal water shortages, shows the high economic, social and political costs of water shortages.

Recycling water is a proven option for bringing supply and demand into a better balance. It is not the only option, but in many cases it is an acceptable and cost effective solution, as the growing number of reuse schemes in different parts of the world testify[1]. A recent comprehensive survey found over 3,300 water reclamation facilities worldwide and is growing.

Water recycling and Integrated Water Resources Management

Water recycling fits the IWRM paradigm – "…a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[2] Recycling avoids putting further pressure on freshwater where it is becoming scarce, and reduces wastewater pollution for downstream users and the natural environment.

The reuse of wastewater is a means of recycling not only water but also nutrients, which would otherwise be wasted[3] during the process of treatment and disposal. "Closing the nutrient loop" entails the return of nutrients, principally nitrogen and phosphate, to the soil where they can benefit plant growth, rather than releasing them into rivers, estuaries, wetlands or coastal waters where they cause harm (variously, eutrophication, algal blooms, fish kills, hypoxia, etc.). The heavy environmental, and eventually economic, cost of such nutrient pollution is a growing concern.

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1 E.g. "Queensland's Traveston Dam proposal has been rejected by the Australian federal government, meaning the state will have to implement alternative water resourcing strategies, including desalination and reuse." *Global Water Intelligence,* Nov 2009.

2 Global Water Partnership, *Integrated Water Resources Management* TAC Background Papers No 4, 2000, p. 22

3 or separated, for instance into sludge.

6.2 SYNERGIES AND WIN-WIN OUTCOMES

Agriculture is the principal focus of this report. Agriculture is the predominant global user of reclaimed water, and its use for this purpose has been reported in around 50 countries, on 10% of all irrigated land. However, it is necessary to place water recycling in a broader context.

Reuse of water can be the source of *win-win* outcomes, in which several different aims can be achieved, and several stakeholders can benefit simultaneously. For the purpose of exposition, this report has divided stakeholders into three parties – urban authorities (*cities*), farmers, and the environment (represented by *environmental custodians*). However, the use of recycled water also appeals to industry, power stations and recreational establishments, and a number of cities are considering using reclaimed water for various municipal purposes, often as an alternative to desalination. The report has implications for each of these potential stakeholders.

Agriculture

The use of untreated or partially treated wastewater is already widespread in urban and peri-urban agriculture, which is an important source of fresh vegetables in many poor cities (Bahri, 2009). The systems for providing this water are often low cost and improvised, treatment costs are absent or minimal, and because of proximity the cost of conveyance and pumping are relatively small. These factors, together with the relatively high value of the produce, make this practice economic. In the course of economic development, and as environmental standards rise, wastewater will increasingly be treated, but in the meantime for many countries the agricultural use of untreated or partially treated wastewater will remain. In these situations a realistic policy response will involve a combination of measures to safeguard public health (see below).

In other situations, and more generally, reuse may be a feasible response to the demands of agriculture in regions of growing water scarcity and competition for its use. There is evidence in the case studies of farmers responding positively to the use of recycled water, either as a sole source, mixed with water from other sources, or used indirectly from recharged aquifers. Reuse has been used both as a temporary expedient in years of drought, and as a long term solution.

Reuse is one amongst a number of options at farm level for improving long term water security and minimizing exposure to seasonal water risk. Where it entails the creation of an expensive distribution network and storage facilities[4], with a high recurrent cost for pumping, in order to furnish water for low value farm purposes, recycling may not be warranted unless there are benefits to other sectors. Where sizeable new infrastructure is required, recycling schemes may not be justifiable purely from their agricultural benefits. Although farmers may be net beneficiaries from using treated wastewater, compared with their previous or alternative sources of water, this depends very much on local circumstances, and in any event their net benefits may not offset the full costs of the scheme. This underlines the importance of viewing reuse as an element in IWRM, with reference to costs and benefits for water management more generally.

Cities

Cities are interested in recycling mainly from two points of view - as a solution for wastewater treatment and disposal, and as a potential source of water for household and other municipal use.

Rapid urbanisation has focused attention on recycling as a potential environmentally sustainable *solution for wastewater treatment and disposal.* The context for this is the growing volume of wastewater, the heavy costs of advanced treatment, and the

4 As well as extra specific treatment where necessary, such as the removal of excessive salts.

downstream pollution caused by untreated and partially treated effluent. There are great differences between cities in their levels of development and available options, which affect their choices of wastewater disposal. It is estimated that in sub-Saharan Africa, less than 1% of wastewater is treated (Keraita *et. al.* 2009). Yet in 3 out of 4 cities in developing countries wastewater is used for irrigation without any effective treatment. In many West African cities, more than 90% of vegetables consumed are grown within the cities, which implies that a high proportion are grown using untreated urban wastewater.

Reuse is an everyday reality for many such locations, and the efforts of national and international authorities have concentrated on promoting the "multiple barrier" approach to risk management, including technically, economically and socially appropriate non-treatment options for health protection, based on WHO, FAO and UNEP Guidelines (Keraita *et. al.* 2009). Where climate and space permits, various low-cost treatment methods (e.g. waste stabilisation lagoons) can also be used as an additional safeguard. Strong arguments have been made for making national policies on wastewater treatment more realistic and pragmatic, in short for: "...a paradigm shift where water reuse defines the required degree of treatment, where technical solutions have to match capacities, and where urban source treatment will be implemented along a multiple-barrier approach combining treatment and different health protection measures"(Bahri, 2009, p. 52).

For countries at an intermediate level of development, the use of *land disposal* for untreated wastewater has been widely resorted to. The Mexico City-Tula case is typical of mutual benefits that have accrued, in this case over a century or more, for the City and farmers from disposing of untreated urban wastewater to agriculture, allowing natural processes to carry out some of the purification *en route*. Recycling allows the dispersion of effluent and its assimilation across a wide area, as compared to the *point source pollution* from WWTPs. The reuse of wastewater nutrients in crop production (as well as *carbon sequestration* potential in soil organic matter), rather than their removal and separation during advanced processes of wastewater treatment, is appealing on grounds of efficiency and environmental sustainability.

The second important motive for recycling is as part of the *solution for urban water consumption*. In the course of their economic development, cities increase their fiscal resources and raise their environmental standards so that, over time, a growing proportion of their wastewaters is treated, to progressively higher standards. This wastewater can be recycled for various urban and industrial uses, such as watering public gardens, industrial cooling and other processes, replenishing aquifers, and – where systems were installed that allowed this – toilet flushing. Using recycled water for these purposes avoids the fresh abstraction of river water or groundwater, where these are scarce. The ultimate development of recycling is direct reuse for all household purposes, including drinking (as in Windhoek, Namibia), though this is still rare (Bahri, 2009). There is an active and rapidly growing market for wastewater reuse projects, much of it aimed at urban and industrial use (GWI, 2009).

One form of "win-win" agreement examined in this report is the surrender of farmers' freshwater entitlements to cities, in return for assured supplies of reclaimed water. This would enable cities to gain access to freshwater at a lower cost than otherwise, to use for any purpose including drinking water. For them to take part voluntarily in such an agreement, farmers would receive water which should be at least as reliable as their alternative sources, and which would contain nutrients for the growth of their crops. Depending on location, there may also be environmental benefits from such a deal.

The case studies illustrate situations with both the presence and absence of conditions for making such an intersectoral exchange feasible. The Llobregat sites in Spain and Durango City in Mexico are examples where physical and geographical conditions appear to be positive, and where legal and economic factors could dictate the outcome. In the other cases there are obvious barriers to an intersectoral agreement of this kind.

6.3 THE FEASIBILITY OF WATER REUSE

The feasibility of reuse projects hinges on a number of key factors. The physical and geographical features of the area should be conducive to the transfer of water between the parties concerned. Where an exchange of water rights is entailed, rights must be legally clear and *alienable*[5]. Any extra costs of treatment, plus that of installing the necessary infrastructure, should be affordable in relation to expected benefits. Farmers should be supportive, which depends on the net impact on their incomes, the status of their rights to freshwater, and what their alternatives are. Environmental impacts should be acceptable.

It is important that public health authorities are satisfied that the projects pose no undue risks, after reasonable precautions have been taken. National and international regulations and guidelines such as those promulgated by the WHO and FAO are available to guide the use of reclaimed wastewater in agriculture. Depending on circumstances, the options for health protection include the level of wastewater treatment, crop restriction, adaptation of irrigation technique and application time, and the control of human exposure.

Chapters 3 and 4 of this report dwell on the financial feasibility of recycling schemes as a necessary complement to the economic analysis. The vantage point of the economic methodology described in this report is the national interest[6]: if a project has sufficient net benefits in national socio-economic terms, it is considered to be justified. However, this is a necessary but not a sufficient condition for it to be implemented, since all the key stakeholders involved in the project need to be persuaded that they will be net beneficiaries. An essential part of building the case for recycling is to analyse the balance between its financial costs and benefits *specific to each party*.

Consequently the feasibility study should contain an analysis of the project's impact on the financial status of key stakeholders, including central and municipal government, regional water boards, utilities, farmers, and other interested parties. This should identify the main gainers and losers, with estimates of their gain or loss. It should also contain an estimation of the financial implications of the project for public capital and recurrent budgets. This part of the analysis provides a basis for understanding the incentives of crucial stakeholders, including farmers, to support, or resist, the project.

Where benefits and costs are out of balance, or not sufficiently decisive, for key parties, proposals will be necessary for financial instruments and transfers that would create conditions to make the project acceptable, and to provide suitable incentives for its major participants. This may entail both penalties (e.g. water charges, pollution taxes or other financial levies) or positive inducements (e.g. subsidies and innovative financial mechanisms such as paying farmers for environmental services[7]).The financial architecture of the project resulting from this analysis will influence the funding of the project, e.g. whether national or international subsidies should be sought, how far it can be self-financing, or whether commercial finance or private equity is feasible.[8]

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[5] capable of being exchanged, e.g. bought and sold, between different parties, in accordance with local legal systems

[6] Which for many, though not all, purposes will coincide with that of the region or river basin.

[7] As described in FAO (2007).

[8] A growing number of reuse projects are funded from commercial sources, including public-private partnerships (BOTs), though these tend to be for industrial and urban non-potable uses.

6.4 PUBLIC AWARENESS

Recycling depends on public acceptance, which in turn relies on awareness and understanding of the issues involved. In different contexts and cultures "wastewater" has connotations and resonances which have to be addressed. Public health and consumer concerns need to be dealt with transparently, using guidelines and procedures outlined in this report. Groups and whole communities affected by water recycling scheme have to be engaged in the decision-making and planning process, as outlined in Chapter 5.

Water issues are rising in the agenda of public actions, especially in the context of adaptation to climate change. Questions about the sustainability of current trends in urbanisation, water quality, environmental stress, and the needs of future food production – to name some driving issues – are leading to radical rethinking of water supply, use and disposal systems.9 The costs of water scarcity and water stress, on the one hand, and the expense and limitations of traditional responses to it, on the other, are key drivers of the new level of interest in recycling. From being an unfashionable and unspoken residual element of the water cycle, wastewater is emerging as a key link in IWRM.

[9] E.g. in the TECHNEAU programme of the SAFIR Project of the European Commission Research DG.

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The wealth of waste

The economics of wastewater use in agriculture

In recent times, the coalescence of different pressures – agriculture water abstraction, population growth, increasing urbanization, drought, reduced run-off, water quality deterioration – has put a major strain on water supply globally. The level of water abstraction is reaching its natural limits, and this calls for a dramatic shift in water utilization concepts. The traditional "linear society" is not a sustainable solution and the "circular society" has to become a new standard. In this context planned water reclamation and reuse for agricultural uses is a strategy gaining wider acceptance in many parts of the world.

The current FAO Water Report addresses the economic and financial issues and the methodology and procedures involved in the analysis of water recycling projects as part of a comprehensive water planning process. The issue is dealt within the wider context of water resources and covers human health, water quality, acceptability, institutional constraints, and other factors, all of which have economic implications and affect the feasibility of reuse schemes. The report has a strong focus on success factors in reuse projects from Case Studies in Spain and Mexico.

The recycling of urban wastewater is a key link in Integrated Water Resource Management – IWRM – that can fulfill several different, but interrelated objectives. These are expressed as win-win propositions, delivering simultaneous benefits to farmers, cities and natural environmental systems, part of the solutions to the urgent global problems of food, clean water, the safe disposal of waters and the protection of the vital aquatic ecosystems.

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Confronting the Livelihood and Environmental Realities

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Foreword

Growing water scarcity threatens economic development, sustainable human livelihoods, environmental quality, and a host of other societal goals in countries and regions around the world. Urban population growth, particularly in developing countries, places immense pressure on water and land resources; it also results in the release of growing volumes of wastewater – most of it untreated. Wastewater is increasingly being used for irrigation in urban and peri-urban agriculture, and even in distant rural areas downstream of the very large cities. It drives significant economic activity, supports countless livelihoods particularly those of poor farmers, and very substantially changes the hydrology and water quality of natural water bodies. There are of course rather serious drawbacks for human health and the environment that result from using wastewater without adequate safeguards. The challenge is to identify practical, affordable safeguards that do not threaten the substantial livelihoods dependent on wastewater, or diminish the important role this resource plays in achieving household food security and supplying low-cost produce to growing cities.

The Millennium Development Goals aim to halve, by 2015, the number of people without access to water supplies or safe and affordable sanitation. Sustainable and safe wastewater use can support the achievement of these goals by preserving valuable fresh water for drinking. Furthermore, sanitation goals have always been difficult to achieve, as other priorities always seem to attract scarce resources. To ensure the efficient use of funds, the goal of improved sanitation should be pursued with the objective of wastewater use in mind, as the type of technology selected can either help or hinder the goal of reuse. Using wastewater for agriculture, i.e. valuing both the water resource and the nutrients for a new productive use, changes the thinking from having to deal with a costly nuisance to trying to harvest a potentially valuable resource.

The present volume addresses these issues head-on through a series of thematic chapters aiming to better understand wastewater use in agriculture in developing countries and detailed case study documentation of what works and what does not. The book is part of ongoing collaboration between the International Water Management Institute (IWMI) and the International Development Research Centre (IDRC). Both our institutions are committed to the sustainable use of natural resources in developing countries, and while we may approach the subject of wastewater from diverse perspectives, we agree that wastewater is a resource of growing global importance and that sustainably managed, it can greatly enhance livelihoods and improve environmental quality. This central tenet is recognized in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume), an important outcome of the joint IWMI-IDRC workshop held 11–14 November 2002 in Hyderabad, India.

The editors and contributing authors represent a wide spectrum of experience and perspectives on wastewater use in agriculture, and collectively form a growing 'community of practice' that will generate, exchange and broker knowledge. The volume should serve to change thinking on the part of decision makers in such international bodies as the World Health Organization, national and state governments (some of whom were present at the November 2002 workshop in Hyderabad), researchers and practitioners. Both IWMI and IDRC see this as an important boost to promoting safe and sustainable use of wastewater.

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1 Wastewater Use in Irrigated Agriculture: Management Challenges in Developing Countries

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Abstract

Cities in developing countries are experiencing unparalleled growth and rapidly increasing water supply and sanitation coverage that will continue to release growing volumes of wastewater. In many developing countries, untreated or partially treated wastewater is used to irrigate the cities' own food, fodder, and green spaces. Farmers have been using untreated wastewater for centuries, but greater numbers now depend on it for their livelihoods and this demand has ushered in a range of new wastewater use practices. The diversity of conditions is perhaps matched only by the complexity of managing the risks to human health and the environment that are posed by this practice. An integrated stepwise management approach is called for, one that is pragmatic in the short- and medium terms, and that recognises the fundamental economic niche and users' perceptions of the comparative advantages of wastewater irrigation that drive its expansion in urban and peri-urban areas. Comprehensive management approaches in the longer term will need to encompass treatment, regulation, farmer user groups, forward market linkages that ensure food and consumer safety, and effective public awareness campaigns. In order to propose realistic, effective, and sustainable management approaches, it is crucial to understand the context-specific tradeoffs between the health of producers and consumers of wastewater-irrigated produce as well as the quality of soils and water, on the one hand, and wastewater irrigation benefits, farmers' perceptions, and institutional arrangements on the other. This introductory chapter to the current volume on wastewater use in agriculture highlights a series of tradeoffs associated with continued use of untreated wastewater in agriculture. Empirical results from the case studies presented in the volume shed light on devising workable solutions.

Rapid Expansion of Wastewater Irrigation in the Coming Decades

The use of urban wastewater in agriculture is a centuries-old practice that is receiving renewed attention with the increasing scarcity of freshwater resources in many arid and semi-arid regions. Driven by rapid urbanisation and growing wastewater volumes, wastewater is widely used as a low-cost alternative to conventional irrigation water; it supports livelihoods and generates considerable value in urban and peri-urban agriculture despite the health and environmental risks associated

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with this practice. Though pervasive, this practice is largely unregulated in low-income countries, and the costs and benefits are poorly understood.

This volume critically reviews worldwide experience in the use of wastewater for agriculture through a series of chapters defining and elaborating on the issues at the centre of the debate around wastewater use in agriculture. Particular emphasis is placed on untreated wastewater use through field-based case studies from Asia, Africa, the Middle East, and Latin America, which address the environmental and health impacts and risks of the practice. These chapters consider multiple aspects including the economic, social, health, agronomic, environmental, institutional, and policy dimensions and the research needs related to this growing practice. The editors conclude with a prognosis of future challenges and realities of wastewater use in agriculture.

Cities throughout the developing world are growing at unprecedented rates, yet there are no reliable data on the sewage volumes they generate or any comprehensive assessments of the fate or use of urban wastewater. However, because sewage collection and its disposal as wastewater are increasing in developing-country cities as a function of the growth in urban water supply, water supply coverage is a reasonable proxy for projecting increases in wastewater volumes. Increases in urban water supply depend on myriad factors and will likely be unable to keep pace with urban population growth, implying falling per capita water supply rates. In spite of the fact that trends show that rates of urbanisation are likely to slow down in developed countries, in many countries of the developing world urbanisation will continue rapidly. As a result, wastewater flows will increase in the future. In developing countries where investments in water supply far outpace those in sanitation and waste management, suffice it to say that treatment and disposal of wastewater are inadequate or non-existent and that raw sewage – full-strength or diluted – is used and even competed for in order to irrigate food, fodder, ornamental and other crops.

We suggest that raw wastewater use in agriculture is presently increasing at close to the rate of urban growth in developing countries subject to urban and peri-urban land being available. Consider the demographics that will drive expansion in the volumes of wastewater generated. It is projected that 88% of the one billion growth in global population by 2015 will take place in cities, essentially all of it in developing countries (UNDP, 1998). Developed countries' populations are expected to decline 6% by 2050, while the global rural population should plateau at approximately 3.2 billion. The result is that after 2015, all worldwide growth in population will take place in developing-country cities. Cities are home to political and economic power and will continue to ensure that their water supply needs are met on a priority basis subject to physical and economic scarcity constraints. The Millennium Development Goals call for halving the proportion of people without access to improved sanitation or water by 2015. As a result, an additional 1.6 billion people will require access to a water supply – 1.018 billion in urban areas and 581 million in rural areas (WHO and UNICEF, 2000).

Water supply ensures wastewater because the depleted fraction of domestic and residential water use is typically only 15–25% with the remainder returning as wastewater. Although the numbers of urban dwellers in developing countries that continue to rely on septic tanks, cesspits, etc. is unexpectedly high, growing numbers are connected to sewers that deliver wastewater – largely untreated – to downstream areas. Very often too in spite of onsite sanitation, substantial volumes of domestic wastewater including toilet wastes find their way into surface water networks within cities. Table 1.1 shows by region the percentages of sewerage coverage and the wastewater actually treated.

This volume covers wastewater management examples from Africa, the Middle East, Latin America, and Asia. Although the challenges are significant in all these regions, in terms of overall magnitude (volumes of wastewater, numbers of people affected, and land irrigated) Asia represents the largest challenge. Despite the relatively high sewerage and treatment figures reported for Asia in Table 1.1, most of the global growth in urban water supply will take place in this region as seen in Fig. 1.1. The total numbers of people in Asian cities will generate such large volumes of wastewater that

Table 1.1. Sewerage coverage and wastewater treatment by world region.

Region	Population (%) in large cities that is sewered	Sewered wastewater (%) that is treated to secondary level
Africa	18	0
Asia[a]	45	35
Latin America/ Caribbean (LAC)	35	14
Oceania	15	Not reported
Northern America	96	90
Europe	92	66

[a]The *Global Water Supply and Sanitation Assessment 2000 Report* figures for Asia include Japan, South Korea, Taiwan, and other developed countries (WHO and UNICEF, 2000).

downstream agriculture with highly polluted wastewater is well nigh unavoidable. In India for example, the major bulk of population growth is expected to occur in 40–45 cities each with population greater than 100,000, not just in the mega cities (Amitabh Kundu, urban demographer, personal communication). Based on Central Pollution Control Board data for 2001, the Infrastructure Development Finance Corporation estimates that 73% of urban wastewater in India is untreated, requiring an investment in treatment capacity of the order of US$65 billion or ten times greater than what the Government of India proposes to spend (Kumar, 2003). China is also experiencing rampant urban growth. In both countries, sewerage coverage and wastewater treatment lag behind water supply, which in turn lags behind population growth.

These demographic processes coupled with increasing purchasing power will create unprecedented demand in urban markets for vegetables, milk, ornamental plants, etc. that are readily – in fact, competitively – produced using the wastewater that urban consumers themselves generate. With water scarcity, land

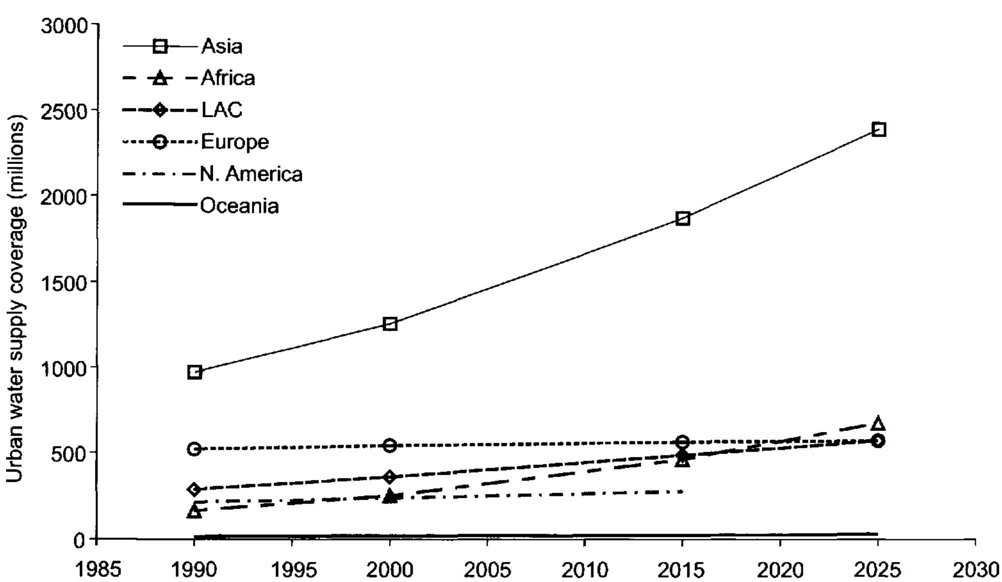

Fig. 1.1. Growth in urban water supply coverage by world region.

pressure, and little feasible budgetary alternative for effectively treating the growing wastewater volumes, the burgeoning of wastewater irrigation in developing country cities is already taking place.

Although it is impossible to devise effective management solutions from such global wastewater trends, our purpose at this juncture is to flag the immensity of the challenges of wastewater management in the urban and peri-urban fringe, where irrigation of a range of produce for urban markets is the most common use of wastewater. The challenges of wastewater management in the urban to peri-urban corridors will unavoidably grow more complex.

Both the pragmatists who see the difficulty in applying bans on wastewater irrigation and the detractors of wastewater use in agriculture find ample cause to bolster their positions. Numerous case studies on the dynamics of urban agriculture show that wastewater irrigation supports countless livelihoods of both marginal and better-established, or even commercial farmers and the labourers they employ, all of whom occupy production and marketing niches. These social and economic processes driving wastewater irrigation may often be overlooked from the regulatory perspective of urban, public health or environmental authorities who view the protection of public health and environmental quality as their primary objectives, despite the fact that regulators may be aware that urban farming using wastewater is a prevalent phenomenon. Furthermore, in many instances regulations are not applied with adequate rigour, entailing that purely regulatory approaches to manage wastewater irrigation tradeoffs are inevitably ineffective. For example, Accra, Ghana has passed regulations on the use of urban wastewater; but farmers largely ignore them and authorities are incapable of enforcement (Keraita and Drechsel, Chapter 9, this volume).

In water-scarce and even humid regions, farmers prize the water and nutrient value and supply reliability of the wastewater stream. And under the most common scenario in water-scare countries of a city expanding more rapidly than its water supply, sewage may water what little green space remains.

Irrigation with untreated wastewater can represent a major threat to public health (of both humans, and livestock), food safety, and environmental quality. The microbial quality of wastewater is usually measured by the concentration of the two primary sources of water-borne infection – faecal coliforms and nematode eggs. A range of viruses and protozoa pose additional health risks. Wastewater has been implicated as an important source of health risk for chronic, low-grade gastrointestinal disease as well as outbreaks of more acute diseases including cholera (e.g. Jerusalem and Dakar) and typhoid (Santiago). Disease agents are found in wastewater that drains from planned residential areas and slums alike. The health of the urban poor is particularly linked to inadequate management of wastewater. Chronic diarrhoeal and gastrointestinal diseases, which disproportionately affect urban slum dwellers who have inadequate sewerage and sanitation facilities, are clearly major negative outcomes of exposure to wastewater. A primary exposure route for the urban population in general is the consumption of raw vegetables that have been irrigated with wastewater (Fattal *et al.*, Chapter 5, this volume). Additional exposure routes for the urban poor, who are often migrants with little access to health services, include direct contact with solid waste and wastewater, as for instance through riverside open defecation grounds.

Additionally wastewater irrigation of vegetables and fodder may serve as the transmission route for heavy metals in the human food chain. Particularly in South Asia, where per capita milk consumption is the highest in the developing world and growing rapidly (Delgado *et al.*, 1999), wastewater is increasingly used to irrigate fodder that supplies an urban and peri-urban livestock-based production chain. Evidence of heavy metal transmission through milk is presented by Swarup *et al.* (1997). In the absence of chilling, storage and transport facilities, milk must be produced as close to market as possible; it represents an important urban and peri-urban agricultural product. Further, fodder cultivation is particularly well matched to wastewater; it requires continual irrigation application and is generally tolerant of the high salinity levels characteristic of urban wastewater.

Finally, the environmental quality of soils, groundwater and surface water, and to a lesser degree, stream channel biota and ecological conditions as indicated by the biodiversity of the wastewater-contaminated river or other receiving water body are often the second-order casualties if wastewater is disposed indiscriminately.

Cities in both arid and humid regions are witnessing unprecedented expansion of urban and peri-urban agriculture using poor-quality water. For example, in Bolivia, indirect use of wastewater takes place in almost all rural and peri-urban areas downstream of the urban centres (Huibers *et al.*, Chapter 12, this volume). Additionally, although wastewater irrigation has been thought to be limited to large cities, in regions such as Gujarat, India, it is common even downstream of small towns and villages (Bhamoriya, Chapter 11, this volume). As seen in the cases of Vietnam (Raschid-Sally *et al.*, Chapter 7, this volume), Jordan (McCornick *et al.*, Chapter 14, this volume), Senegal (Faruqui *et al.*, Chapter 10, this volume), or Bolivia (Huibers *et al.*, Chapter 12, this volume), the implications for public health and the environment are equally serious whether wastewater is intentionally used for irrigation or whether it is simply mixed with freshwater that is used for irrigation.

In sum, wastewater is a resource of growing global importance and its use in agriculture must be carefully managed in order to preserve the substantial benefits while minimising the serious risks. This reality was recognised and its implications deliberated in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume), one of the outcomes of a workshop held 11–14 November 2002 in Hyderabad, India and sponsored by the International Water Management Institute (IWMI, based in Colombo, Sri Lanka) and the International Development Research Centre (IDRC, based in Ottawa, Canada). The other outcome is this volume – most of the chapters were drawn from the workshop, which had the following objectives:

- To critically review experience worldwide in the use of wastewater for agriculture
- To present lessons learned from specific field-based case studies, including the environmental and health impacts and risks of wastewater use in agriculture
- To refine a methodology developed and applied by IWMI for selected countries that seeks to assess the global extent of wastewater use in agriculture
- To evaluate the institutional arrangements, constraints, and policy implications for sustained livelihoods based on wastewater use in agriculture
- To build a wastewater 'community of practice' integrating a variety of research, implementation and policy institutions and partners
- To offer some conclusions and recommendations for further research that help balance the need to protect public health and farmers' incomes.

This introductory chapter sets the stage for the chapters that follow in this book. The initial chapters address key thematic issues for wastewater management: a wastewater use typology, an overview of a wastewater-based sustainable livelihoods framework, discussion of public health guidelines, and assessment of the cost-effectiveness of treatment required to meet guidelines. There follow a series of case studies detailing wastewater use practices around the world, focusing on the complex set of challenges and identifying potential solutions. The emerging view is that a realistic approach requires that tradeoffs are considered in both the short and long terms. Several factors drive wastewater irrigation: the lack of equally remunerative livelihood alternatives, the continued expansion of the wastewater resource base, and the ineffectiveness of regulatory control approaches that have characterised most attempts at management. The experiences of countries that are in the process or have completed the conversion from untreated to regulated, treated reuse can serve as important lessons. The cases of Tunisia, Jordan and Mexico are presented in this volume.

Treated wastewater currently represents approximately 5% of Tunisia's total available water; this is planned to increase to 11% by 2030 (Shetty, Chapter 15, this volume). Salinity management remains a major objective of the Tunisian wastewater use programme. In Jordan, wastewater represents 10% of the current total water supply (McCornick *et al.*, Chapter 14, this volume). Groundwater recharge is one of the explicit uses of wastewater in Jordan, but not for aquifers that are used for drinking water supply. The previous (waste-) water quality standards required some revision in order to accommodate Jordan's plans to reuse water, particularly for sprinkler irrigation, which was prohibited for wastewater. In order to meet strict export phytosanitary controls, the irrigation of vegetables eaten raw with reclaimed water, no matter how well treated, remains prohibited in Jordan. In Mexico, implementation of wastewater treatment (but not necessarily its use) has been mandated by federal environmental quality regulations (Silva-Ochoa and Scott, Chapter 13, this volume). While wastewater use in agriculture is a common practice, particularly in Mexico's vast arid and semi-arid areas, it is mostly practised informally with the result that planned treatment for use in agriculture is not common. Instead, municipal water boards that bear the cost of treatment prefer to seek paying customers for treated wastewater, particularly golf courses, urban green spaces, etc.

Estimating the Magnitude of Wastewater Use in Irrigated Agriculture

Just how prevalent wastewater irrigation is today is a matter of conjecture; no sound, verifiable data exist. Earlier approximations by Scott (in Future Harvest, 2001, that were intended to stir the debate), based on figures for sewage generated, treatment capacity installed, assumptions of the proportion of peri-urban areas without wastewater demand for agriculture (e.g. coastal cities, etc.), freshwater mixing ratio, and annual irrigation depths, placed the area at 20 million ha of irrigation using raw or partially diluted wastewater. Since the release of this first-cut estimate, the reactions have been multiple that:

1. The 20 million ha figure is an overestimation of 'raw sewage irrigation' given that it includes areas irrigated with partially diluted wastewater
2. Wastewater irrigation is not important enough a phenomenon to warrant resources for research and management
3. The magnitude of the problem is significantly greater than that implied by the 20 million ha estimate
4. Isolated case studies barely scratch the surface and indeed irrigation using wastewater or seriously polluted water is pervasive and represents a major concern.

Clearly there is a need to establish and apply a verifiable method for determining the prevalence of wastewater irrigation. As an important first step in this direction, van der Hoek (Chapter 2, this volume) presents a typology. Raschid-Sally *et al.* (Chapter 7, this volume) and Cornish and Kielen (Chapter 6, this volume) present assessments at the country level with estimates of 9,000 ha for Vietnam and 11,900 ha for Ghana. Ensink *et al.* (2004) estimate that 32,500 ha are irrigated with wastewater in Pakistan. These results are based on a typological definition of undiluted wastewater, i.e. 'end-of-pipe' sewage irrigation, which does not account for irrigation using water polluted with wastewater, that poses many of the same risks and management challenges. Van der Hoek's typology includes marginal quality water, i.e. polluted surface water; however, country estimates have tended to focus on undiluted wastewater irrigation, suggesting that 20 million ha is an overestimation of the global extent of the practice. It is important to recognise, however, that improved estimates of global wastewater irrigation would need to account for a number of countries with rapidly growing cities and large national irrigation sectors including particularly China, Egypt, India, Indonesia, Iran, Mexico, and Pakistan.

This does not detract from the importance of wastewater irrigation or the difficulty of the management challenges in other countries or regions. Further, getting a precise fix on the global extent of wastewater irrigation should not deflect attention or resources from the far more substantive management issues that are invariably context-specific as demonstrated in the case studies presented in this volume.

Multiple complementary factors drive the increased use of wastewater in agriculture. Water scarcity, reliability of wastewater supply, lack of alternative water sources, livelihood and economic dependence, proximity to markets, and nutrient value all play an important role. Water scarcity and reliability of wastewater supply are crucial. The case studies in this volume of Dakar in Senegal, Cochabamba in Bolivia, and Vadodara in India all demonstrate this. That farmers have few alternative water sources may be true where wastewater is mixed with freshwater; however, in water-scarce regions, wastewater is invariably the only source. Interestingly in some cases, as in Pakistan where canal irrigation water is available, although with reliability and supply constraints particularly in the tail-end reaches of the irrigation systems, many farmers convert to wastewater by choice. Livelihood dependence for poor farmers remains the single most important socioeconomic driver of the practice, yet it is misleading to assume that all wastewater farmers are poor (Buechler, Chapter 3, this volume). Indeed, larger, commercial-scale farmers have made inroads and may compete with small-scale farmers for wastewater as well as for markets. Additionally, because of the market orientation of much wastewater agriculture in urban and peri-urban contexts, it absorbs significant labour, much of it female (Keraita and Drechsel, Chapter 9, this volume, and Faruqui *et al.*, Chapter 10, this volume). Finally, while most farmers acknowledge the nutrient value of wastewater this appears to be a secondary driver, i.e. the scarcity or poor quality (usually salinity) of alternative sources is generally more important.

Wastewater irrigation will remain consigned to informal practice and as a result management approaches must start at the informal or semi-formal level. Two important characteristics of wastewater irrigation in the case studies on Asian cities presented in this volume (Bhamoriya and Buechler from India; Ensink *et al.* from Pakistan) are semi-formal institutional arrangements and prominent, yet farmer-initiated, infrastructure for irrigation using untreated wastewater. Both suggest a degree of institutionalisation that is not evident in untreated wastewater use in other regions. While the use and livelihood dependence on wastewater in African cities is not entirely dissimilar, it is hypothesised that social relations and land tenure issues related to state or communal ownership of land may not result in the same formalisation of wastewater irrigation in urban and peri-urban agriculture as seen in Asian cities. By contrast, many countries in North Africa (Shetty, Chapter 15, this volume), the Middle East (McCornick *et al.*, Chapter 14, this volume), and Latin America (Silva-Ochoa and Scott, Chapter 13, this volume) have embarked on formal *treated* water reuse programmes. These provide important lessons, discussed in the conclusions, for the design of programmes to make the transition from informal to formal wastewater use.

Uni-dimensional management solutions for wastewater irrigation that employ exclusively technical (treatment) or regulatory (bans, crop restrictions, etc.) approaches have generally been inadequate. In isolation neither fully takes account of the multiple drivers of the process, nor the need for integrated management solutions. Realistic and effective management approaches rarely hold up technical or regulatory approaches as the complete solution, but instead seek to apply these in an integrated way. The more difficult question, particularly in the context of weak regulatory implementation, lies in the multiple – often competing – needs to secure livelihoods based on wastewater irrigation on the one hand, and public health and environmental protection imperatives on the other. Should the economic realities of a few override the need to protect broader societal goals? Clearly not, yet a more pragmatic approach is required than has been implemented in most developing country contexts. As discussed in the concluding chapter of this volume, we advocate a graduated approach to meeting targets [termed 'stepwise' in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume)], specifically that all aspects of the solution must be realistic. The concluding chapter elaborates the essential recommendations from this volume, i.e. 1. develop and apply appropriate guidelines for wastewater use, 2. treat wastewater and control pollution at source, 3. apply a range of non-treatment management options, and 4. conduct research to improve understanding of the practice as well as opportunities and constraints to adoption of these recommendations.

Guidelines for Health and Environmental Quality

The single most important rationale for more stringent control over wastewater use in agriculture is the risk posed to human health (of irrigators, consumers of produce, and the general public) and to the environment. Guidelines for wastewater use and standards for water quality matched to particular end uses have been developed and applied with varying degrees of success. Two sets of guidelines that aim to protect human health under conditions of planned reuse of treated wastewater – those set out by the World Health Organization (see Carr *et al.*, Chapter 4, this volume) and the United States Environmental Protection Agency (USEPA) – have raised considerable controversy in particular with respect to their feasibility and applicability in different developing country contexts. Fattal *et al.* (Chapter 5, this volume) estimate that the cost of treating raw sewage used for direct irrigation to meet the current WHO microbial guideline of 10^3 faecal coliforms/100 ml is approximately US$125 per case of infection (of hepatitis, rotavirus, cholera, or typhoid) prevented. By comparison, the incremental cost of further treating wastewater from the WHO to the USEPA microbial guideline is estimated to be US$450,000 per case of infection prevented.

It is not our purpose here to join the guidelines debate, except to insist that cost-effective risk mitigation be the primary goal of any programme that includes guidelines for wastewater use in agriculture. Developing and applying pragmatic guidelines based on *managed risk* or *acceptable risk* instead of *'no risk'* criteria must be the approach adopted. As detailed by Carr *et al.* (Chapter 4, this volume), the Stockholm Framework encourages flexibility in the adoption of wastewater use guidelines to facilitate progressive implementation of guidelines and to account for local conditions, particularly other risk factors that may be more acute than microbial diseases linked to wastewater. Additionally, Carr *et al.* identify a number of beneficial outcomes of wastewater use that tend to be overlooked in the guidelines debate. A key factor that needs to be integrated in any future approach is the livelihoods dimension of such unplanned use and the associated benefits (Buechler, Chapter 3, this volume; Drechsel *et al.*, 2002).

There are two primary constraints to the adoption of any set of guidelines: firstly infrastructure, operation and maintenance, and the associated investment and recurring costs that are required to handle or treat wastewater to the quality levels stipulated in the guidelines, and secondly regulatory enforcement to ensure compliance with required practice on the part of water authorities, those discharging wastewater, and those handling and using wastewater. Invariably the infrastructure issue is seen as the principal challenge, so that much of the debate is centred on wastewater treatment plants, their design, cost of operation, maintenance, etc. The assumption appears to be that with adequate technical control, the need to limit wastewater discharge and subsequent use is sufficiently minimised. This places ultimate responsibility for guidelines compliance on urban development authorities who control the finance of wastewater infrastructure and on wastewater treatment plant operators. Yet in the case of planned reuse there are larger institutional issues that permit (or impede) the implementation of wastewater use programmes, of which guidelines may be an important component. As seen in the Tunisian and Jordanian cases, the other 'software' components of such programmes including inter-agency coordination, public awareness campaigns, and emergency response (to disease outbreaks, etc.) are critical to risk mitigation.

In developing-country contexts, however, use of wastewater is an unplanned activity, and authorities tend to view the responsibility of regulating its use as a burden. In the absence of resources for treatment infrastructure and regulatory control, the guidelines proposed by the WHO, while relevant in a planned reuse context, are relegated to the status of targets (usually unachievable) instead of norms for practice. The distinction between norms and targets is an important one. Norms require compliance with a minimum acceptable level of practice, e.g. wastewater discharge for unrestricted irrigation must have less than 10^3 faecal coliforms per 100 ml. Targets are feasible but invariably unachieved levels, e.g. wastewater treatment plant X discharges effluent with 10^4 faecal coliforms/100 ml, almost meeting the 10^3 target.

Short-term and Long-term Scenarios and Tradeoffs

Based on projected increases in urban water supply coupled with improved sewage collection resulting from sanitation programmes, the volumes of wastewater released from developing-country cities will certainly increase in the short (next 5 years) and long (next 25 years) terms. At least three factors relevant to the subject of this volume make long-term future projections of the global extent of wastewater irrigation problematic:

1. The poor reliability of water supply goals as a proxy for increases in the volumes of wastewater generated over the long term
2. Uncertainty in the degree and effectiveness of treatment that is implemented and sustained for those volumes of sewage that are collected
3. Changing societal demands for health and environmental protection that necessarily must be the driving force behind compliance and enforcement of wastewater irrigation guidelines and related regulatory frameworks.

In the short term, wastewater use will continue to grow and the immediate priority challenges are posed by the need to mitigate both chronic and acute risks while simultaneously addressing medium- and long-term constraints to integrated wastewater management. A priority short-term objective is to control wastewater exposure (through crop selection to minimise exposure of both consumers and producers, providing extension support for affordable but safer irrigation practices including piped distribution, field application using broad furrows that minimise crop and irrigators' exposure, protective equipment supported by public awareness, etc.). Second order, but potentially effective measures include therapeutic medical care for irrigators, e.g. anti-helminthic drugs, and provision of safe water in markets to protect consumers of vegetables eaten raw by ensuring that market produce is not washed or 'freshened' using wastewater.

In the medium term (10–15 years), wastewater treatment capacity is unlikely to keep pace even with water supply increases much less to make up the current gap between wastewater generated and collected and that actually treated. To find workable interim solutions, it is essential to table a dialogue among wastewater managers, urban authorities and existing irrigation users of untreated wastewater. For example, farmers should make known their interest in nutrients and organic matter. Urban authorities responsible for watering green spaces should share information with farmers to best allocate dry-season wastewater flows. Finally, downstream users should demonstrate to upstream producers of wastewater and to sanitation planning authorities that downstream agriculture is providing *de facto* treatment, but should insist on effective upstream contaminant source control and efforts to prevent particularly the more toxic constituents from entering the waste stream. Industrial sources of heavy metals, organics, and pharmaceutical waste need to be recovered in on-site or industrial park common effluent treatment plants before the liquid discharge is mixed with wastewater of primarily residential and commercial origin. End-of-pipe regulations for industries are much more enforceable from a purely logistical perspective – though perhaps more difficult institutionally when corruption and associated 'insider deals' are at play – than will be efforts to sewer, collect and treat wastewater from millions of dispersed urban residents in growing urban centres.

In the long term, wastewater treatment to at least primary level using settling basins or facultative lagoons must be the norm. Lowering the cost is essential if efforts to treat wastewater are to be effective. Although the costs of technology and even operation and maintenance of primary treatment are low, land value or the opportunity cost of urban or peri-urban land is often a formidable barrier to effective treatment in the long term. Urban authorities need to recognise the growth requirements now and set aside land for future treatment facilities in order to offset high future land acquisition costs. They must also plan for integrated wastewater management that includes downstream beneficial uses of the wastewater.

At all stages, public awareness for farmers, authorities, and the public at large is essential, not just of the risks and benefits, but more importantly of several of the tradeoffs discussed here.

Conclusions

We have shown, based on our own experience and collaborations spanning multiple countries, continents, and contexts that irrigation using untreated wastewater is a prevalent phenomenon with multiple tradeoffs – between livelihoods and the need to protect health and the environment, between water demand under conditions of scarcity and the need for waste (water) disposal, and finally between informal practice led by farmers and formal institutional initiatives involving health, urban, water and agricultural authorities. A supreme degree of pragmatism and commitment is required under the realisation that effective solutions must be incremental and will take time to implement.

Planned reuse that seeks to maintain the benefits and minimise the risks will require an integrated approach. Key to the success of endeavours to make the transition to planned strategic reuse programmes are a coherent legal and institutional framework with formal mechanisms to coordinate the actions of multiple government authorities, sound application of the 'polluter pays' principle, conversion of farmers towards more appropriate practices for wastewater use, public awareness campaigns to establish social acceptability for reuse, and consistent government and civil society commitment over the long term with the realisation that there are no immediate solutions.

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2 A Framework for a Global Assessment of the Extent of Wastewater Irrigation: The Need for a Common Wastewater Typology

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Abstract

Policies on wastewater use have tended to focus on treatment before use and the implementation of strict regulations. But in many low-income developing countries untreated urban wastewater is used for irrigation. Clear policy guidelines on how to optimise the benefits and minimise the risks of this practice are lacking. A better estimate of the extent of wastewater irrigation is needed before the reality of its use can become an agenda item for policy and decision-makers. Secondary data and results of nationwide assessments should be aggregated to obtain a global estimate of use. For this, a common typology of wastewater use is needed that would need to address such aspects as: the direct use of urban wastewater versus the dilution of urban wastewater by natural surface water before use, the relative contributions of domestic wastewater, industrial effluent, and stormwater to urban wastewater, the extent to which the wastewater is treated, and the use of wastewater in formal irrigation schemes, or as informal irrigation by smallholders without external support or control. A typology of wastewater irrigation and a database structure for consolidation of results are proposed. It is intended that this should be developed into a framework for a global assessment of the extent and importance of wastewater irrigation.

Introduction

With the increasing scarcity of freshwater resources that are available to agriculture, the use of urban wastewater in agriculture will increase, especially in arid and semi-arid countries. The major challenge is to optimise the benefits of wastewater as a resource of both the water and the nutrients it contains, and to minimise the negative impacts of its use on human health. From the environmental aspect there are potentially positive and negative impacts that should be considered. International guidelines for use and quality standards of wastewater in agriculture exist (Mara and Cairncross, 1989). These standards can only be achieved if the wastewater is appropriately treated. Because of high treatment costs, most cities in low-income developing countries will not have wastewater treatment facilities in the foreseeable future. However, while the use of untreated wastewater has become a routine

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practice in most developing-country cities, policies on its use have not taken this reality into consideration. Such policies range from active enforcement of legislation that totally prohibits the use of untreated wastewater, to turning a blind eye. Clearly, there is a need for better-informed decision-making.

To put wastewater use onto the international policy agenda there is a need to describe the importance of wastewater for integrated water resources management (IWRM), agricultural production, and to the livelihoods of poor urban, peri-urban, and rural populations. At present there are no clear estimates of the extent of irrigation with urban wastewater. Some people say it is an insignificant source of water for agriculture because the amounts of water diverted to cities and later disposed as wastewater are small in relation to the amount of water needed for agriculture in most developing countries. Others claim that worldwide, more than 20 million ha are irrigated with urban wastewater, and that wastewater has an important impact on agricultural productivity and livelihoods.

The International Water Management Institute (IWMI) proposes to lead a collaborative global assessment of the extent of wastewater use and has already initiated nationwide assessments in Vietnam and Pakistan. By linking up with other interested international and national institutions, a global database will be built that will be accessible in the public domain. This Global Assessment of the Extent of Wastewater Irrigation is linked to the Global Irrigated Area Mapping proposed by IWMI (Droogers, 2002), and the CGIAR's Comprehensive Assessment of Water Management in Agriculture (CGIAR, 2001a) which is a key component of the knowledge base for the Dialogue on Water, Food and Environment (CGIAR, 2001b).

This chapter aims to promote a common understanding of the characteristics of wastewater and its use in order to provide a framework for a global database of wastewater irrigation.

Definition of Wastewater

Definitions and concepts of wastewater are given in various reports and textbooks (Metcalf and Eddy, 1995; Westcot, 1997; Asano and Levine, 1998; Martijn and Huibers, 2001). In this report it is assumed that *urban wastewater* (Fig. 2.1) may be a combination of some or all of the following:

- Domestic effluent consisting of blackwater (excreta, urine and associated sludge) and greywater (kitchen and bathroom wastewater)

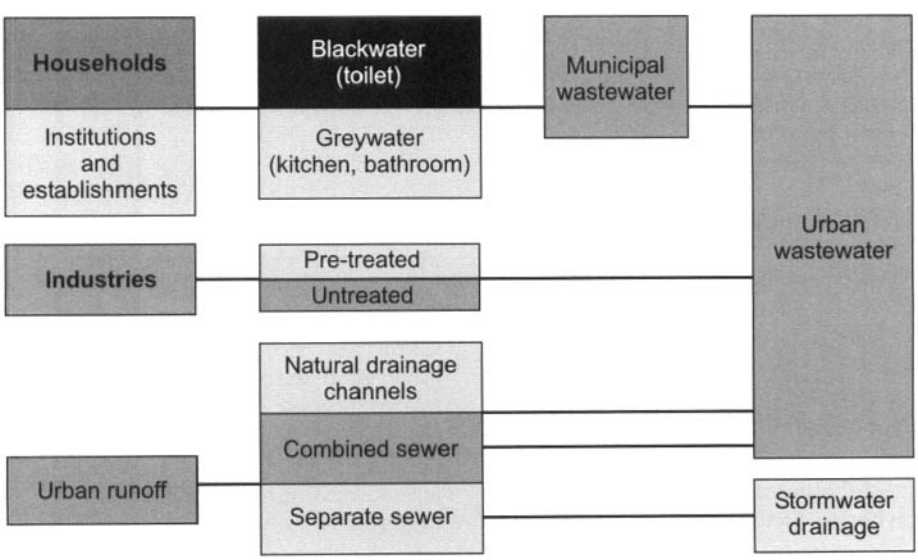

Fig. 2.1. Urban wastewater components.

- Water from commercial establishments and institutions, including hospitals
- Industrial effluent
- Stormwater and other urban runoff.

The actual proportion of each constituent within any given urban sewage load will vary due to spatial and temporal differences. For instance, monsoon climatic patterns will have a marked effect by diluting wastewater during heavy rains with the converse effect during hot and dry summers when there is more evaporation.

In irrigation sometimes the term **marginal quality water** is used. This refers to water whose quality might pose a threat to sustainable agriculture and/or human health, but which can be used safely for irrigation provided certain precautions are taken. It describes water that has been polluted as a consequence of mixing with wastewater or agricultural drainage (Cornish *et al.*, 1999). It can also include water with a high salt content. Such water can also be considered wastewater in the context of this chapter, but is not included in the Pakistan and Vietnam national assessments mentioned above.

The Need for a Typology of Wastewater Use

All kinds of variations in wastewater use are possible and it is to be expected that different uses will have different impacts on agricultural productivity, the environment, and human health. Appropriate policy decisions and technical interventions are likely to depend on the nature and characteristics of the wastewater and the way in which it is being used. A typology that can effectively capture these characteristics is required to ensure that those involved in this field are aware of the important differences that exist, and are able to identify where a given research finding, policy instrument, or technical intervention will and will not find relevant application. Cornish and Kielen (Chapter 6, this volume) propose a framework describing wastewater sources and use. The search for a single, all-embracing definition that says what is included and what is excluded from the notion of wastewater irrigation appears futile. Rather, a typology or a classification of the most common forms of wastewater use in irrigation must be developed. It is important that such a typology can be readily understood by all those involved in building the global database. Obviously, a typology that is so complex and sub-divided that every single situation requires a separate definition should be avoided. Instead, a certain minimum number of basic 'types' need to be agreed. Once a typology is agreed upon, then it is possible to debate, which 'types' of wastewater irrigation will be included and which excluded from the global assessment.

Typology of Wastewater Use

The following three types of wastewater use are the most relevant (Fig. 2.2):

Direct use of untreated wastewater is the application to land of wastewater directly from a sewerage system or other purpose-built wastewater conveyance system. Control exists over the conveyance of the wastewater from the point of collection to a controlled area where it is used for irrigation (Westcot, 1997). The irrigation source is wastewater that is directly taken from the sewerage system, or from stormwater drains that carry large sewage flows. An example of this situation is that found in Haroonabad, Pakistan, where untreated wastewater from a sewerage outlet

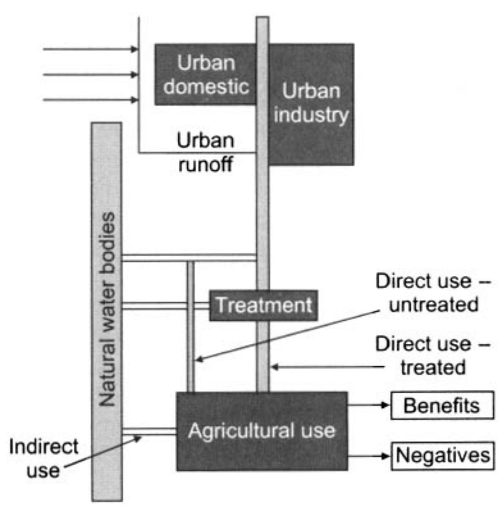

Fig. 2.2. Basic types of wastewater use.

is directly disposed on land where it is used for vegetable production (van der Hoek *et al.*, 2002). Another type of such use is when numerous informal irrigators draw water directly from the sewers or open drains, upstream of the site where disposal or treatment occurs. For example, this happens in Nairobi, Kenya, where farmers block sewers deliberately causing them to overflow (Cornish and Kielen, Chapter 6, this volume).

Direct use of treated wastewater is the use of treated wastewater where control exists over the conveyance of the wastewater from the point of discharge from a treatment works to a controlled area where it is used for irrigation. Many countries in the Middle East make use of wastewater stabilisation ponds to remove pathogens from wastewater. The effluent from the ponds is used for irrigation. To describe such a situation the term **reclaimed water** is often used, meaning water that has received at least secondary treatment and is used after it flows out of a domestic wastewater treatment facility. It must be noted that in many cases wastewater can only be considered partially treated to the design standard because the levels of wastewater production far exceed treatment capacity.

Indirect use of wastewater is the planned application to land of wastewater from a receiving water body. Municipal and industrial wastewater is discharged without treatment or monitoring into the watercourses draining an urban area. Irrigation water is drawn from rivers or other natural water bodies that receive wastewater flows. There is no control over the use of water for irrigation or domestic consumption downstream of the urban centre. As a consequence, many farmers indirectly use marginal quality water of unknown composition that they draw from many points downstream of the urban centre. In other cases the water is abstracted at one or two well defined sites for use in a **formal** irrigation system. An example of **indirect use of untreated** urban wastewater is found in Kumasi, Ghana, where large parts of the urban development have no operational sewerage or drainage network. A river passes through the urban centre and is progressively polluted by diffuse urban runoff. The water from this polluted river is abstracted by many users at many points downstream of the urban centre (see also Cornish and Kielen, Chapter 6, this volume).

Asano and Levine (1998) make the distinction between **wastewater reuse** which is the beneficial use of reclaimed (treated) wastewater and **wastewater recycling**, which normally involves only one use or user, who captures the effluent from the user and directs it back into the use scheme. Please note the assumption in this description that it is always treated wastewater. Wastewater reuse implies that the wastewater is used a second time. In fact, it is the water, not the wastewater that is being reused. Wastewater use therefore seems to be a better term than reuse, because the wastewater is generally used only once. Wastewater use can take place at the household level or off-site when there is a sewerage system.

As wastewater use can be defined as the deliberate application of urban wastewater for a beneficial purpose, it is in most cases *planned*, either by state agencies or farmers. However, there are also situations where natural rivers passing through cities become so heavily polluted with wastewater that they become *de facto* sewers. Asano (1998) describes the diversion of water from a river downstream of a discharge of wastewater as an incidental or unplanned reuse. Asano states that indirect reuse normally constitutes unplanned reuse whereas direct reuse normally constitutes planned reuse. There are important exceptions to this definition. For example, the effluent from the As-Samra treatment plant in Jordan ends up in an irrigation scheme after dilution in an intermittent stream locally known as a *wadi* and in a reservoir (McCornick *et al.*, Chapter 14, this volume). Although the scheme was never planned to use wastewater, it is clearly an irrigation scheme with planned development and managed by an irrigation agency that levies water tariffs. Along the Musi River in India irrigation schemes controlled by the Irrigation Department depend primarily on urban wastewater from the city of Hyderabad (Buechler, Chapter 3, this volume).

The distinction between planned and unplanned use does not seem to be of much practical relevance for the typology. Instead, it is suggested that the typology should indicate the main reason for use of the wastewater by farmers. In many cases the wastewater supply is more reliable than other sources of irrigation water, or it may even be the only source of water that is available to farmers. In other cases it is the nutrients in the wastewater that make it attractive to farmers.

Another distinction that is often made is between formal and informal use. The concepts of formal and informal irrigation are, to some extent, synonymous with planned and unplanned irrigation. Formal irrigation could refer to the presence of an irrigation infrastructure or to a certain level of permission and control by state agencies. In most cases this will apply to a single point type of abstraction. If the abstraction of wastewater is at numerous scattered points, then it is unlikely that there is an irrigation infrastructure, and probably no control by state agencies, hence the wastewater use is informal.

Nationwide Assessments

The question is, 'Can the proposed typology be meaningfully applied at the national level? While there are only limited data available on the extent of wastewater irrigation, the salient features of wastewater use in some countries and the applicability of a typology can be described.

Pakistan

Pakistan has a rapidly growing population, that is expected to increase from 139 million in 1998 to 208 million in 2025. By that time, about 50% of the population will live in urban centres. In almost all towns in Pakistan that have a sewerage system, the wastewater is directly used for irrigation. IWMI has made a nationwide survey of wastewater use in Pakistan and the results indicate that 32,500 ha are directly irrigated with wastewater (Ensink *et al.*, 2004). A negligible proportion of this wastewater is treated and no clear regulations exist on crops that can be irrigated with wastewater. Vegetables are the most commonly irrigated crops, because they fetch high prices in the nearby urban markets. The wastewater used for irrigation is valued by farmers mainly because of its reliability of supply. In some cases the wastewater is auctioned by the municipal council to the highest bidder, often a group of richer farmers who then rent out their fields to poor landless farmers. Under these conditions, the use of untreated wastewater is considered a win-win situation by both the authorities that are responsible for wastewater disposal and the farmers who get a reliable supply of water with high nutrient content. There are therefore very few incentives to invest scarce resources in wastewater treatment.

India

The situation in the semi-arid parts of India is not much different from that in Pakistan, except that industrial effluent probably plays a bigger role. India has a population of one billion people (as of the 2001 census), with a population increase of 181 million during the 1990s alone. More than 28% of this population lives in cities with a percentage decadal growth in the urban population at 31%. Strauss and Blumenthal (1990) estimated that 73,000 ha were irrigated with wastewater in India. Surely, the typology used to obtain this estimate must have been different from the one used for China, where Mara and Cairncross (1989) estimated 1.3 million ha were irrigated with wastewater. Most wastewater irrigation in India occurs along rivers, which flow through such rapidly growing cities as Delhi, Kolkata, Coimbatore, Hyderabad, Indore, Kanpur, Patna, Vadodara, and Varanasi. Many of the Indian peninsular rivers would not have much or any flow during most of the year if they were not used to funnel wastewater away from cities to peri-urban and rural areas. In such cases this can hardly be considered disposal in surface waters as it is, in fact, disposal in a natural conveyance channel. Along the rivers the water is diverted via anicuts (weirs) to canals and often to tanks and then channelled to the fields for irrigation. If such uses were included, a much higher figure than 73,000 ha would be obtained, since for the area along one river, the Musi in Andhra Pradesh alone there are approximately 40,500 ha irrigated with wastewater.

Vietnam

Vietnam has a centuries-old tradition of using human waste in agriculture and aquaculture. Hanoi and other cities in the Red River delta have natural ponds that collect wastewater and drainage water from cities. These ponds are used for aquaculture and as sources of irrigation water, and also play an important role in flood control. While there are hardly any conventional treatment facilities, the natural ponds are likely to provide at least some purification of the wastewater. The ponds generally discharge wastewater directly into irrigation canal systems and rivers. Wastewater from city drains is also pumped into irrigation canal systems at certain times of the year, and at locations where there is insufficient irrigation water. Ongoing IWMI research in Vietnam shows that the area irrigated directly with urban wastewater is limited, but that indirect use after passage through natural ponds is widespread.

Mexico

Mexico accounts for about half of the 500,000 ha irrigated with wastewater in Latin America. Much of the recent scientific work on health impacts and other aspects of wastewater use has been done in Mexico. In most cases the wastewater is used at some distance from the urban centre in a formal irrigation setting. The bulk of the untreated wastewater from Mexico City goes to Mezquital, immediately north of the Mexico Valley where it is used for irrigation via an extensive network of irrigation canals. This is probably the largest and longest-standing wastewater use system in the world.

Jordan

In Jordan most of wastewater from urban areas is treated and used in agriculture. The As-Samra plant is one of the largest wastewater treatment plants in the world. It is a wastewater stabilisation pond system, consisting of 32 ponds occupying 200 ha and serving about half the population of the country. The benefits of this system have been well described. For example, aubergine yield under trickle irrigation with the effluent from the system was twice the average Jordanian aubergine production under freshwater irrigation using conventional fertilisers (Al-Nakshabandi *et al.*, 1997). This could be considered direct use of treated wastewater. However, much of the effluent is transported over long distances and is blended with rainwater stored in a reservoir. So indirect use of treated wastewater also takes place. A second point is the effectiveness of the treatment plants. Some treatment plants are clearly overloaded and the effluent from such plants could at best be called 'partially treated' if it is directly used. The effluent that is transported over some distance from overloaded plants receives a form of additional unintended natural treatment. There is no information on water quality from nationwide assessments so it is suggested that a very simple categorisation that includes 'treatment, but largely dysfunctional' is a possibility.

Global Database

Initially the database generated from the proposed global assessment of wastewater irrigation should provide estimates of the national and global areas irrigated with wastewater. As the database expands and more results of nationwide surveys become available, the possibilities for further analyses should be explored. For example, the area irrigated with wastewater in a country and the crops grown could be related to the total area irrigated and total agricultural production. A further step would be to estimate the impact of wastewater use on agricultural production, the economy in general, and livelihoods. Different scenarios could then be developed and their impact on agricultural production and the economy modelled.

Table 2.1 suggests a basic set of data requirements for the global database. Primary data collection will only be possible in a limited number of countries and the level of detail is therefore determined to a large extent by the availability of secondary data. To avoid the diversity of real-life situations being squeezed into a rigid format, any city-level description would need an additional description to the standard item scored.

Table 2.1. Proposed database outline for a global assessment of the extent of wastewater use in agriculture.

Type	Record	Field
General information	Country	Name
	City	Name
	Population size of city	Actual number
	Date of information	Calendar year
	Reference	First author, year
	Number of farmers/households involved in wastewater farming	Actual number
Use[a]	Direct – formal use	Area in hectares
	Direct – informal use	Area in hectares
	Direct use – total	Area in hectares
	Indirect – formal use	Area in hectares
	Indirect – informal use	Area in hectares
	Indirect use - total	Area in hectares
	No information on type of use available	Area in hectares
Treatment[b]	Conventional treatment	% of total area
	Natural/biological treatment	% of total area
	Treatment, but largely dysfunctional	% of total area
	No treatment	% of total area
	No information on treatment available	% of total area
Source	Municipal	Yes / No
	Industrial	Yes / No
	Mixed	Yes / No
Crops	Vegetables	Yes / No
	Rice	Yes / No
	Other cereals	Yes / No
	Fodder	Yes / No
	Cotton	Yes / No
	Fruit trees	Yes / No
	Ornamentals	Yes / No
	Pastures	Yes / No
	Fish/aquaculture	Yes / No
Reason for use	Only source of water available	Yes / No
	More reliable than other sources of irrigation water	Yes / No
	Supplies crop nutrients	Yes / No
Conveyance	Sewers or other formal collection network	Yes / No
	Other collection methods	Yes / No
	Natural drainage	Yes / No
Disposal	River or surface water body	Yes / No
	Irrigation	Yes / No
	Groundwater recharge	Yes / No

[a] Direct use — Wastewater conveyed to a defined area for irrigation, often single point type of abstraction from sewers or treatment plants.
Indirect use — Wastewater discharged into river or surface water bodies with numerous scattered points of uncontrolled downstream abstraction.
Formal use — Use of wastewater in an irrigation infrastructure with a certain level of permission and control by state agencies.
Informal use — Use of wastewater without an irrigation infrastructure (for indirect use) or irrigation lacking permission and control by state agencies (for direct use).

[b] In most cases the wastewater is untreated, i.e. not deliberately modified. In conventional wastewater treatment systems the wastewater is deliberately modified in order to obtain an effluent that is of better quality. In the case of natural/biological treatment such as natural ponds there is only limited or no control over retention time and other processes.

A reality check of data on the extent of area irrigated with urban wastewater can be obtained from a few typical scenarios that could apply to most countries. For example, assuming an annual rate of irrigation of 500 mm and per capita sewerage production of 100 l/day, a city of one million people would produce enough wastewater to irrigate an area of 7000 ha using efficient irrigation methods (Strauss, 2001).

Table 2.2 provides an overview of the information on the extent of wastewater irrigation that is currently available from a limited number of sources.

Limitations of the Typology

The proposed typology, like every typology, has limitations. It clearly focuses on those situations where (part of) cities have a conveyance system for wastewater, either sanitary sewers or stormwater drains that carry large sewage flows. There are, of course, many cities that do not have purpose-built sewers or drains. These obviously have a serious sanitation problem, but one could argue that for them the issue of wastewater use does not arise. Certain well-known types of wastewater use such as informal backyard (on-site) use of wastewater will have to be excluded from a global assessment because data are unlikely to be available. To document such practices, detailed case studies are likely to be more relevant than a global assessment. Certain types of on-site use are receiving increasing attention. These include the use of greywater, community-controlled decentralised wastewater disposal and use systems, and ecological sanitation. Obviously, in the countries where nationwide surveys can be organised, more details of wastewater use, on-farm conditions, and characteristics of the irrigators (men, women, children, socioeconomic status, ownership of land, land and water rights, etc.) can be collected.

Indirect wastewater use implies that there is a certain retention time and that certain processes take place before the water is used for irrigation. These include a certain die-off and removal of pathogens from the wastewater before its final use by the farmer. After a period of retention and at some distance downstream from the urban centre it is expected that the water quality improves, to the extent that it should no longer be called wastewater. However, there are at present no criteria to distinguish between: river water of good quality, polluted river water, and wastewater. In fact, the alternative to direct use of untreated wastewater is often the disposal of this wastewater in natural rivers and the two would be expected to have opposite effects on surface water quality. The disposal of untreated wastewater in rivers is an environmental problem, while one of the advantages of direct use of wastewater is that environmental (water) pollution is reduced.

Conclusions

In the foreseeable future, many towns in developing countries will continue or expand the direct or indirect irrigation of crops with untreated wastewater. Current government policies focus on regulation of wastewater use and wastewater treatment and are unable to offer practical solutions to the users. An important input into more realistic policies on wastewater use is information on the area irrigated with urban wastewater at national and global levels. Such macro-level estimates can only be obtained when there is a common understanding of the different types of wastewater use.

Table 2.2. Information currently available on the extent of wastewater irrigation from a limited number of sources.

Country/City	Population ('000)	Year	Farmers (number)	% of ww treated	Direct use (ha)	Indirect use (ha)	Vegeta-bles	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Afghanistan														
Kabul							Yes							Shuval *et al.*, 1986
Argentina														
Mendoza	320			100	3,700		Yes			Yes	Yes			Mara and Cairncross, 1989
Australia														
Melbourne				100	10,000									Mara and Cairncross, 1989
Bahrain														
Tubli					800									Mara and Cairncross,1989
Chile														
Santiago					16,000		Yes							Mara and Cairncross, 1989
Colombia														
Ibague	430					26,000		Yes						Young, 2002
Germany														
Braunschweig	325	1985	440	100	2,800									Mara and Cairncross, 1989
Ghana														
Accra		2001	700			300	Yes							Sonou, 2001
Kumasi	1,000	2000	12,700	0		11,500	Yes							Cornish and Aidoo, 2000
India														
Ahmedabad				0	890			Yes	Yes	Yes				Juwarkar *et al.*, 1988
Amritsar				0	1,214				Yes					Juwarkar *et al.*, 1988
Bhilai				100	607		Yes	Yes	Yes					Juwarkar *et al.*, 1988
Bikaner				0	40		Yes		Yes					Juwarkar *et al.*, 1988
Calcutta		1989	17,000	0		12,900	Yes	Yes					Yes	Mara and Cairncross, 1989; Edwards, 2001
Delhi	8,400	2001		52	1,214		Yes		Yes					Juwarkar *et al.*, 1988; Farooqui 2002
Gwalior				0	202		Yes	Yes	Yes					Juwarkar *et al.*, 1988
Hubli-Dharwad	800			0			Yes			Yes	Yes			Bradford, *et al.*, 2002.
Hyderabad	3,700	2001		24	110	40,500	Yes	Yes		Yes	Yes	Yes	Yes	Buechler and Devi, 2002
Jamshedpur				100	113				Yes	Yes				Juwarkar *et al.*, 1988
Kanpur				0	1,300		Yes	Yes	Yes					Strauss and Blumenthal, 1990
Lucknow				0	150		Yes	Yes						Juwarkar *et al.*, 1988

Table 2.2. Continued.

Country/City	Population ('000)	Year	Farmers (number)	% of ww treated	Direct use (ha)	Indirect use (ha)	Vegeta-bles	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Madras				0	133					Yes				Juwarkar *et al.*, 1988
Madurai				0	77					Yes				Juwarkar *et al.*, 1988
Nagpur				0	1,500		Yes	Yes	Yes	Yes				Juwarkar *et al.*, 1988
Trivandrum				0	37					Yes				Juwarkar *et al.*, 1988
Vadodara	1,400	2002		0		14,567			Yes			Yes		Bhamoriya, 2004
Iran														
Teheran							Yes							Shuval *et al.*, 1986
Kenya														
Nairobi	2,000		3,700	0	2,000		Yes	No	No	No	No	No	No	Hide and Kimani, 2000
Kuwait														
Kuwait		1986		100	9,000		Yes			Yes				Shuval *et al.*, 1986
Mexico														
Alfajayucan		2000	19,540	0	33,051									Scott *et al.*, 2000
Atoyac-Zahupan				30	3,800									Peasey *et al.*, 2000
Cienega de Chapala				0	10,469									Peasey *et al.*, 2000
Cindad Juarez				0	7,503									Peasey *et al.*, 2000
Chiconautla				0	3,123									Peasey *et al.*, 2000
Culiacan				0	800									Peasey *et al.*, 2000
Delicias				0	589									Peasey *et al.*, 2000
Estado de Jalisco				0	13,077									Peasey *et al.*, 2000
Estado de Mexico				0	5,498									Peasey *et al.*, 2000
Estado de Morelos				10	23,000									Peasey *et al.*, 2000
Guanajuato		2000		0		140								Scott *et al.*, 2000
Irapuato	300			83										Buechler and Scott, 2000
La Antigua				0	1,000									Peasey *et al.*, 2000
Lazaro Cardenas				0	21,899									Peasey *et al.*, 2000
Leon	1,100	1995			3,030				Yes	Yes				Chilton *et al.*, 1998
Mexico City				11		350,000				Yes				Peasey *et al.*, 2000
Mezquital Valley		1995	45,000			90,000	Yes		Yes	Yes				Chanduvi 2000; Cifuentes *et al.*, 2000
Quitupan														
Magdalena				0	5,000									Peasey *et al.*, 2000
R. Lago				0	1,600									Peasey *et al.*, 2000

Table 2.2. Continued.

Country/City	Population ('000)	Year	Farmers (number)	% of ww treated	Direct use (ha)	Indirect use (ha)	Vegeta-bles	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Rio Blanco				1	13,000									Peasey *et al.*, 2000
Rio Colorado				0	69									Peasey *et al.*, 2000
Rosario-Mezq.				0	33,080									Peasey *et al.*, 2000
San Juan del Rio				100	230									Peasey *et al.*, 2000
Santo Domingo				0	22									Peasey *et al.*, 2000
Tepecuac y Q.				0	100									Peasey *et al.*, 2000
Tula			31,316	0	45,125									Scott *et al.*, 2000
Tulancingo				0	300									Peasey *et al.*, 2000
Tuxpan				10	4,300									Peasey *et al.*, 2000
Valsequillo				87	20,600									Peasey *et al.*, 2000
Xicotencatl				0	2,300									Peasey *et al.*, 2000
Zamora				0	2,000									Peasey *et al.*, 2000
Morocco														
Beni Mellal	210	1993			600		Yes		Yes		Yes			Habbari *et al.*, 1999
Pakistan														
Arif Wala	74			0	300		Yes	Yes		Yes		Yes		van der Hoek *et al.*, 2002
Bahawanagar	111			0	55		Yes			Yes				van der Hoek *et al.*, 2002
Bahawalpur	408			0	600		Yes							van der Hoek *et al.*, 2002
Burewala	153			0	500		Yes		Yes	Yes		Yes		van der Hoek *et al.*, 2002
Faisalabad	2,000		2,000	0			Yes							Ensink, J., 2003.
Fort Abbas	35			0	100		Yes							van der Hoek *et al.*, 2002
Haroonabad	63		80	0	150		Yes			Yes		Yes		van der Hoek *et al.*, 2002
Khairpur	27			0	25		Yes			Yes				van der Hoek *et al.*, 2002
Minchinabad	26			0	12			Yes						van der Hoek *et al.*, 2002
Vihari	94			0	160		Yes		Yes	Yes		Yes		van der Hoek *et al.* 2002
Peru														
Chiclayo		1991		0	390									Chanduvi, 2000
Ica		1989		100	530									Mara and Cairncross, 1989
Lima		1987		2	6,800		Yes			Yes	Yes	Yes		Chanduvi, 2000; Mara and Cairncross, 1989
Piura		1991		100	116									Chanduvi, 2000
Tacna		1991		100	210		Yes							Strauss and Blumenthal, 1990

Table 2.2. Continued.

Country/City	Population ('000)	Year	Farmers (number)	% of ww treated	Direct use (ha)	Indirect use (ha)	Vegeta-bles	Rice	Other cereals	Fodder	Fruit trees	Cotton	Fish	Reference
Trujillo	400	1989		0	1,300									Mara and Cairncross, 1989
Saudi Arabia														
Riyadh					2,850									Mara and Cairncross, 1989
South Africa														
Johannesburg					1,800									Mara and Cairncross, 1989
Sudan														
Khartoum				100	2,800									Mara and Cairncross, 1989
Tunisia														
Tunis				100	4,450		Yes			Yes	Yes			Mara and Cairncross, 1989
USA														
Bakerfield, California					2,250									Mara and Cairncross, 1989
Chandler, Arizona					2,800									Mara and Cairncross, 1989
Fresno, California					1,625									Mara and Cairncross, 1989
Kearny, Nebraska				100	1,200									Mara and Cairncross, 1989
Lubbock, Texas					3,000									Mara and Cairncross, 1989
Muskegon, Michigan					2,000									Mara and Cairncross, 1989
Santa Rosa, California					1,600									Mara and Cairncross, 1989
Vietnam														
Bac Ninh	76	2001		0		100	Yes	Yes					Yes	Doan Doan Tuan, 2001
Ha Tinh	57	2001		0		223	Yes	Yes					Yes	Doan Doan Tuan, 2001
Hanoi	2,736	2001		0		1,560		Yes					Yes	Doan Doan Tuan, 2001
Ho Chi Minh	5,169	2001	4,000	0		1,000	Yes	Yes						Doan Doan Tuan, 2001
Ninh Binh	63	2001	1,400	0		304								Doan Doan Tuan, 2001
Thai Binh	132	2001		0		355	Yes	Yes						Doan Doan Tuan, 2001
Thanh Hoa	179	2001		0		360	Yes	Yes					Yes	Doan Doan Tuan, 2001
Viet Tri	132	2001		100		200	Yes	Yes						Doan Doan Tuan, 2001

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3 A Sustainable Livelihoods Approach for Action Research on Wastewater Use in Agriculture

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Abstract

The dearth of holistic studies that use a combination of technical and socio-economic, quantitative and qualitative methodologies impedes advances in the formulation of recommendations that could enhance the benefits and mitigate the harmful effects of wastewater use for both producers and consumers of wastewater-irrigated crops. New research based on a sustainable livelihoods framework can integrate multiple perspectives. Sustainable livelihoods analyses are actor-centred and can be used for studies on the socio-economic and biophysical context surrounding wastewater use and users in a given area. This chapter draws on case study material from Hyderabad, India and Irapuato and Chihuahua, Mexico.

A multi-disciplinary approach is imperative in studies of wastewater use so that both the public and private sectors, farmers and consumers can be informed about: 1. the livelihood activities of different stakeholder groups that are sustained by wastewater, 2. the benefits and risks of its use, and 3. the options available to manage such use more effectively. Currently, there is a dearth of holistic studies that include both technical and non-technical research on a particular wastewater use area. This impedes advances in the formulation of recommendations for the use and management of wastewater. Such studies could enhance the benefits and mitigate the harmful effects for wastewater-dependent people and for consumers of wastewater-irrigated produce. New research on wastewater use that utilises a sustainable livelihoods (SL) framework of analysis, can address issues hitherto neglected in social scientific studies. The SL approach can also, it is argued here, begin to be used to bridge the divide between technical and non-technical studies.

The Sustainable Livelihoods Approach

A livelihood is comprised of the capabilities, assets (including both material and social resources) and activities required to make a living (Chambers and Conway, 1992). Livelihoods are based on income (in cash, kind, or services) obtained from employment, and from remuneration through assets and entitlements. In 1987, a report by an advisory panel of the World Commission on Environment and Development (WCED) stressed the need for a new concept to address both equity and sustainability and termed it 'sustainable livelihood security'. Robert Chambers, Gordon Conway and others working with the Institute

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of Development Studies (IDS) and the International Institute for Sustainable Development (IISD) developed the Sustainable Livelihoods (SL) approach from the mid-1980s onwards to bridge initiatives centred on the environment, development and livelihoods. The SL approach builds on the Integrated Rural Development (IRD) model, participatory development and basic needs approaches, food security studies, and sector-wide approaches (DFID, 2003) and incorporates other types of analyses related to households, gender, governance and farming systems to arrive at a more holistic understanding of poverty (Farrington *et al.*, 1999). Chambers noted that:

> 'Professions and the Government Ministries and Departments which preserve and accentuate their specialisation, focus quite narrowly, overlooking linkages which are often important for resource-poor farmers. Agroforestry, meaning the interaction of trees and crops and/or livestock is a classic example where agronomists are concerned with crops, not trees or livestock; animal specialists are concerned with animals, not trees or crops; and foresters are concerned with trees, not crops or animals, and moreover trees in forests and not trees on farmers' lands'. Chambers (1987).

The SL approach shifted the focus to poor people to overcome this overly narrow type of analysis. The focus on people rather than on resources, structures, or physical areas entails a bottom-up approach that encompasses both the macro- (policy) and micro- (users, field) levels. Chambers (1987) argued that the emphasis placed on physical problems rather than on people hindered research as well as development projects that aimed at achieving sustainability.

Chambers and Conway's work focused on how rural households and members within households diversify their activities to increase income, reduce vulnerability and improve the quality of their lives. They argued that a livelihood is sustainable if it:

> '. . . can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and . . . contributes net benefits to other livelihoods at the local and global levels and in the short and long-term' (Chambers and Conway, 1992).

Livelihood activities of the poor are dynamic and context-specific. The SL approach includes an analysis of the vulnerability of the poor which results from 'sudden shocks, long-term trends or seasonal cycles' as discussed by Moser (1996) and can be studied by examining such assets as labour, social and human capital, productive assets, and household relations (Moser and Holland, 1997).

One of the main reasons why the SL approach was developed was to foster the incorporation of the poor, women, and those in rural areas into research and into development programmes (Chambers, 1987). Livelihood strategies often remained invisible to both researchers and development specialists. This stemmed partly from the fact that different members of a household engage in different types of livelihood activities. Each household member above a certain age attempts to procure different sources of food, fuel, animal fodder and cash; these sources are likely to vary according to the month of the year. Therefore, researchers need to ask each household member about these activities, and to include the changes incurred by season and by household life cycle stage.

The scale of analysis can be at the micro- and meso-levels of the individual, household, kin networks, village, or region, or at the macro-level of the nation (Scoones, 1998). A livelihoods framework of analysis is unusual in that it fosters the study of macro–meso–micro linkages. These linkages include how macro-level policies affect the livelihood options of poor individuals and communities as well as how the poor affect policies and institutions. Such research can provide policymakers and planners with critical information that can improve the efficacy of poverty alleviation programme and policies. This chapter will address how the approach can be used to study macro-, meso- and micro-level issues pertaining to wastewater use.

In the late 1990s, Scoones at IDS centred his work on the institutional processes (formal and

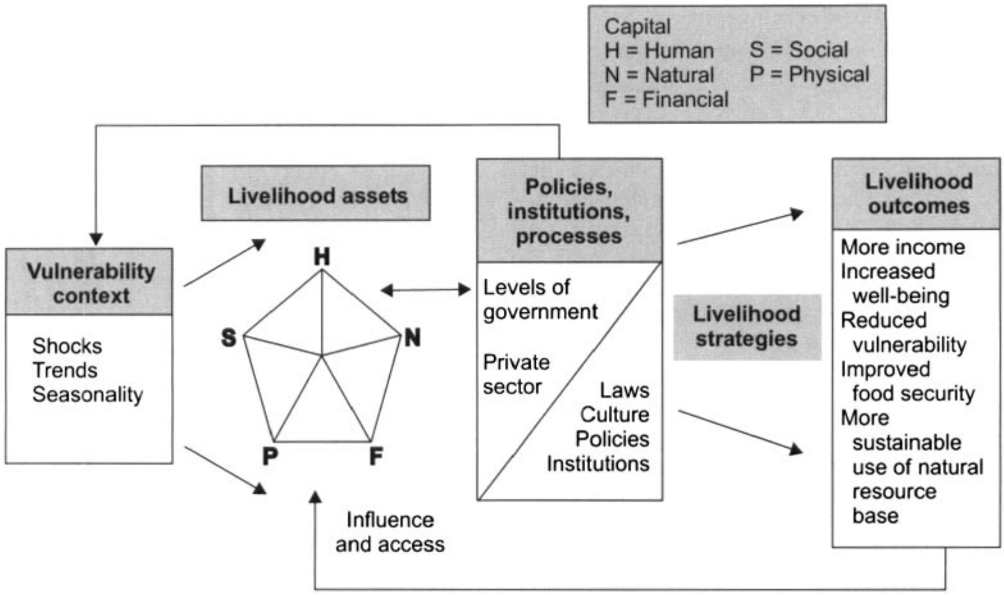

Fig. 3.1. Sustainable Livelihoods Framework.
Source: DFID, 2003

informal institutions and organisations) which enable or act as a barrier to achieving positive livelihood outcomes (Scoones, 1998). The SL approach was adapted for the study of urban areas by Caroline Moser (1998) and John Farrington *et al.* (2002) by shifting the focus from natural assets and environmental sustainability for the study of rural areas to households, housing and financial assets for the study of urban areas (Farrington *et al.*, 2002). The interconnectedness of urban, peri-urban and rural livelihood systems incurred through remittances, short-term migration and daily or seasonal labour was also illuminated (Sharma, 1986; Barret and Beardmor, 2000; Satterthwaite and Tacoli, 2002 in Farrington *et al.*, 2002).

Livelihoods, Water Availability and Wastewater Use

Most livelihood activities depend on the availability of water. However, in many semi-arid and arid regions of the world, freshwater is a scarce resource. Fresh surface water is usually also only available in sufficient quantities during the rainy season. But, the rainy season may only last for 4 months during which rainfall can be erratic, necessitating irrigation. Water for irrigation is also required for the long dry season. Groundwater may be expensive to access because of low water tables that translate into the high costs associated with drilling wells and pumping the water. Seeking other sources of water to support livelihoods therefore becomes critical to the question of poverty reduction. Near urban centres wastewater is often available year-round in sufficient quantities. It is in this context that wastewater needs to be studied as natural capital required to sustain the means of living in arid and semi-arid, drought-prone areas.

In many arid and semi-arid regions, wastewater use may either be the only option, or the only economically viable option available to many groups of people. Livelihood activities directly dependent on wastewater are practised by different social groups on different scales and include (but are not limited to) agriculture, agro-forestry, livestock rearing, aquaculture, floriculture, and the washing of clothes[1]. Activities indirectly dependent on wastewater include the sale of seeds, pesticides and other inputs to wastewater farmers, rental of harvest machinery or equipment, agricultural labour, services related to the transportation of produce to markets, marketing produce, animal husbandry with purchased wastewater-irrigated fodder and the provision of fish seedlings for pisciculture.

The amount of wastewater produced depends on the population of a city or town. Industrial and domestic liquid wastes are frequently channelled either into the same sewerage system (if a sewerage system exists) or into the same open drains. Wastewater quality is affected by the volume and types of industrial effluent released into the sewerage system or drains, and the degree of dilution with domestic water and natural sources of flow where these exist. The wastewater is either released untreated, after partial treatment, or after more complete treatment (to the secondary or tertiary levels), into drains, into channels, and then frequently into rivers.

There is no simple solution to wastewater use or how to minimise its negative consequences. What seems transparent and evident is that the wastewater must be treated. However, building, operating and maintaining treatment plants is very costly and can drain a government's financial resources. Even if growing cities were able to afford to treat all of the domestic and industrial wastewater they produce (about 80% of the water delivered to an urban area comes out of the city as wastewater), urban water authorities often want to use the treated water within the city for watering public parks and other urban areas in order to save the costs of drilling wells and pumping groundwater for such uses. Urban water authorities also often wish to recover costs by providing treated wastewater to users who can pay a fee for it, such as golf course operators and upper-class residents who use it to water their gardens. Thus smallholders or landless people, who rent land to cultivate crops, can lose access to a resource critical to their livelihoods, and consumers can be deprived of cheap, fresh produce. This is happening in the arid city of Chihuahua, Mexico (Horacio Almazán Galache, 2003, personal communication).

Current Approaches to Social Scientific and Biophysical Studies

Socio-economic studies on wastewater irrigation that address livelihood issues have just begun to gain currency. Some of the economic benefits accruing to farmers from wastewater-irrigated crops have been documented by Keraita *et al.* (2002), Niang *et al.* (2002), Cornish and Aidoo (2000) and others. Socio-economic analyses of groundwater users in wastewater-irrigated areas and the political and institutional arena in which wastewater production, treatment and use occurs, for example, are just beginning to appear in the literature (Cirelli, 2000; Peña, 2000; Abderrahman, 2001; Buechler, 2001; Keraita *et al.*, 2002; Ouedraogo, 2002; Buechler and Devi, 2003a; Chandran *et al.*, 2003; Parkinson and Tayler, 2003; Shetty, Chapter 15 this volume). The socio-cultural acceptability of wastewater use in Palestine was addressed by Khateeb (2001). The health effects of wastewater production and the social and economic consequences of these effects for wastewater farmers, agricultural labourers and their household members and consumers of wastewater-irrigated produce have also been studied in some areas (Shuval *et al.*, 1986; Blumenthal *et al.*, 2000; Feenstra *et al.*, 2000; van der Hoek *et al.*, 2002; Ensink, 2003). Many of the health studies, however, lack what Mara and Cairncross called for in their well-known *Guidelines for the Safe Use of Wastewater in Agriculture and Aquaculture* (WHO, 1989), that is, 'a thorough assessment of the local socio-cultural context'.

[1] Washing clothes in wastewater, e.g. in Hyderabad and Madurai, India, tends to occur only in the rural areas downstream of urban centres where wastewater quality is better. It tends to be practised by hired clothes-washers rather than by individual households who prefer to use groundwater.

Social scientific studies on wastewater to date report basic background information on climate and average rainfall, together with data on the various sources, quality and quantity of industrial and domestic sources of wastewater. Such studies foster an understanding of the risks associated with this use for a particular user group. However, they rarely integrate more-advanced information on the spatial distribution of precipitation and wastewater availability, yet social groups dependent on wastewater for their various livelihood activities are deeply affected by these complex interactions. Therefore, a more holistic picture is necessary. The types of crops, livestock, and fish that farmers can raise are affected by the quality of the wastewater and the characteristics of the natural environment. In hot climates with a long dry season high rates of evaporation cause wastewater to be more saline with high total dissolved solids (TDS) concentration that may restrict the variety of crops that can be cultivated. Since many types of grass fodder can be grown with saline wastewater, this water is more likely to be used in urban and peri-urban areas for fodder production, particularly where there is an urban demand for dairy products as is the case in India and Mexico.

The impacts of such imposed choices, though, are not limited to a change in cropping practices. With deteriorating wastewater quality, the health of the livestock may be seriously impaired as is currently the case near Hyderabad, India and the quality of their milk may be affected which may transfer the danger to humans. The dairy producers' income may decrease if there are reductions in milk production per animal. Similarly, many varieties of fish are sensitive to changes in water quality and the varieties of fish raised by fisherfolk in a sewage pond would need to be changed if the water quality deteriorated (Buechler and Devi, 2002a). The SL approach offers a way in which to assess the vulnerability context of those who depend on wastewater. Shocks, trends and seasonality all define the context of vulnerability in this approach and can be applied to sudden, gradual or seasonal deterioration in the quality of wastewater.

Biophysical studies on wastewater often focus on industrial and domestic wastewater treatment technologies (van Lier and Lettinga, 1999; Jindal *et al.*, 2003; Mullai and Sabarathinam, 2003; Environline, 2003) or on wastewater quality (Goewie and Duqqah, 2002), groundwater quality in wastewater-irrigated areas (Farid *et al.*, 1993; Haruvy, 1997; Chilton *et al.*, 1998; Gallegos *et al.*, 1999), soil contamination and remediation in wastewater-irrigated areas (Jeyabaskaran and Sree Ramulu, 1996; Mendoza *et al.*, 1996; Gupta *et al.*, 1998), heavy metal uptake in wastewater-irrigated crops (Chino, 1981; Mitra and Gupta, 1999; Rattan *et al.*, 2002), bacteriological analyses (Sinton *et al.*, 1997), helminth infection in wastewater users (Srivastava and Pandey, 1986; Blumenthal *et al.*, 2000; Peasey, 2000) and GIS analyses of wastewater-irrigated areas (Palacio-Prieto, *et al.*, 1994; Buechler and Scott, 2000; Nobel and Allen, 2000; Aramaki, 2001).

Assessing the social, political, economic and technical applicability of technical and management solutions for particular wastewater-related practices becomes difficult, if not impossible, with purely biophysical analyses. Essential data, for example, on the capacity of varied social groups or communities and of individual women or men within these to invest labour, capital and time in certain management techniques and technologies is invariably lacking. Similarly, information on the organisations and institutions that govern wastewater use is required, particularly on whether or not they have the necessary financial and institutional capacities, willingness and political clout to implement new management strategies in a sustainable manner.

Research conducted in urban, peri-urban and rural areas near Hyderabad city, India, shows that such socio-economic characteristics as caste, class, ethnicity, gender and land tenure influence the type of wastewater-dependent livelihood activities in which each person engages (Buechler and Devi, 2002a; Buechler *et al.*, 2002; Buechler and Devi, 2003b, c). At present, the barter and sale of vegetables in the wastewater-irrigated urban and peri-urban areas is controlled by women and improves their ability to gain access to a wider variety of vegetables for themselves and for their household members. Recommendations based on biophysical studies that include a switch in crops from leafy vegetables to tree crops might have ramifications for women's income-generating capabilities and food-security status. Toddy (fermented palm juice) production and fishing are practised currently only in rural areas downstream of Hyderabad and are controlled by men of particular caste groups. Therefore, it would be difficult to promote these as alternative income-generating schemes for other social groups. Technical studies critical of profligate water use for paddy rice production near Hyderabad must take into consideration that the food security of smallholders, of landless people who rent land for paddy rice production, and of landless labourers is dependent upon paddy rice production in the rural areas. Farming families are often already innovating by changing cropping patterns (Buechler and Devi, 2002b) or are mixing groundwater with wastewater to improve the overall quality of the water (Buechler and Devi, 2003a).

Sustainable wastewater use means that this resource will serve as a reliable asset for livelihoods now and in the future. This would require wastewater to be of a sufficiently high quality, so that it will not damage the natural environment or the agriculture practised using this resource. The interplay between wastewater users, agriculture, agroforestry, animal husbandry and aquaculture on the one hand, and soil, plant and wastewater quality on the other, needs to be elucidated through an integrated, holistic conceptual framework.

SL Approach for Integrating Problem Identification and Management Recommendations

In seeking pragmatic solutions to sustainable wastewater use, the need for holistic studies incorporating the missing dimensions cited above becomes clear. Using a livelihoods approach for wastewater use studies would centre research on the actors[2] who directly or indirectly benefit or are put at risk from wastewater. Of particular importance are decision-making processes pertaining to wastewater management and livelihood choices. A livelihoods approach views livelihoods as dynamic rather than static. Actors decide how best to adapt wastewater-dependent livelihood activities to changing external conditions. These include changes in wastewater availability, improvements in or deterioration of wastewater quality, and new government incentives or disincentives related to crop production. Changes in wastewater-dependent livelihood activities in turn require new decisions on how best to manage wastewater. These decisions will be influenced by social, economic, political, institutional, legal, and health-related factors as well as by environmental and technical factors. Livelihood analyses that include a study of the reasons behind actors' decisions to initiate changes in wastewater-dependent livelihoods over time will produce a more integrated understanding of wastewater management at different levels (individual, household, village, city, and potentially, even region and nation) leading to more appropriate policy recommendations for the present and future (see Box 3.1).

Methods Used in Livelihoods Analysis

In order to procure rich data that is actor-centred and interdisciplinary, research methodologies must be diverse. Both socio-economic and biophysical data can be collected through field observations, water, soil and plant sampling and analysis, rapid appraisal techniques, geographic information systems, various mapping techniques including vulnerability analysis and mapping tools, focus group discussions, surveys with closed and open-ended questions and in-depth interviews with different categories of representatives and users responsible for wastewater management at different levels in intra-urban, peri-urban, and rural areas. As part of the surveys and interviews, some key questions eliciting the users' perceptions on wastewater dependency for livelihoods need to be recorded, transcribed

[2] I use the term 'actor-centred' rather than 'people-centred' approach in this chapter because I believe that this is a more comprehensive term that more clearly connotes the inclusion of individuals and institutions and organisations as the units of analysis, enabling both micro- and macro-level analyses.

Box 3.1. Critical Questions for the Analysis of Wastewater Management using an SL Approach

- **Who** is earning or saving income through direct wastewater use or through secondary activities that are dependent on wastewater-derived products? (Gender, caste, class, ethnicity, religion, land-tenure characteristics of the direct users and others who gain an income or save money from wastewater-dependent activities).
- **Why** does each social group depend on the wastewater? (Lack of other water sources, drought, lack of financial resources to use other water, and need for: dependable, year-round water, nutrients in wastewater to reduce fertilizer costs, more fertile soil, etc.).
- **For which activities** are varied groups using this water and what types of secondary activities are generated that create a chain of economic beneficiaries? (Primary activities include agriculture on rented or family land, agroforestry, aquaculture, domestic use and recreation. Secondary activities include livestock rearing and dairy production, agricultural labour [casual, migrant and permanent], transportation to and sale of products in markets, etc.).
- **What are the positive and negative implications** of this wastewater use now and for the future? (For socio-economically distinct women, men, and children and their livelihoods, for agricultural workers' health and the health of their household members, for consumers' health and for the quality of water, soil and plant resources in the downstream area).
- **What management measures** at the community, local, regional and national levels by individuals or by those acting within institutions (informal and formal) mitigate risks and ensure sustainability of this use? Who are the most vocal actors in these organisations?
- **What alternatives to current management practices could be proposed at different levels?** (Improve identification and wider dissemination of farming households' innovations; work with industry to decrease amount of water used, to treat effluent and to reuse chemicals; improve water retention rates such as in storage tanks/ponds before irrigation, change irrigation and harvesting methods and promote decentralized, affordable treatment systems).

and used as integral parts of written text and audiovisual media (video, radio, and television) so that use patterns can be better understood. Interviews must be conducted with more than one household member of different genders and ages.

The next sections identify the main units of analysis and some major issues in the study of wastewater users using an SL approach.

Macro-level

SL analyses at the macro-level focuses on wastewater use in a basin context. By studying the river from its source to its confluence with other rivers, or its outlet to the sea, use patterns by different actors that affect wastewater quantity and quality downstream can be discerned. If significant amounts of the water are abstracted for livelihood activities (and industrial use) upstream, there may be less water available for the city and therefore less wastewater generated by the city. Industrial contamination upstream of, within, and downstream of the city can affect wastewater users since it will place limitations on the types of livelihood activities in which they can engage. Inter-basin transfers must be considered when urban areas that can obtain water even from other basins grow rapidly, and release increasing volumes of wastewater. By including institutions and organisations regulating intra- and inter-basin water abstraction and use in basin-level analyses, light can be shed on how actors within them mediate the use of natural capital in the basin.

Livelihood activities near cities sometimes consume the entire amount of wastewater being discharged by the urban area as is the case with the Musi river in Andhra Pradesh, India. All of the wastewater in the Musi is used before its confluence with the Krishna, a major river that flows into the Bay of Bengal (Buechler and Devi, 2002a). Studies employing a SL approach would complement other types of studies that set the macro-level context in which wastewater use is inserted from a historical, macro-economic, political, institutional or socio-cultural perspective or a hydrological (water balance, water quality), agronomic or animal husbandry perspective.

Meso-level

At the meso-level, an important unit of analysis for SL studies on wastewater is the wastewater delivery system. The delivery system can be composed of the river itself and/or man-made infrastructure, such as pipes and culverts, open or closed sewer canals, storm drains, canals, earthen channels, diversion weirs, ponds and wells, that delivers or stores the water in each area. Technical and institutional perspectives should be incorporated into this level of analysis. The delivery system may extend beyond the peri-urban areas, therefore it is important that the urban to peri-urban to rural transect be investigated. Large cities like Hyderabad, or even medium-sized cities such as Irapuato in Mexico frequently produce enough wastewater to sustain livelihoods in the rural areas (Buechler, 2001; Buechler and Devi, 2003b). The infrastructure is likely to be different at each location and tailored to suit such local livelihood needs as labour costs and availability, cropping patterns and crop water requirements and such environmental conditions as the availability and topography of the land, flow rates and soil types together with micro-climatic conditions such as temperature and rainfall patterns. The delivery system constitutes a crucial component of the physical assets to which people have or do not have access; this access is influenced by their access to other assets.

In order to understand the manner in which this infrastructure is built, operated and maintained, the meso-level organisations (and micro-level institutions and organisations, see below) surrounding these structures for channelling the water must be identified and researched. The SL approach is a useful tool to analyse the ways in which policies, institutions and processes help shape livelihood outcomes. Formal and informal institutions at various levels are both shaped by and help mould the natural, social, economic and political environment in which wastewater users and their livelihoods are inserted. Institutions should be studied as 'complexes of norms and behaviours at the village (and higher) level that persist over time by serving some collectively valued purpose' (Uphoff, 1992). The various wastewater-dependent actors who follow these 'norms and behaviours' or, what North (1990) has termed the 'rules of the game', group together into organisations that influence wastewater management in different, and at times, conflicting ways.

At the meso-level, the roles of actors within governmental, non-governmental and private-sector organisations in controlling water pollution and regulating wastewater use (by either encouraging, passively allowing, or actively discouraging it) need to be studied. Pollution control boards, metropolitan water and sanitation boards and irrigation departments may all play important roles in waste and wastewater management but some of these roles may not be immediately obvious. The *de jure* and *de facto* functioning of various actors with positions in governmental agencies responsible for wastewater management requires attention because the two may be very different. What is legally sanctioned may differ widely from the everyday practices of the actors within the organisations. These practices will affect how the wastewater is actually managed. The work of researchers and practitioners in non-governmental organisations that operate at a regional level should also be included in analyses especially those that have programmes addressing infrastructure development, land and water access, agricultural extension, occupational training, public health, etc. Non-governmental programmes targeting issues concerning gender, religion, occupation/caste/class and income may also serve wastewater-dependent people and aid them in wastewater management for livelihoods in specific ways that are to date not well understood and therefore not replicated.

Employing a SL approach which combines technical and institutional analysis at the meso-level ensures that infrastructure will be viewed as a dynamic tool that can influence livelihood outcomes. Changing such conditions as wastewater quantity and/or quality will change the ways in which people make use of the existing infrastructure and may even create demand for physical changes to it. For example, near Irapuato, Mexico, farmers pressured the government to build an additional canal branch from the city wastewater drainage channel to their peri-urban fields when wastewater volumes became substantial (Buechler, 2001). It must be understood that infrastructure related to wastewater delivery is continuously adapted by actors to serve livelihood needs. Those in certain positions of power (with greater political and often financial capital) or those who are connected to people in powerful positions (with greater social capital) have greater opportunities to adapt this infrastructure to their own or to their supporters' specific and current livelihood needs (Cirelli, 2000; Peña, 2000).

Micro-level

At the micro-level, the following units of analysis help reveal and interpret livelihood activities present in a given area:

1. The chain of economic beneficiaries that are dependent on wastewater
2. Households
3. Infrastructure from which the wastewater is extracted (drainage culvert, pipe, river, canal, pond, etc.) and channelling methods used
4. The local institutions that shape local wastewater use.

The chain of economic beneficiaries

A chain of economic beneficiaries from wastewater-dependent activities is formed by those who benefit directly or indirectly from the production, use and/or sale of wastewater-irrigated products. As discussed at the beginning of this chapter, those directly dependent on wastewater include farmers involved in agriculture and agroforestry together with fisherfolk, and those who depend indirectly are dairy producers who use wastewater-irrigated fodder, migrant and non-migrant agricultural labourers who work in wastewater fields, vegetable and fodder market vendors who sell wastewater-irrigated produce, and transporters of this produce. Some of these actors have fewer overall assets than others and some have more diversified income sources than others. In analysing this chain, the point of departure is the wastewater-derived product that is traced from its origins to the marketplace and then to the consumer. However, using an agricultural commodity chain analysis is not sufficient because it may not capture non-market benefits of wastewater production such as the use of wastewater-irrigated fodder for the farmer's own livestock or household consumption of the food produced. It is also unlikely to capture that one household member may derive benefits from multiple wastewater-produced commodities. Development programmes and policies need to be able to identify the separate links in this chain and to understand the nature of the connections between the links.

Household-level analysis that examines the role of each constitutive member

At the micro-level, the household is the key unit of analysis. The SL approach uses the household as an important unit of analysis but also stresses the importance of disaggregating the household in order to be able to understand the role of each member in livelihood creation. The composition of the class, caste, gender, age, ethnicity and religious affiliations of its members are likely to affect the household's principal activity related to wastewater. The location of the parcel of land in terms of its elevation with respect to the wastewater channel(s), i.e. the value of the land which is an indicator of the household's class position, will determine whether pumping from the channel is necessary influencing the profitability of the agriculture. The landholding status of the adults in a household as landowners, land leasers, landless labourers or a combination of these also affects the types of crops they grow, the profitability of agriculture or other income-generating activities, and the diversification of livelihood strategies by household member. The number and types of livestock the household owns (part of their physical capital) will influence the types of wastewater-related activities in which they engage (such as fodder production) (Buechler and Devi, 2002a). Caste still plays an important role in India in shaping each person's type of employment. From birth, for example, boys from the *Gouda* community, considered to be a low caste, learn toddy[3] tapping from their fathers (girls cannot become toddy tappers). However, educational opportunities and affirmative action programmes are expanding the types of employment that the young can obtain. Gender is likely to shape the power of each member to negotiate which wastewater-related activities to engage in and which person will retain the earnings from those activities. One example is vegetable production, which is mainly done by women in some areas, e.g. the peri-urban area of Hyderabad city (Buechler and Devi, 2002a) and by men in other areas, e.g. Kumasi, Ghana (Cornish and Kielen, Chapter 6, this volume). Ethnicity also shapes the types of wastewater-related activities in which people are engaged, e.g. the *Lambadis*, a nomadic tribal group in India, often work as landless agricultural labourers in wastewater-irrigated fields. Religion frequently plays a role especially influencing the type of animals raised and whether or not people engage in agriculture or the trading of agricultural commodities. One of the main reasons the SL approach was developed was to draw attention to the role of women and the poor in livelihood creation.

Frequently, the different types of labour necessary to perform each particular activity vary by gender and age of the constitutive household members (e.g. women and children mainly provide water for domestic use, while men tend to be more involved than women in irrigation; men tend to predominate in fodder grass production and women and children in feeding the fodder to buffaloes and cows). The type of remuneration for each of these activities varies across different categories of people and different types of activities. Women tend to be remunerated at a lower rate than men for the same or more labour-intensive activities. Household food security may be enhanced if payment is made in kind. In the wastewater-irrigated paddy rice fields near Hyderabad, in-kind payment in rice helps ensure that male labourers from drought-prone and other areas contribute to household dietary requirements rather than spending their wages on alcohol (Buechler and Devi, 2003c). The stage in the household life cycle[4] and the total number of members able to undertake income-generating and income-saving activities also determines whether or not the household as a unit can afford to engage in labour-intensive activities. Low-income households cannot afford to hire all of the labour needed for such activities. The amount of labour available to the household is its human capital. A livelihoods analysis by household member will contribute to wastewater research through improved understanding by gender, age and household characteristics of how much time is dedicated to each particular wastewater-related activity, how much wastewater-derived income is earned (or saved) and in which other types of wastewater and non-wastewater related activities the household is engaged.

A livelihoods approach specifically stresses the importance of studying the different access to resources within a household between men and women. The degree of involvement of each household member provides insight into the poverty dimensions of who would be the most vulnerable if changes in the quantity and quality of the resource occurred due to external factors. Some examples from case studies are, diversion to other, perhaps more powerful, interests in the event of the construction of a new treatment plant (see Silva-Ochoa and Scott on Guanajuato, Mexico, Chapter 13, this volume), the upstream diversion of large

[3] Toddy is a beverage tapped from a toddy palm tree that is often drunk fermented.

[4] If a household is at an early stage in its life cycle, most of the children are very young and cannot yet make economic contributions. If a household is at a late stage in its life cycle, many members will be too elderly to contribute economically and in some cultures the adult sons and/or daughters may already have set up their own households elsewhere.

amounts of wastewater by large landholders or other users depriving downstream users of sufficient water (Buechler, 2001), or the construction of a pipeline from the urban area to transport the wastewater to another river basin as is planned in Hyderabad.

Research must be conducted on the degree of involvement in fieldwork to determine individual and group risks to health. Wastewater irrigation and such activities as transplanting or weeding in flooded areas like paddy fields often require the closest and most prolonged contact with the wastewater. In many areas of the world, these tasks are affected by gender divisions of labour that make it culturally more acceptable, for example, for men in Latin America and most of South Asia to irrigate, and women to weed and transplant. These agricultural operations are practiced mainly by lower-income groups (farmers with few assets or labourers hired by farmers with more assets). To take the case of wastewater-irrigated paddy rice in the rural areas near Hyderabad, it is men who usually irrigate the rice and women who transplant and weed it. During all of these operations, the person must stand in the wastewater, increasing their risk of skin diseases and possibly other health problems, but for weeding and transplanting women are in the water for about 8 hours per day compared to 1 hour per day for the men, because for most of the time they are irrigating they do not stand in the water. In one year, therefore, with two paddy rice crops in wastewater-irrigated areas, women could be in the water for 100 days for 8 hours per day for a total of 800 hours whereas the number of hours for men is far less at about 240 days for about 1 hour per day or 240 hours. Women spend more time weeding wastewater-irrigated vegetable fields in urban and peri-urban Hyderabad than men (Buechler and Devi, 2002a), therefore their risk of helminth infections from contact with the soil may also be higher. So risks, are also likely to be gender-related. Class/caste issues play a role in risk since those from lower- income categories generally have more contact with the wastewater than richer social groups, who can afford to hire others to perform the work that requires the most contact with the wastewater.

Infrastructure at the micro-level

Infrastructure at the micro-level, similar to that at the meso-level, affects livelihoods. For example, health risks at the micro-level are influenced by the types of infrastructure available to a community to store and to channel the wastewater to the field. Retaining water in a pond could make it safer to use by reducing the number of helminth eggs and microorganisms such as *Escherichia coli* it contains through oxidation, radiation, and settling. Varying degrees of contact by irrigators with the soil and with the wastewater are necessary to channel the water to the field (e.g. watering cans versus earthen field channels), with greater contact meaning greater risk to irrigators.

Institutions and organisations at the local level

Participation and/or membership in organisations and institutions related to wastewater use at the micro-level (for example, at the level of the municipality, or the local level of the town, village, urban or peri-urban neighbourhood) may be based upon such affiliations as landholding and water-access status, and the overlapping affiliations of class, caste, religion, gender and ethnicity. For example, in Hyderabad, an urban farmers' association exists that is primarily composed of wastewater farmers who own land; in the peri-urban and rural areas water-user associations are composed of landed farmers with access to wastewater for irrigation; and caste groups in urban, peri-urban and rural wastewater-irrigated areas have their own organisations and meet in the caste community centre.

Similarly, at the local level a *de facto* situation exists in relation to rules and regulations governing water pollution and wastewater use. The interactions between user groups, industry and governmental agencies are both locally specific and dynamic in nature. In practice, the application of national-level or even state-level laws is renegotiated at the local level, but often not on a level playing field. Large industries and commercial establishments are often able to dominate. This affects livelihoods in the area. An example of this is found in Patancheru, Andhra Pradesh, India, 20 km from Hyderabad city. Here industries were able to pressure the Government of Andhra Pradesh to create a pipeline to Hyderabad so that they are able to release industrial effluents into the sewage treatment plant (STP) there that is currently equipped only for primary treatment of domestic sewage which is subsequently released into a system of irrigation canals and into the Musi river. However, farmers' associations, environmental groups and citizen action groups in and near Hyderabad were able to apply pressure and challenge this Supreme Court decision forcing the Court to declare a Stay Order on the proposed pipeline. The pipeline is still under construction, however, and farmers fear that the effluents may be piped in even before the mandatory upgrade of the STP has been completed (Buechler, fieldwork 2003).

Conclusions

There is a critical need to utilise an SL approach for the study of wastewater. This approach must be actor-centred, can be multi-disciplinary, and should be oriented towards the study of change. A focus on actors involved in wastewater management at all levels generates knowledge that is tailored to the needs of the varied groups of people and institutions who use and manage wastewater and to the complex contexts in which wastewater use occurs. This will lead to solutions that are appropriate for the present with a view to preserving natural resources and income-generating activities based on those resources for future generations. Wastewater-dependent people have a rich knowledge base stemming from their daily experience in wastewater management and can provide information on where interventions might be necessary and on which types of interventions would address their particular problems. The livelihood security of these individual women, men and children and of their households is invariably linked to benefits derived from and problems related to wastewater dependence. The various assets (in the form of social, financial, natural, physical, human and political capital) that wastewater-dependent people have at their disposal are affected by social, economic, political and environmental factors.

For a complete understanding of issues related to wastewater use at a basin level, the macro-, meso- and micro-levels need to be studied from a multi-disciplinary perspective addressing socio-economic, health and technical issues. Macro-level analyses should include river basin issues focusing particularly on upstream and downstream tradeoffs.

Meso-level analyses need to focus on the wastewater delivery system from both technical and organisational perspectives to ensure that infrastructure will be viewed as a dynamic tool for livelihood creation and sustenance. Pollution control boards, metropolitan water and sanitation boards and irrigation departments may all play important but different roles than expected in waste and wastewater management. The *de jure* and *de facto* functioning of various actors with positions in governmental agencies responsible for wastewater management requires attention. What is legally sanctioned may be very different from the everyday practices of the actors within the organisations.

By highlighting users and their perceptions about changes in wastewater quality and quantity, micro-level analyses can lead to improved planning and management surrounding wastewater issues at the level of the nation, region, district, municipality, peri-urban area or village. The gender, caste, class, ethnic, religious and economic characteristics of the users in urban, peri-urban and rural areas affect the types of wastewater-related activities in which they engage. When studying the micro-level of the user, it is important to analyse the interconnections between users. There is a chain of economic beneficiaries from wastewater whose livelihoods depend indirectly and directly on it. Household-level analysis of the contributions of wastewater to livelihoods examines the effects of household composition and stage in the household life cycle on, for example, the contributions of each member to wastewater and non-wastewater dependent income-generating and income-saving activities.

Using a SL framework of analysis to study infrastructure use at the local level will reveal that this infrastructure is altered according to the separate needs of the different users at distinct and localised areas. The infrastructure needs of the users will depend on the area's economic conditions, formal and informal educational facilities, and geophysical characteristics together with the hydrology and hydraulics of the wastewater system.

Institutions and organisations at the level of the village or neighbourhood shape the ways in which wastewater is managed through members active in these organisations. Organisations may be composed of members with similar socio-economic characteristics. Similar to those at higher levels, at the local level a *de jure* and *de facto* distinction exists in relation to rules and regulations governing water pollution and the use of wastewater.

Integrated analyses for action research are imperative when attempting to ensure the sustainability of livelihoods based on wastewater. A SL approach to data collection and analysis helps ensure the social acceptability, economic viability and technical feasibility of the recommendations derived from action research on wastewater. Long-term studies on particular wastewater use areas using the SL approach are also vitally important because the growing volumes of wastewater produced as cities grow often changes the location and expands farming activities. Long-term SL analyses will show the dynamism inherent in wastewater use for household sustenance.

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4 Health Guidelines for the Use of Wastewater in Agriculture: Developing Realistic Guidelines

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Abstract

The use of wastewater in agriculture – often untreated or inadequately treated – is occurring more frequently because of water scarcity and population growth. Often the poorest households rely on this resource for their livelihood and food security needs. However, there are negative health implications of this practice that need to be addressed. In 1989 the World Health Organization (WHO) developed guidelines for the safe use of wastewater in agriculture, which are currently being revised based on new data from epidemiological studies, quantitative microbial risk assessments and other relevant information. The revisions being developed are in accordance with the *Stockholm Framework* that provides a tool for managing health risks from all water-related microbial exposures. The *Stockholm Framework* encourages a flexible approach to setting guidelines, allowing countries to adapt the guidelines to their own social, cultural, economic, and environmental circumstances. It is important to recognise that in many situations where wastewater is used in agriculture, the effective treatment of such wastewater may not be available for many years. WHO guidelines must therefore be practical and offer feasible risk-management solutions that will minimise health threats and allow for the beneficial use of scarce resources. To achieve the greatest impact on health, guidelines should be implemented with such other health promoting measures as: health education, hygiene promotion, provision of adequate drinking water and sanitation, etc.

Introduction

The use of wastewater in agriculture is growing due to water scarcity, population growth, and urbanisation, which all lead to the generation of yet more wastewater in urban areas. Wastewater can be used to substitute for other better-quality water sources, especially in agriculture – the single largest user of freshwater and wastewater worldwide. However, the uncontrolled use of wastewater in agriculture has important health implications for produce consumers, farmers and their families, produce vendors, and communities in wastewater-irrigated areas. Negative health impacts from the use of untreated or inadequately treated wastewater have been documented in many studies. Less attention has been paid to the positive health impacts of the use of wastewater in agriculture that may result from improved

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household food security, better nutrition, and increased household income.

Guidelines for the safe use of wastewater in agriculture need to maximise public health benefits while allowing for the beneficial use of scarce resources. Achieving this balance in the variety of situations that occur worldwide (especially in settings where there may be no wastewater treatment) can be difficult. Guidelines need to be adaptable to the local social, economic, and environmental conditions and should be co-implemented with such other health interventions as hygiene promotion, provision of adequate drinking water and sanitation, and other healthcare measures. The *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume) recognises these principles and recommends a holistic approach to the management of wastewater use in agriculture.

Following a major expert meeting in Stockholm Sweden in 1999, the International Water Association (IWA) on behalf of the World Health Organization (WHO) published *Water Quality: Guidelines, Standards and Health: Assessment of Risk and Risk Management for Water-related Infectious Disease*. This publication outlines a harmonised framework for the development of guidelines and standards for water-related microbiological hazards (Bartram *et al.*, 2001; Prüss and Havelaar, 2001). The suggested framework involves the assessment of health risks prior to setting health targets; defining basic control approaches, and evaluating the impact of these combined approaches on public health status (Fig. 4.1). The framework is flexible and allows countries to adjust the guidelines to local circumstances and compare the associated health risks with risks that may result from microbial exposures through drinking water or recreational/occupational water contact (Bartram *et al.*, 2001). It is important that health risks from the use of wastewater in agriculture be put into the context of the overall level of gastrointestinal disease within a given population. Future WHO water-related guidelines will be developed in accordance with this framework.

The regulation of water quality for irrigation is of international importance because trade in agricultural products across regions is growing and products grown with contaminated water may cause health effects at both the local and transboundary levels. Exports of

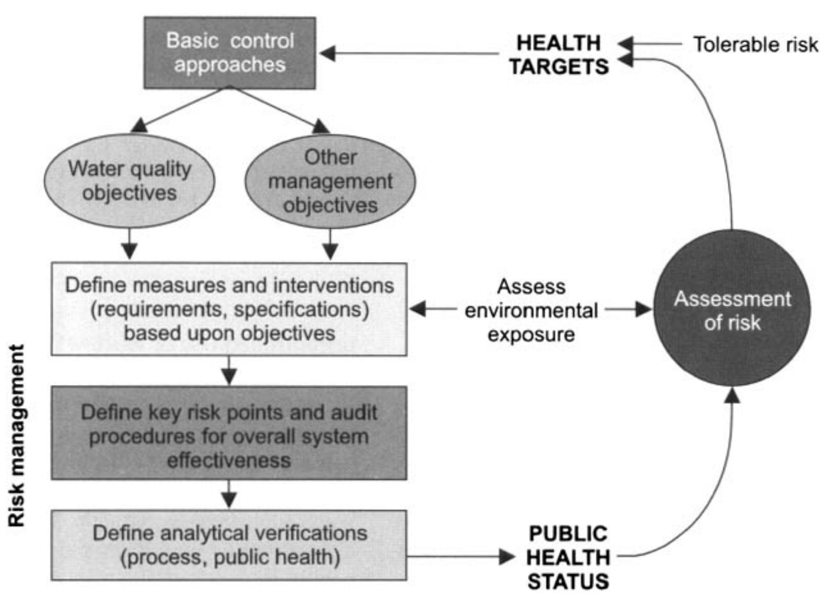

Fig. 4.1. Stockholm Framework for assessment of risk for water-related microbiological hazards (adapted from Bartram *et al.*, 2001).

contaminated fresh produce from different geographical regions can facilitate the spread of both known pathogens and strains with new virulence characteristics into areas where such pathogens are not normally found or have been absent for many years (Beuchat, 1998).

Effective guidelines for health protection should be: feasible to implement; adaptable to local social, economic, and environmental factors; and include the following elements:

- Evidence-based health risk assessment
- Guidance for managing risk (including options other than wastewater treatment)
- Strategies for guideline implementation (including progressive implementation where necessary).

This chapter provides an overview of the current status of wastewater use in agriculture, reviews the evidence on health impacts, and outlines management steps that can be implemented to reduce potential health impacts especially in low-resource settings.

Background

Worldwide, it is estimated that 18% of cropland is irrigated, producing 40% of all food (Gleick, 2000). A significant portion of irrigation water is wastewater. Hussain *et al.* (2001) report on estimates that at least 20 million ha in 50 countries are irrigated with raw or partially treated wastewater. Smit and Nasr (1992) estimated that one tenth or more of the world's population consumes foods produced on land irrigated with wastewater. Wastewater and excreta are also used in urban agriculture. A high proportion of the fresh vegetables sold in many cities, particularly in less-developed countries are grown in urban and peri-urban areas. For example, in Dakar, Senegal, more than 60% of the vegetables consumed in the city are grown in urban areas using a mixture of groundwater and untreated wastewater (see Faruqui *et al.*, Chapter 10, this volume).

In many developing countries, wastewater used for irrigation, is often inadequately treated. For example, WHO/UNICEF (2000) estimate the median percentage of wastewater treated by effective treatment plants to be 35% in Asia, 14% in Latin America, and the Caribbean, 90% in North America and 66% in Europe. Other figures are even lower: for example, Homsi (2000) estimates that only around 10% of all wastewater in developing countries receives treatment. Given these circumstances, WHO guidelines must include feasible strategies for maximising health protection when untreated wastewater is used in agriculture.

Evidence Base

Health effects

Previous WHO guidelines (see Table 4.1; WHO, 1989) were based on a number of available epidemiological studies, many of which were reviewed by Shuval *et al.* (1986). The evidence at that time suggested that the use of untreated wastewater in agriculture presented a high actual risk of transmitting intestinal nematodes and bacterial infections especially to produce consumers and farm workers; but that there was limited evidence that the health of people living near wastewater-irrigated fields was affected. There was less evidence for the transmission of viruses and no evidence for the transmission of parasitic protozoa to farm workers, consumers or nearby communities. The review of epidemiological evidence by Shuval *et al.* (1986) also indicated that irrigation with treated wastewater did not lead to excess intestinal nematode infections among field workers or consumers (WHO, 1989).

In 2002, Blumenthal and Peasey completed a critical review of epidemiological evidence on the health effects of wastewater and excreta use in agriculture for WHO. A sub-set of analytical epidemiological studies were selected that included the following features: well-defined exposure and disease, risk estimates calculated after allowance for confounding factors, statistical testing of associations between exposure and disease, and evidence of causality (where available). These were used as a basis for estimating threshold levels below which no excess infection in the exposed population could be expected. Further information on the risks of infection attributable to exposure, and in particular on the proportion of disease in the study population attributable

Table 4.1. Recommended revised microbiological guidelines for treated wastewater use in agriculture[a,b].

Category	Reuse conditions	Exposed group	Irrigation technique	Intestinal nematodes[c] (arithmetic mean number of eggs/l[d])	Faecal coliforms (geometric mean number/ 100 ml[e])	Wastewater treatment expected to achieve required microbiological quality
A	*Unrestricted irrigation* A1 Vegetable and salad crops eaten uncooked, sports fields, public parks[f]	Workers, consumers, public	Any	$\leq$0.1 [$\leq$1][g]	$\leq 10^3$	Well-designed series of waste stabilisation ponds (WSP), sequential batch-fed wastewater storage and treatment reservoirs (WSTR) or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration and disinfection)
B	*Restricted irrigation* Cereal crops, industrial crops, fodder crops, pasture and trees[h]	B1 Workers (but no children <15 years), nearby communities	(a) Spray/ sprinkler	$\leq$ 1	$\leq 10^5$ [no standard]	Retention in WSP series including one maturation pond or in sequential WSTR or equivalent treatment (e.g. conventional secondary treatment supplemented by either polishing ponds or filtration)
		B2 As B1	(b) Flood/ furrow	$\leq$ 1	$\leq 10^3$ [no standard]	As for Category A
		B3 Workers including children <15 years, nearby communities	Any	$\leq$0.1 [$\leq$ 1] [no standard]	$\leq 10^3$	As for Category A
C	Localised irrigation of crops in category B if exposure of workers and the public does not occur	None	Trickle, drip, or bubbler	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation.

Sources: Adapted from Blumenthal *et al.*, 2000a; WHO, 1989.

[a] Values in brackets are the 1989 guideline values.
[b] In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account and the guidelines modified accordingly.
[c] *Ascaris* and *Trichuris* species and hookworms; the guideline is also intended to protect against risks from parasitic protozoa.
[d] During the irrigation season (if the wastewater is treated in WSP or WSTR which have been designed to achieve these egg numbers, then routine effluent quality monitoring is not required).
[e] During the irrigation season (faecal coliform counts should preferably be done weekly, but at least monthly).
[f] A more stringent guideline ($\leq$ 200 faecal coliforms/100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
[g] This guideline can be increased to $\leq$1 egg/l if (i) conditions are hot and dry and surface irrigation is not used, or (ii) if wastewater treatment is supplemented with antihelminthic chemotherapy campaigns in areas of wastewater re-use.
[h] In the case of fruit trees, irrigation should cease 2 weeks before fruit is picked and no fruit should be picked off the ground. Spray/sprinkler irrigation should not be used.

to exposure (and therefore potentially preventable through improvement in wastewater quality), was used to inform proposals on appropriate microbiological guidelines for wastewater reuse in agriculture. A summary of the results of this epidemiological review are presented in Table 4.2.

Wastewater is often a resource for the poor and in many cases the water and nutrients it contains can have important – yet largely uncharacterised – impacts on food security (Buechler and Devi, 2003). Improving nutrition, especially for children, is very important in maintaining the overall health of individuals and communities. Malnutrition is estimated to have a significant role in the deaths of 50% of all children in developing countries – 10.4 million children under the age of 5 die each year (Rice *et al.*, 2000; WHO, 2000). Malnutrition affects approximately 800 million people, or 20% of all people in the developing world (WHO, 2000). Malnutrition may also have long-term effects on the health and social development of a community, and leads to both stunted physical growth and impaired cognitive development (Berkman *et al.*, 2002).

Improving the living standards of the poor through developing irrigation (with wastewater or freshwater) can lead to better health, in some cases, even when irrigation leads to an increase in disease vectors (van der Hoek *et al.*, 2001a). For example, a study in Tanzania showed that a village where a rice irrigation scheme had been developed had more malaria vectors than a nearby savannah village but a lower level of malaria transmission (Ijumba, 1997).

Table 4.2. Summary of health risks associated with the use of wastewater in irrigation.

	Health threats		
Group exposed	Nematode infection	Bacteria/Viruses	Protozoa
Consumers	Significant risks of *Ascaris* infection for both adults and children with untreated wastewater; no excess risk when wastewater treated to <1 nematode egg/l except where conditions favour survival of eggs	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; sero-positive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 FC/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces but no direct evidence of disease transmission
Farm workers and their families	Significant risks of *Ascaris* infection for both adults and children with contact with untreated wastewater; risks remain, especially for children when wastewater treated to <1 nematode egg/l; increased risk of hookworm infection to workers	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 FC/100ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to Norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection was insignificant for contact with both untreated and treated wastewater, Increased risk of amoebiasis observed from contact with untreated wastewater
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor quality water 10^{6-8} TC/100 ml, and high aerosol exposure associated with increased rates of viral infection; use of partially treated water 10^{4-5} FC/100 ml or less in sprinkler irrigation not associated with increased viral infection rates	No data for transmission of protozoan infections during sprinkler irrigation with wastewater

Sources: Blumenthal and Peasey, 2002; Blumenthal *et al.*, 2000a; Armon *et al.*, 2002

The village with the irrigation scheme had more resources to buy food, children had a better nutritional status, and the villagers were more likely to buy and use mosquito nets (Ijumba, 1997). Similar results may also be applicable to the development of wastewater-use schemes in some countries.

Microbial guideline derivation

Worldwide many different microbial standards for wastewater use in agriculture have been developed. Most guidelines lay heavy emphasis on microbial standards, but it should be recognised that other strategies for managing health risks may also be effective. Based on an approach that used empirical epidemiological studies, microbiological studies of the transmission of pathogens, and quantitative microbial risk assessment (see Table 4.3), Blumenthal *et al.* (2000a) proposed revisions to the WHO microbiological guidelines for treated wastewater use in agriculture (Table 4.1). The main differences from the 1989 WHO guidelines are new recommendations for a faecal coliform (FC) value for restricted irrigation ($\leq 10^5$ FC/100 ml) and new FC and nematode egg limits in certain conditions when children are exposed.

Risk assessment

The health risk from pathogens in wastewater can be estimated by using a quantitative microbial risk assessment (see Table 4.3) based on data derived from the following evaluations:

- Hazard identification (HI)
- Exposure assessment (EA)
- Dose-response analysis (DRA)
- Risk characterisation (RC)

Quantitative microbial risk assessment (QMRA) provides a technique for estimating the risks from a specific pathogen associated with a specific exposure pathway. QMRA is a sensitive tool that can estimate risks that would be difficult to measure and therefore provides a useful supplement to epidemiological investigations that are less sensitive and more difficult to perform. However, QMRA is only as good as the data available and the assumptions made.

A number of QMRA have been performed for the use of wastewater in agriculture. Table 4.4 presents some information on the estimated health risks associated with different levels of indicator organisms (*Escherichia coli*) present in the wastewater. *Escherichia coli* is almost always found in human and animal faeces and thus indicates the presence of faecal contamination in water. The presence of *E. coli* in a water sample will often (but not always) mean that other excreta-related pathogens are also present. It is easier to measure *E. coli* concentrations and assume that this represents a group of similar pathogens than to measure concentrations of individual pathogens.

Tolerable Risk and Decision-making

A level of risk can be estimated for almost any exposure, in other words, there is no such thing as zero risk, only very low risks. Because a level of risk can always be estimated, it is important that a risk tolerable to society be defined. To facilitate the comparison of different health outcomes (e.g. diarrhoea compared to cancer) risks can be framed in terms of disability adjusted life years (DALYs) which are a measure of years lost due to premature death and/or disability caused by a disease (Prüss and Havelar, 2001).

For water-related exposures, WHO has determined that a disease burden of 1×10^{-6} DALYs per person per year (one 'microDALY') from a disease caused by either a chemical or infectious agent transmitted through drinking water is a tolerable risk (WHO, 2004). This level of health burden is equivalent to a mild illness (e.g. watery diarrhoea) with a low case-fatality rate (e.g. 1 in 100,000) at an approximate 1 in 1000 (10^{-3}) annual risk or 1 in 10 lifetime risk of disease in an individual (Havelaar and Melse, 2003; WHO, 1996, 2004). For exposure to a carcinogen, this level of disease burden is broadly equivalent to a 10^{-5} lifetime excess risk of renal cancer (1 excess case of cancer/100,000 individuals exposed to the chemical over a lifetime) (Havelaar and Melse, 2003). The third edition of the *WHO Guidelines for Drinking Water Quality* will use the approach described above to define tolerable risks (WHO, 2004).

Table 4.3. Types of evidence used to develop microbial guidelines.

Data source	General principles	Wastewater-specific concerns
Epidemiological studies	Evaluate the actual disease transmission due to a specific exposure, e.g., compare the level of disease in similar populations with different exposures, i.e. a population that uses wastes with an unexposed or control population that does not. The difference in disease levels may then be attributed to the practice of using wastes. Data from epidemiological studies are crucial for guideline derivation, but studies must be large enough to capture significant differences in levels of disease due to a specific exposure	Wastewater use studies focus on the transmission of excreta-related diseases (e.g. gastrointestinal illness, diarrhoea, helminth infections, parasitic protozoal infections and some viral infections). Risks to produce consumers, exposed communities and workers can be evaluated
Microbiological studies	Studies that identify pathogens in the environment and evaluate pathogen survival. Provide useful information concerning the presence or absence of pathogens	Evaluate pathogen presence and quantity in wastewater, conduct studies of pathogen survival in fields and on crops, and test wastewater-irrigated crop surfaces for pathogens
Quantitative microbial risk assessment (QMRA)	Used to complement other studies. Determines a theoretical risk of disease transmission given a specific exposure Is more sensitive than an epidemiological study but requires validated assumptions	
	Hazard identification (HI) Identify potential hazards e.g. pathogenic organisms and toxic chemicals and potential exposure routes to the hazard. Concentrations of excreta-related pathogens can be approximated by monitoring reference organisms such as *E. coli* that have similar characteristics to groups of pathogens	Identify excreta-related hazards. Determine if exposure routes exist e.g. through direct contact with wastewater, consumption of contaminated crops, inhalation of pathogen-containing aerosols, and consumption of animal products that have been exposed to the wastewater (e.g. beef tapeworm)
	Exposure assessment (EA) Estimates the quantities of pathogens to which a person (or animal) might be exposed via the different exposure routes	Based on evaluations of the quantities of pathogens in the wastewater, reductions in pathogens due to various treatment stages, pathogen transport to crops, and pathogen die-off in soil and on crops
	Dose-response analysis (DRA) The number of pathogens to cause infection/disease – determined from experimental studies using volunteers, depends on the virulence of the pathogen, the susceptibility of the population and immune status of the population	Helminths, protozoa, and viruses often have very low infectious doses e.g. 1–100. Bacteria have higher infectious doses e.g. 1,000–1,000,000
	Risk characterisation (RC) Combines the information from the EA and DRA to determine if a significant health risk due to the exposure is likely. The risk is compared to a defined level of tolerable risk	Irrigation with wastewater may result in a certain level of contamination, a probability of disease can be calculated based on the estimated numbers of pathogen in the food, the amount of food consumed, and the frequency that food is consumed. Risks can be estimated for each exposure route

Sources: Blumenthal and Peasey, 2002; Petterson and Ashbolt, 2003; Teunis *et al.*, 1996.

Tolerable risks also need to be put into the context of all exposures leading to disease. For example, Mead *et al.* (1999) estimated that the average person (including all age groups) in the USA suffers from 0.8 episodes of acute gastroenteritis (GI) (characterised by diarrhoea, vomiting or both) per year (i.e. an 8×10^{-1} annual GI risk). The incidence rates of GI among adults worldwide are generally within the same order of magnitude (Murray and Lopez, 1996), but children living in high-risk situations where poor hygiene, sanitation and water quality prevail have more frequent gastrointestinal illnesses. Kosek *et al.*, (2003) found that children under the age of 5 in developing countries experienced a median of 3.2 annual episodes of diarrhoea per child (an annual risk of 3.2×10^{0}).

Risks of viral infection and diarrhoeal disease associated with contact with wastewater of different qualities have been estimated by QMRA techniques (Table 4.4). Guidelines should take these levels of risk into account. For example, if the background GI incidence rate in adults in a given population is 0.8 episodes per year, then treating wastewater to ≤2.2 total coliforms/100 ml (see Table 4.4) will potentially only add an extra 10^{-7} annual episodes of viral diarrhoea to the background level, i.e. the background level will increase from 0.8 to 0.8000001. Such a small increase is impossible to detect and, in any case, contributes virtually nothing to the background level. This implies that it is not necessary to treat wastewater to such a high quality.

However, with the same background rate of GI in adults, use of untreated wastewater would add an additional 0.2–0.6 annual GI episodes that would have a substantial impact on the level of GI, increasing it from 0.8 to 0.99 or 1.39 – i.e. increases of 25% and 76%, respectively. Treating the wastewater to the WHO guideline level of 1000 FC/100ml would add an extra 10^{-4}–10^{-5} infections, increasing the level from 0.8 to 0.8001, or 0.80001 annual episodes, that again does not perceptibly change the background level. This emphasises that the background levels of disease should be taken into consideration when microbial guideline values are established. The costs incurred in reaching different levels of risk must also be considered. Achieving such very low levels of risk through more advanced wastewater treatment technologies substantially increases costs (Fattal Shuval, 1999).

The Stockholm Framework requires that the risk of gastrointestinal illness in a given population be considered in the context of total risk from all exposures (i.e. drinking water, recreational water contact, and contaminated food). This facilitates making risk-management decisions that address the greatest risks first. For example, it will have very little impact on the disease burden if the number of cases of salmonellosis attributed to the use of wastewater in irrigation is halved if 99% of the cases are transmitted in other ways, most notably through contaminated food (Bartram *et al.*, 2001).

It is important to note that water quality requirements for the use of wastewater in unrestricted irrigation are often stricter than surface water quality requirements for unrestricted irrigation. In many places surface water would not meet WHO FC guideline targets for

Table 4.4. Estimated risks from the use of untreated or treated wastewater in irrigation of viral infection per person per year for various concentrations of *E. coli*[a].

E. coli concentration/100 ml	Risk of viral infection[b]		Reference
10^7 (i.e. untreated)	0.2–0.6	(I) CV	Fattal and Shuval, 1999
1000	$2–9 \times 10^{-5}$	(I) CV	Shuval *et al.*, 1997
≤2.2[c]	$1 \times 10^{-7} – 7 \times 10^{-9}$	(I) CV	Tanaka *et al.*, 1998
≤2.2[d]	$2 \times 10^{-8} – 4 \times 10^{-10}$	(I) WC	Tanaka *et al.*, 1998

[a] *E. coli* concentrations in wastewater do not necessarily correspond to viral concentrations in wastewater.
[b] Risks are based on either the consumption of irrigated raw vegetables (CV) or contact with the wastewater during/after irrigation (WC).
[c] Total coliforms in chlorinated secondary effluent used for unrestricted crop irrigation.
[d] Total coliforms in chlorinated tertiary effluent used for golf course irrigation.

unrestricted irrigation (UNEP, 1991; Mara and Cairncross, 1989). Thus in some cases, strict wastewater quality standards for irrigation will paradoxically encourage the use of more contaminated water for irrigation resulting in greater health risks. For example, in irrigated areas near Santiago, Chile, 60% of the river water used for irrigation contained in excess of 10,000 FC/100 ml (ten times the recommended WHO standard) (FAO, 1993). Additionally, the United States Environmental Protection Agency (USEPA) recommends a standard for irrigation with treated wastewater of ≤2.2 total coliforms/100 ml, but when surface waters are used for irrigation a standard of ≤1000 FC/100 ml is required (USEPA, 1973). However, a percentage of FC in surface waters may not originate from sewage effluents or waste discharges, especially in tropical/sub-tropical regions, and this may have significant implications in terms of human health risk assessment (WHO, 1996).

In some places where freshwater is scarce people often drink water that is of a quality that does not meet drinking water standards, and would not meet strict standards (e.g. California Title 22 standards) for unrestricted irrigation. For example, in some areas in the southern Punjab, Pakistan, groundwater supplies are too brackish to drink, so people rely on irrigation water for their drinking water supplies. In one study, 58% of the water from the village reservoirs contained >100 *E. coli*/100 ml (van der Hoek *et al.*, 2001b). In these circumstances it would be highly inappropriate to expect that wastewater be treated to a higher quality than drinking water. Clearly, as the Stockholm Framework suggests, interventions that would yield higher health benefits should be given more priority.

Water quality guidelines need to be adapted to the social, economic, and environmental conditions of each country. When countries with high levels of excreta-related disease background levels and inadequate resources for wastewater treatment adopt overly strict water quality standards for use in agriculture, it may lead to a lower level of health protection because, in these circumstances, the standards may not significantly change the background level of disease and/or may be viewed as unachievable and thus ignored entirely.

Chemical Guidelines

In many countries, industrial wastewater is often mixed with the municipal wastewater used for irrigation. Industrial wastes may contain toxic organic and inorganic chemicals that can be taken up by the crops. The health risks associated with chemicals found in wastewater and sludge may need to be given more attention, particularly as industrialisation increases in developing countries. To minimise adverse health and environmental effects from toxic substances, industrial wastes should be adequately pre-treated to remove these chemicals, or should be treated separately from municipal wastewater and excreta.

It is difficult to assess the health impacts from toxic chemicals in wastewater used for irrigation because of the difficulty in associating chronic exposure to chemicals and chemical mixtures to diseases with long latency periods. However, in some parts of China, the use of heavily contaminated industrial wastewater for irrigation is thought to be associated with health problems. For example, in these areas a 36% increase in hepatomegaly (enlarged liver), and a 100% increase in both cancer and congenital malformation rates were observed compared to those problems in control areas where industrial wastewater was not used for irrigation (Yuan, 1993). Heavy metals in the wastewater can also pose a health risk, e.g. in Japan, China and Taiwan rice accumulated high concentrations of cadmium (and other heavy metals) when it was grown in soils contaminated with irrigation water containing substantial industrial discharges (Chen, 1992). In Japan, Itai-itai disease – a bone and kidney disorder – associated with chronic cadmium poisoning, occurred in areas where rice paddies were irrigated with water from the contaminated Jinzu river (WHO, 1992).

WHO is currently developing standards for a selection of harmful chemicals that might be found in wastewater. In many situations the safety of the wastewater for use in irrigation will need to be determined on a case-by-case basis, depending on the type of chemicals suspected to be present. Chemical analysis of such wastewater may be necessary. Chemical guideline values will be presented in the revised guidelines.

Strategies for Managing Health Risk

The protection of public health can best be achieved by using a 'multiple barrier' approach that interrupts the flow of pathogens from the environment (wastewater, crops, soil etc.) to people. Human pathogens in the fields do not necessarily represent a health risk if other suitable health protection measures can be taken. These measures may prevent pathogens from reaching the worker or the crop or, by selection of appropriate crops (e.g. cotton), may prevent pathogens on the crop from affecting the consumer (Mara and Cairncross, 1989). The measures available for health protection can thus be grouped into five main categories:

- Waste treatment
- Crop restriction
- Irrigation technique
- Human exposure control
- Chemotherapy and vaccination.

It will often be desirable to use a combination of several methods. For example, crop restriction may be sufficient to protect consumers, but will need to be supplemented by additional measures to protect agricultural workers. Sometimes partial treatment to a less-demanding standard may be sufficient if combined with other measures. The feasibility and efficacy of any combination will depend on many factors that must be carefully considered before any option is put into practice (Mara and Cairncross, 1989). These factors will include the following:

- Availability of resources (labour, funds, land)
- Existing social and agricultural practices
- Market demand for wastewater-irrigated products
- Existing patterns of excreta-related disease.

For example, if sufficient funds and/or sufficient land are not available for wastewater treatment, some of the other three types of health protection measure will be needed.

Treatment

When municipal or domestic wastewater is used in agriculture, the removal or inactivation of excreted pathogens is the principal objective of wastewater treatment. Conventional wastewater treatment options (primary and secondary treatments), as applied in developed countries, have traditionally focused on the removal of environmental pollutants [e.g. suspended solids, or biological oxygen demanding (BOD) substances] and not on pathogens. Many of these processes may be difficult and costly to operate properly in developing-country situations due to their high energy, skilled labour, infrastructure and maintenance requirements (Carr and Strauss, 2001). In some cases, tertiary treatment (e.g. filtration and/or disinfection) will be required to reduce the concentrations of pathogens in the effluents to WHO-recommended microbial guideline values. In some situations, the quality of primary or secondary treated effluents could be improved by retaining them for 5 days in a single polishing (maturation) pond to reduce the risk of disease transmission (Mara and Cairncross, 1989).

There is a need for research and development work to improve the helminth egg removal efficacy of conventional systems to meet microbial standards. Such processes as lime treatment, chemically enhanced primary treatment (CEPT), upward-flow anaerobic sludge blanket, sand filtration, and storage in compartmentalised reservoirs deserve further study (Mara and Cairncross, 1989). Parr *et al.* (2000) present a brief overview of some wastewater treatment options that might be suitable for developing countries.

CEPT is a treatment technique that uses specific chemicals (e.g. ferric chloride plus an anionic polymer) to facilitate particle coagulation and flocculation. Improving these processes increases the removal of suspended solids, BOD and intestinal nematode eggs (Morrissey and Harleman, 1992; Harleman and Murcott, 2001). Studies in Mexico City showed that CEPT was capable of producing effluents with 2–5 nematode eggs/l. When CEPT effluents were filtered through polishing, sand filters effluents with <1 nematode egg/l were produced at significantly lower cost than in a conventional secondary treatment system (primary plus activated sludge) (Harleman and Murcott, 2001).

Waste stabilisation ponds (WSP) have been used successfully in many situations for treating wastewater. When designed and operated properly, WSP are highly effective in removing pathogens and can be operated at low cost where inexpensive land is available. Ponds for

FC and helminth removal can designed using specific equations (Mara, 1997; Ayres *et al.*, 1992), examples of their use are given by Mara in Blumenthal *et al.* (2000b). However, WSP should be designed, operated and maintained in such a way as to prevent disease vectors from breeding in them.

Where effective treatment is not available, it may be possible to consider other options that improve microbial water quality, such as storage reservoirs that partially treat wastewater through simple sedimentation. For example, in Mexico, irrigation with untreated or partially treated wastewater was estimated to be directly responsible for 80% of all *Ascaris* infections and 30% of diarrhoeal disease in farm workers and their families, but, when wastewater was retained in a series of reservoirs there was minimal risk of either *Ascaris* infection or diarrhoeal disease (Cifuentes *et al.*, 2000). The use of reservoirs has the added advantage that wastewater can be stored for use in the dry season – the time of peak irrigation demand.

Crop restriction

Crop restriction can be used to protect the health of consumers when water of sufficient quality is not available for unrestricted irrigation. For example, water of poorer quality can be used to irrigate such non-vegetable crops as cotton, or crops that will be cooked before consumption (e.g. potatoes).

Crop restriction does not, however, provide protection to farm workers and their families where low-quality effluents are used in irrigation or where wastewater is used indirectly, i.e. through contaminated surface water (Blumenthal *et al.*, 2000b). Crop restriction is therefore not an adequate single control measure, but should be considered as part of an integrated system of control. To provide protection for both workers and for the consumers, it should be complemented by such other measures as partial waste treatment, controlled application of wastes, or human exposure control (Mara and Cairncross, 1989).

Crop restriction is feasible and is facilitated in several circumstances including the following (Mara and Cairncross, 1989):

- Where a law-abiding society or strong law enforcement exists
- Where a public body controls allocation of the wastes, and has the legal authority to require that crop restrictions be followed
- Where an irrigation project has strong central management
- Where there is adequate demand for the crops allowed under crop restriction, and where they fetch a reasonable price
- Where there is little market pressure in favour of excluded crops.

Crop restriction has been used effectively in Mexico, Peru and Chile (Blumenthal *et al.*, 2000b). In Chile when implemented with a general hygiene education programme the use of crop restriction reduced the transmission of cholera from the consumption of raw vegetables by 90% (Monreal, 1993).

Waste application methods

The choice of wastewater application method can have impact on the health protection of farm workers, consumers, and nearby communities. Spray/sprinkler irrigation has the highest potential to spread contamination on crop surfaces and affect nearby communities. Bacteria and viruses (but not intestinal nematodes) can be transmitted through aerosols to nearby communities. Where spray/sprinkler irrigation is used with wastewater it may be necessary to set up a buffer zone, e.g. 50–100 m from houses and roads, to prevent health impacts on local communities (Mara and Cairncross, 1989).

Farm workers and their families are at the highest risk when furrow or flood irrigation techniques are used. This is especially true when protective clothing is not worn and earth is moved by hand (Blumenthal *et al.*, 2000b).

Localised irrigation techniques, e.g. bubbler, drip, trickle offer farm workers the most health protection because they apply wastewater directly to the plants. Although these techniques are generally the most expensive to implement, drip irrigation has recently been adopted by some farmers in Cape Verde and India (FAO, 2001; Kay, 2001).

Vaz da Costa Vargas *et al.* (1996) demonstrated that stopping irrigation 1–2 weeks before harvest can effectively reduce crop contamination. However, this is likely to be difficult to implement in unregulated circumstances because many vegetables (especially lettuce or other leafy vegetables) need watering up to the point of harvest to increase their market value. This technique may be possible for some fodder crops that do not have to be harvested at the peak of their freshness (Blumenthal *et al.*, 2000b).

Human exposure control

The following four groups of people can be identified as being at potential risk from the agricultural use of wastewater:

- Agricultural field workers and their families
- Crop handlers
- Consumers (of crops, meat and milk)
- Those living near affected fields.

Agricultural field workers are at high potential – and often actual – risk, especially from parasitic infections. Exposure to hookworm infection can be reduced, even eliminated, by the use of less-contaminating irrigation methods (see above) and by the use of appropriate protective clothing, i.e. shoes for field workers and gloves for crop handlers. Rigorous health education programmes are needed (Blumenthal *et al.*, 2000b; Mara and Cairncross, 1989). Field workers should be provided with adequate water for drinking and hygiene purposes, in order to avoid the consumption of, and any contact with, wastewater. Similarly, safe water should be provided at markets for washing and 'freshening' produce. Consumers should cook vegetables and meat, boil milk, and practise good personal and domestic hygiene measures to protect their health.

Health education campaigns that focus on improving personal and domestic hygiene should target produce consumers, farm workers, produce handlers and vendors. Hand washing with soap should be emphasised. It may be possible to link health education and hygiene promotion to agricultural extension activities or other health programmes, e.g. immunisation (Blumenthal *et al.*, 2000b).

Chemotherapy and vaccination

Immunisation against helminthic infections and most diarrhoeal diseases is currently not feasible. However, for highly exposed groups, immunisation against typhoid and hepatitis A may be worth considering.

Additional protection can be provided if adequate medical facilities to treat diarrhoeal diseases, are available and by regular chemotherapy. This might include chemotherapeutic control of intense nematode infections in children and control of anaemia in both children and adults, especially women and post-menarche girls. Chemotherapy must be reapplied at regular intervals to be effective. The frequency required to keep worm burdens at a low level (e.g. as low as those in the rest of the population) depends on the intensity of the transmission, but treatment may be required 2–3 times a year for children living in endemic areas (Montresor *et al.*, 2002; Mara and Cairncross, 1989). Albonico *et al.* (1995) found that re-infection with helminths could return to pre-treatment levels within 6 months of a mass chemotherapy campaign if the prevailing conditions did not change.

Chemotherapy and immunisation cannot normally be considered adequate strategies to protect farm workers and their families exposed to raw wastewater or excreta. However, where such workers are organised within structured situations, such as on government or company farms, these treatments could be beneficial as palliative measures, pending improvement in the quality of the wastes used, or the adoption of other control measures, e.g. protective clothing (Mara and Cairncross, 1989).

Guideline Implementation

The scarcity of surface and groundwater in many countries has led, or is leading to the development of national plans for the rational allocation, utilisation and protection of available water resources. The objective of such plans is to ensure, as far as is practically possible, the maximum economic yield from the use of an increasingly scarce resource. Human wastes are relevant to these national water plans as they can alter the physico-chemical and microbiological quality of water, and thus place restrictions on its use. The incorporation of protocols for waste use planning into national water plans is important, especially when water is scarce, not only to protect water quality but also to minimise treatment costs, to safeguard public health, and to obtain the maximum possible agricultural benefit from the nutrients and organic matter contained in the wastes (Mara and Cairncross, 1989).

Human wastes are already used for crop production in many countries, mostly informally and without official recognition by the health authorities. The *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume) recognises this reality. Where the practice is traditional or has arisen spontaneously, untreated or insufficiently treated wastes are commonly used. Experience in many countries has shown that simply to ban the practice is not likely to have much effect, if any, on its prevalence or on the level of public health risk involved. On the contrary, banning the practice is unlikely to stop it, but may make it more difficult to supervise and control, and may also interfere with disease surveillance and health care among those most exposed to the risk of infection. A more promising approach is to provide support to improve existing use practices, not only to maximise health protection, but also to increase productivity, as the major stakeholders are usually relatively poor farmers and consumers (Mara and Cairncross, 1989).

Additional legal controls will often be required, but, it is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce) it is important to plan for the institutions, staff and resources necessary to ensure they are followed. Perhaps even more important is to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach, or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country (Mara and Cairncross, 1989). Some of the problems countries encounter when setting up and implementing standards have been reviewed by von Sperling and Fattal (2001).

Measures to protect public health are particularly difficult to implement when there are many individual sources or owners of the waste, whether these are individual septic tank overflows or farmers with riparian rights to pump from a river so polluted that it comprises only slightly diluted wastewater. If the wastewater can be brought under unified control by: installing a sewerage system, establishing a treatment plant (or plants), or diverting the wastewater from the river to a treatment works, this will give the controlling authority much greater power to influence the ways in which the wastewater is subsequently used, and thus to maximise health protection (Mara and Cairncross, 1989).

Implementation of the *WHO Guidelines for the Safe Use of Wastewater in Agriculture and Aquaculture* (WHO, 1989) will be of maximum benefit in protecting public health when they are integrated into a comprehensive public health programme that includes other sanitary measures including education and outreach that aim to change personal and domestic hygiene behaviour. For example, if the guidelines are followed in the field but produce is 'freshened' with contaminated water in the market, some of the potential health gains are likely to be erased.

Steps that will facilitate developing a guideline implementation plan are presented below. A sample action plan for incremental adoption of WHO guidelines is presented in Box 4.1. Further discussion of stepwise guideline implementation can be found in von Sperling and Fattal (2001).

Guideline implementation plan

1. Design and conduct a survey of wastewater and excreta use practices throughout the country or in specific districts. The survey could contain questions concerning:
    - The availability and types of wastewater treatment available
    - The types of crops grown in the area (whether they are eaten cooked or raw)
    - Techniques for wastewater and excreta application, e.g. bucket, furrow, sprinkler, other
    - An assessment of human exposure to wastewater and excreta during agricul-

Box 4.1. Sample action plan for incremental adoption of WHO guidelines[a]

Strengthen local capacity
Assemble a team of health and agricultural outreach workers who can work with farmers and villagers to improve health and agricultural practices and develop feasible crop restriction strategies and other interventions as necessary.

Health and hygiene education
Expand existing hygiene and sanitation outreach programmes to include information on potential health effects of wastewater use; educate farmers, produce vendors and consumers about food safety and hygiene.

Crop restriction
Work with farmers to develop feasible and health protective crop restrictions, especially in the areas of highest risk (e.g. where undiluted raw wastewater is used).

Waste application
Determine the safety level of current practices. As resources/technologies permit, shift to safer wastewater/excreta application practices where there is less human contact (e.g. drip and bubbler irrigation).

Human exposure control
Expand hygiene and health education programmes in affected communities. Require protective clothing at larger wastewater/excreta use projects and where feasible. Provide clean water at markets for 'freshening produce'. Inspect general hygiene at food markets.

Treatment
Introduce or upgrade treatment at strategic locations, phase in over a period of time (e.g. 10–15 years).

Examples

***First stage of treatment*:** natural purification processes (e.g. abstraction suitable distance downstream from discharge); irrigation storage reservoirs designed for pathogen removal, waste stabilisation ponds, primary treatment plus additional treatment (e.g. storage reservoir, chemically enhanced coagulation, coagulation + rapid sand filtration).

***Second stage of treatment*:** waste stabilisation ponds, conventional secondary treatment (e.g. activated sludge, trickling filter, etc.), aeration ponds, etc.

***Third stage of treatment*:** waste stabilisation ponds, conventional secondary treatment + storage reservoir or disinfection, advanced processes (e.g. membrane filtration).

Microbial wastewater quality standards
Phase in WHO microbial wastewater quality standards over suitable period of time according to treatment capabilities. For example, the initial standards may be set at $\leq 10^5$ FC/100 ml and ≤ 5 viable intestinal nematode eggs/l for unrestricted irrigation (and/or with specific crop restrictions). As resources become available to build treatment facilities the standard could be tightened to $\leq 10^4$ FC/100 ml and ≤ 1 viable intestinal nematode egg/l, and eventually to the current recommendations ($\leq 10^3$ FC/100 ml and ≤ 1 viable intestinal nematode egg/l).

Other health interventions
Initiate or expand vaccination campaigns in affected areas, e.g. typhoid, hepatitis A. Complement hygiene and sanitation programmes with periodic antihelminthic drug campaigns (this works well where antihelminthic drugs are widely available at low cost and where wastewater and excreta use is limited to distinct areas in a country, e.g. Pakistan (Feenstra *et al.*, 2000). Mass antihelminthic drug campaigns against intestinal nematode infection may need to be considered at least once per year in areas where 50–70% of the school-aged children are infected with soil-transmitted helminthic infections. Where the prevalence of these infections exceeds 70% in school-aged children and more than 10% of the individuals are moderately or heavily infected, then children should be treated 2–3 times a year (Montresor *et al.*, 2002).

Industrial effluents
Initial efforts should be made to identify sources of industrial discharges. Phase in an approach that first requires large polluters to clean up their wastes or divert them from the municipal waste stream and eventually requires all of the industrial discharges to be treated separately.

[a] For more discussion on progressive guideline implementation see von Sperling and Fattal (2001).

tural practices, e.g. do fieldworkers wear protective clothing? do they practice good hygiene?

- Evaluation/prioritisation of health risks in the context of the national burden of disease, associated with the use of wastewater and excreta in agriculture.

  Quantitative: scientific studies of disease, review of clinical data, outbreak information, prevalence data, etc.

  Qualitative: interviews with health staff (doctors, nurses, pharmacists), farmers, families, community workers, teachers, etc.

3. National or district-level workshops to formulate appropriate (realistic) strategies for mitigating health impacts that include relevant stakeholders, e.g. farmers.
4. Develop national or other action plan/policy for the safe use of wastewater and excreta in agriculture.
5. Strengthen institutional capacities – designate responsible authority(-ies) to monitor and enforce safe wastewater and excreta use practices.
6. Review and revise national plan/policy as needed.

Conclusions

Developing realistic guidelines for using wastewater in agriculture involves the establishment of appropriate health-based targets prior to defining appropriate risk-management strategies. Establishing appropriate health-based targets primarily involves an assessment of the risks associated with wastewater use in agriculture, using evidence from available studies of epidemiological and microbiological risks, and risk-assessment studies. Considerations of what is an acceptable or tolerable risk are then necessary; these may involve the use of internationally derived estimates of tolerable risk, but these need to be put into the context of actual disease rates in a population related to all the exposures that lead to that disease, including other water- and sanitation-related exposures together with food-related exposure. Positive health impacts resulting from increased food security, improved nutrition, and additional household income should also be considered. Individual countries may therefore set different health targets, based on their own contexts.

Strategies for managing health risks to achieve the health targets include wastewater treatment to achieve appropriate microbiological quality guidelines, crop restriction, waste application methods, control of human exposure, chemotherapy, and vaccination. Phased implementation of the WHO microbial water quality standards may be necessary as treatment is gradually introduced and improved over a period of time, e.g. 1–15 years. For optimal public health effect, the guidelines should be co-implemented with such other health interventions as hygiene promotion, provision of adequate drinking water and sanitation, and other healthcare measures.

Note: The opinions expressed in this chapter are those of the authors and do not necessarily reflect the views or policies of WHO.

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5 A Fresh Look at Microbial Guidelines for Wastewater Irrigation in Agriculture: A Risk-assessment and Cost-effectiveness Approach

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Abstract

This study aimed to develop a risk-assessment/cost-effectiveness approach, to compare the risks of irrigating with wastewater treated to meet various recommended microbial guidelines – World Health Organization (WHO) versus United States Environmental Protection Agency (USEPA) – for unrestricted use in agriculture with the risk of irrigating with untreated wastewater. According to the authors' estimates, the annual risk of contracting infectious diseases including typhoid fever, rotavirus infection, cholera and hepatitis A from eating raw vegetables irrigated with untreated wastewater is in the range of 1.5×10^{-1} to 5×10^{-2}, or 5–15% of consumers eating such vegetables will develop a case of disease compared to 10^{-6} (0.0001%) of those eating vegetables irrigated with treated wastewater effluent that meets the WHO guideline of 1000 faecal coliforms (FC)/100 ml. The USEPA considers a 10^{-4} (0.01%) annual risk of becoming ill with an infectious disease acceptable for drinking water. Cost-effectiveness analysis shows that, on average, in a city with a population of one million, the prevention of a single case (out of 61 cases/year) of the four diseases: hepatitis A, rotavirus infection, cholera and typhoid according to WHO guidelines versus USEPA guidelines would entail an extra annual expenditure of wastewater treatment of US$450,000/case. It is questionable if this is a cost-effective or reasonable public health expenditure. The authors estimate that if every one of a million people ate raw vegetables irrigated with untreated wastewater, there would be a 1 in 10 annual risk (100,000 cases/year) of contracting one of these four diseases. Thus, in the authors' view irrigating vegetables eaten with raw untreated wastewater presents an unreasonably high health risk. However, treatment to meet WHO guidelines would cost US$125/case prevented. This appears to be reasonably cost-effective, but, is a question that must be decided upon by each community. Evaluating health risks by disability adjusted life years (DALY) is also considered.

Introduction

This study aimed to further develop a risk-assessment approach based on a mathematical model and experimental data, in order to conduct a comparative risk analysis of the various recommended wastewater irrigation microbial health guidelines for unrestricted irrigation of vegetables normally eaten raw (uncooked) based on the initial study by Shuval *et al.*, 1997. The guidelines evaluated were those recommended by WHO (1989) and USEPA/USAID

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in 1992. Consideration was also given to the implications of irrigating such crops with untreated (raw) wastewater as discussed in other chapters of this volume.

Regulations to protect the health of people who consume crops irrigated by wastewater were initiated by the California State Board of Health. In 1933 they established the first microbial effluent standard that was equivalent to the one required for drinking water, which was then set at a most probable number (MPN) of 2.2 faecal coliforms (FC)/100 ml (Ongerth and Jopling, 1977). However, this standard was difficult to achieve even in developed countries, and was not feasible for most developing countries. In fact, hundreds of cities in the developing world could not afford to meet the very rigorous standards that they had innocently copied from the United States, and, thus, did not build any appropriate wastewater treatment plants.

In 1982 the World Bank and the World Health Organization embarked on a broad-spectrum, multi-institutional scientific study involving three independent teams of scientists to review the available epidemiological and technological evidence on health risks associated with wastewater irrigation (Shuval *et al.*, 1986; Feachem *et al.*, 1983; Struass and Blumenthal, 1989). These studies resulted in the publication in 1989, World Health Organization (WHO) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture.* Based on the new epidemiological and technological evidence, the guidelines recommended a mean of 1,000 FC/100 ml and less than one helminth egg per litre of effluent, for the wastewater irrigation of vegetables eaten raw. The new guidelines have become widely accepted by international agencies including the Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and the World Bank and have been adopted by French health authorities and the governments of a number of developing, and developed countries.

In 1992 USEPA together with USAID published their own guidelines for water reuse. These were primarily intended for use within the USA, but were also developed so that they could be used as guidelines by USAID missions working in developing countries. These new guidelines for the irrigation of crops eaten raw are even stricter than the original California standards and call for no (zero) detectable FC/100 ml, biochemical oxygen demand (BOD) of 10 mg/l or less, turbidity of 2 nephalometric turbidity units (NTU) or less and chlorine residual of 1 mg/l. In addition, the guidelines stipulate rigorous engineering requirements for biological treatment, sand filtration, chemical disinfection and various fail-safe redundancies and back-up equipment facilities. The standard of zero detectable FC/100 ml had become the current American drinking water standard, so that once again United States thinking was apparently based on a zero indicator organisms or 'no risk' concept, regardless of its technical feasibility and cost-effectiveness for other parts of the world.

Risk-assessment Model

The risk-assessment model developed by Haas *et al.* (1993) for estimating the risk of infection and disease from ingesting microorganisms in drinking water, was used in this study. However, certain modifications were required to fit the risk of infection associated with eating vegetables irrigated with wastewater of variable microbial quality (Shuval *et al.*, 1997). The probability of infection (P_I) from ingesting pathogens in water, according to Haas *et al.* (1993), is presented in Equation 1:

$$P_I = 1 - [1 + N/N_{50}\,(2^{1/\alpha} - 1)]^{-\alpha} \qquad (1)$$

P_I = The risk of infection by ingesting pathogens in drinking water
N = The number of pathogens ingested
N_{50} = The number of pathogens that will infect 50% of the exposed population
α = A slope parameter; the ratio between N_{50} and P_I

Since not every person infected by the ingestion of pathogens becomes ill, an independent estimate is made of P_D – the probability of contracting a disease (see Equation 2):

$$P_D = P_{D:I} \times P_I \qquad (2)$$

P_D = The risk of an infected person becoming ill
$P_{D:I}$ = The probability of an infected person developing clinical disease

The Number of Pathogens Ingested

Based on laboratory determinations, the authors found that the amount of wastewater of varying microbial quality that would cling to the external surface of wastewater-irrigated cucumbers is 0.36 ml/100 g (one large cucumber) and 10.8 ml/100 g of long-leaf lettuce (about 3 lettuce leaves) (Shuval *et al.*, 1997). Based on these measurements, the amount of indicator organisms that might remain on the vegetables if irrigated with untreated wastewater (with 10^7 FC/100 ml) and with wastewater meeting WHO guidelines (10^3 FC/100 ml) were estimated. According to Schwartzbrod (1995), the ratio of enteric virus : FC is 1:10^5. For the preliminary risk estimate, it was assumed that all of the enteric viruses are a single pathogen species, such as the viruses of hepatitis A or poliomyelitis, therefore certain assumptions as to median infectious dose and infection to morbidity ratios need to be made.

It was also assumed that under actual field conditions there would be a certain degree of indicator and pathogen die-away and/or removal from the wastewater source until final ingestion by the consumer at home. Factors affecting die-away include: settling, adsorption, desiccation, biological competition, UV irradiation from sunlight, and a degree of removal and/or inactivation as a result of washing the vegetables at home. A number of studies have indicated that there is a rapid die-away or removal of both bacterial indicator organisms and of pathogenic bacteria and viruses in wastewater-irrigated soil and on crops of as much as 5-log in 2 days under field conditions (Bergner-Rabinowitz, 1956; Rudolfs *et al.*, 1951; Sadovski *et al.*, 1978; Armon *et al.*, 1995). Asano and Sakaji (1990) determined virus die-away under field conditions of wastewater reuse, and found that within 2 weeks total virus inactivation reaches about 99.99%, while in 3 days there is a 90% reduction in virus concentration. Even superficial washing of vegetables at home can remove an additional 99–99.9% of the viral contamination. Schwartzbrod (1995) estimated that there would be as much as a 6-log reduction of virus concentration between irrigation with wastewater and consumption of the crops if the total elapsed time reached 3 weeks. To be on the conservative side, it was estimated that the total entero-viruses and bacteria inactivation and/or removal from the wastewater source until ingestion, results in a reduction in pathogenic microorganism concentration by 3-log, or 99.9%, although a 99.99% loss is not unreasonable and might occur in most cases. It can be assumed that this also applies in the case of irrigation with untreated wastewater.

Estimates of Risk of Infection and Disease

Based on the above tests and assumptions, the number of pathogens ingested by a person who eats a 100-g cucumber or 100 g (three leaves) of long-leaf lettuce irrigated with wastewater of various quality was estimated. Four pathogens were selected: two enteric viruses (rotavirus and hepatitis A) and two enteric bacteria (*Vibrio cholera* and *Salmonella typhi*), with epidemiological evidence indicating the possibility of their being environmentally transmitted and/or waterborne (Schwartzbrod, 1995). It was assumed that a minimal infectious dose for 50% of the exposed population to become infected (N_{50}) ranges between 5.6 and 10^4 depending on the pathogen (see Tables 5.1a and b). While the authors are fully aware that the ratio of infection to clinical disease is often as low as 100:1, they assumed conservatively for this study, that 50% of those infected will succumb to clinical disease ($P_{D:I} = 0.5$). They also assumed, based on vegetable consumption patterns in Israel, that on an annual basis a person would consume 100 g of lettuce or cucumbers/day for a total of 150 days. The risk was calculated, using both a severe α value of 0.2, rather than 0.5 (Tables 5.1 and 5.2). However, if $\alpha = 0.5$ were used it would decrease the risk by about 1-log.

First, as a positive control test of the model the risk of infection and disease from consuming vegetables irrigated with untreated wastewater with an estimated initial FC level of 10^7/100 ml. Assuming a 3-log die-away prior to consumption of the vegetables, it was estimated that under such conditions a 100-g cucumber or 100 g of lettuce irrigated with untreated wastewater would have a final FC level of 30 to 10^3. Based on this FC level and a virus:FC ratio of 1:10^5, there is a probability that when irrigated with untreated wastewater, 3 out of 10,000

Table 5.1. The risk of infection and disease caused by various pathogens from:

a. Eating 100 g (3 leaves) of long-leaf lettuce irrigated with untreated wastewater once or for 150 days/year.

		One-time risk		Annual risk	
Pathogens	$(N_{50})^a$	P_I	P_D	P_I	P_D
Rotavirus[b]	5.6	2.7×10^{-3}	1.3×10^{-3}	4.0×10^{-1}	1.0×10^{-1}
Hepatitis A virus[c]	30	1.3×10^{-3}	6.5×10^{-4}	1.7×10^{-1}	4.4×10^{-2}
V. cholera[c]	10^3	6.2×10^{-3}	3.1×10^{-3}	6.0×10^{-1}	1.5×10^{-1}
S. typhi[c]	10^4	6.2×10^{-3}	3.1×10^{-3}	6.0×10^{-1}	1.5×10^{-1}

b. Eating 100 g (3 leaves) of long-leaf lettuce irrigated with treated wastewater effluent meeting the WHO guidelines for unrestricted irrigation of vegetables (1000 FC/100 ml) once or for 150 days/year.

		One-time risk		Annual risk	
Pathogens	$(N_{50})^a$	P_I	P_D	P_I	P_D
Rotavirus[b]	5.6	2.7×10^{-7}	1.3×10^{-7}	4.0×10^{-5}	1.0×10^{-5}
Hepatitis A virus[c]	30	1.3×10^{-7}	6.5×10^{-8}	1.9×10^{-5}	4.7×10^{-6}
V. cholera[c]	10^3	6.2×10^{-7}	3.1×10^{-7}	9.2×10^{-5}	2.3×10^{-5}
S. typhi[c]	10^4	6.2×10^{-7}	3.1×10^{-7}	9.2×10^{-5}	2.3×10^{-5}

[a]Number of pathogens that infect 50% of the exposed population
[b]$\alpha = 0.265$
[c]$\alpha = 0.2$

cucumbers and 3 leaves of lettuce in 1000 would carry a single enteric virus. According to these estimates of pathogen ingestion, it was estimated that the risk of infection and disease that might result from irrigating lettuce with raw untreated wastewater would vary between 1.5×10^{-1} and 5×10^{-2} or 5–15%/year for each of the four diseases studied, with a total of 40% of the population becoming ill with these four diseases each year. To remain on the cautious and conservative side annual total disease risk of some 20% for a range of vegetable crops irrigated with untreated wastewater was assumed. Table 5.1a presents the estimated risk of irrigating lettuce with untreated wastewater, which is a higher than that for cucumbers.

However, if the effluent is treated to meet the WHO guidelines of 1000 FC/100 ml for irrigation of vegetables to be eaten raw, the risk of infection and disease estimates for lettuce are those shown in Table 5.1b. The risk assessment of consuming 100 g cucumbers irrigated with effluent meeting the WHO guidelines for *V. cholera* is 10^{-9} for a one-time risk of infection or disease, whereas in the case of lettuce it is approximately 10^{-7} (Table 5.2). The annual risk of *V. cholera* from eating lettuce is between 10^{-5} and 10^{-6}.

Table 5.2. The risk of infection and disease caused by *Vibrio cholera* from eating 100 g of cucumbers or 100 g of long-leaf lettuce irrigated with untreated or treated wastewater effluent meeting the WHO guidelines for unrestricted irrigation.

Type of wastewater	Type of vegetable	One-time risk of infection[a] P_I	One-time risk of disease[a] P_D
Untreated	Cucumber	6.2×10^{-5}	3.1×10^{-5}
Untreated	Lettuce	6.2×10^{-3}	3.1×10^{-3}
Treated[b]	Cucumber	6.2×10^{-9}	3.1×10^{-9}
Treated[b]	Lettuce	6.2×10^{-7}	3.1×10^{-7}

[a]$N_{50} = 10^3$ and $\alpha = 0.2$
[b]Treated according to the WHO guidelines of 1000 FC/100 ml.

Is this a high- or low-risk level? To shed some light on what are considered reasonable levels of risk for communicable disease transmission from environmental exposure it should be noted that the USEPA has determined that guidelines for drinking water microbial standards should be designed to ensure that human populations are not subjected to a risk of infection by enteric disease greater than 10^{-4} (or 1 case per 10,000 person/year) (Regli *et al.*, 1991). Thus, compared with the USEPA estimates of reasonable acceptable risks for waterborne disease-associated microbes ingested directly in drinking water, the WHO wastewater reuse guidelines appear to be some one or two orders of magnitude more rigorous, if not more.

Validation of the Model

a. The 1970 cholera outbreak in Jerusalem

In 1970 an outbreak of cholera involving some 200 cases of clinical disease occurred in Jerusalem. Our investigation and analysis provided strong evidence that the main route of transmission was through the consumption of vegetables, including lettuce and cucumbers, illegally irrigated with untreated wastewater from Jerusalem, which villagers sold door-to-door throughout the city (Fattal *et al.*, 1986). Since considerable and detailed data pertaining to that epidemic were available, it provided an opportunity to test and validate the risk-assessment model against the actual data. Based on microbial tests carried out during the epidemic and other studies, it was estimated that the concentration of cholera vibrios in the raw municipal wastewater was 10–10^4/100 ml. It was also assumed, based on the literature (Feachem *et al.*, 1983), that the (N_{50}) for cholera in Jerusalem under conditions of good health and nutrition was 10^3 vibrios. Table 5.2 shows the theoretical risk of infection and disease from cholera, based on the risk-assessment model. The total number of cases of disease reported in Jerusalem was 200 and it was estimated that some 100,000–200,000 persons purchased the contaminated vegetables and were exposed to the pathogen. Thus, it can be estimated that the case rate in Jerusalem was in the order of 10^{-3}–10^{-4}, which falls within the range of the theoretical risk of disease of some 10^{-3}–10^{-5} from lettuce and cucumbers irrigated with untreated wastewater calculated according to the risk-assessment model. It can also be assumed that had the Jerusalem wastewater been treated according to WHO guidelines, the risk of disease transmission by wastewater irrigation would essentially have been negligible, even if the concentration of cholera vibrios in the untreated wastewater had reached the levels it did during the epidemic.

b. The typhoid fever outbreaks in Santiago, Chile, 1978 and 1983

Shuval (1993), who investigated the typhoid fever outbreaks in Santiago in 1978 and 1983, claimed that the use of untreated wastewater for the irrigation of 13,500 ha of various vegetables (tomatoes, lettuce, cabbage, celery, cauliflower), that were consumed raw, was responsible for the transmission of this disease and its high infection rate (~200 cases/100,000 residents). As can be seen in Table 5.1, the one-time risk of becoming ill from *S. typhi* infection due to the consumption of lettuce irrigated with untreated wastewater is 3.1×10^{-3}. The number of cases of both cholera and typhoid fever predicted by this assessment model is validated by the numbers of actual cases in Jerusalem and Santiago. According to this model, if the wastewater in Jerusalem and in Santiago had been treated according to WHO guidelines (1000 FC/100 ml), the risk of cholera or typhoid infection as a result of eating lettuce irrigated with untreated wastewater would have been very small. The risk run by eating tomatoes or cucumbers would have been negligible.

Cost-effectiveness Analysis

The cost-effectiveness associated with meeting the various wastewater effluent guidelines was estimated. As an example, the hypothetical case of a city in a developing country with a population of one million where currently large areas of vegetable crops are irrigated with untreated wastewater is presented. It is assumed that the city is considering the construction of a wastewater treatment plant to ensure safe utilisation of the effluent for agricultural irrigation of vegetable crops, including those eaten raw. It is assumed that in order to meet WHO guidelines, authorities would opt for a stabilisation pond treatment system with multiple ponds. The authorities would want to compare the cost and risks at that level of treatment with the cost and risks entailed if they did nothing and continued to irrigate vegetables with untreated wastewater, and alternately, if they adopted the USEPA/USAID recommended guidelines for treatment of vegetables eaten raw. For the purpose of this illustration only, the unit cost of wastewater treatment to meet the various guidelines can be roughly estimated as:

WHO guidelines – 1000 FC/100 ml	**US$**
(in stabilisation ponds)	0.125/m^3
or the annual cost/person (assuming consumption 100 m^3/person)	12.50/person
USEPA/USAID guidelines – 0 FC/100 ml	0.40/m^3
or annual cost/person (100 m^3/person/year)	40.00/person

The estimate of treatment costs to meet WHO guidelines does not necessarily apply to all situations but is generally illustrative of a situation that may apply in hot sunny climates in developing countries where low-cost land is available for effective stabilisation pond treatment. The annual cost of treatment to the recommended WHO guidelines is estimated at some US$12,500,000 for a population of one million persons. According to this estimate, the additional annual cost for that city to meet the USEPA/USAID guidelines would be US$27,500,000.

Assuming that half the hypothetical city's population of one million consumes wastewater-irrigated vegetables on a regular basis, and that the annual risk of contracting rotavirus, hepatitis A virus, *V. cholera* and *S. typhi* infections associated with the use of vegetables, eaten raw and irrigated with untreated wastewater is the worst case, it is assumed that these vegetable crops are currently irrigated with untreated wastewater, and based on conservative risk estimates some 20% of the exposed half of the population, or 100,000 people become ill every year from one of the four diseases.

There would be 10 (10×10^{-5}) cases of rotavirus, 5 (4.7×10^{-6}) cases of hepatatis A, and 23 (23×10^{-5}) cases each of cholera and typhoid, making 61 cases in all (Tables 5.1b and 5.3). If it is assumed that the USEPA/USAID guidelines, that call for no detectable FC/100 ml, entail an essentially zero risk of disease, then it can be estimated that these annual cases of diseases could have been prevented if the USEPA/USAID microbial guidelines had been met. The additional cost of wastewater treatment would be about US$5,500,000 for each case of hepatitis A prevented. In the case of rotavirus disease, the cost would be some US$2,750,000; and US$1,200,000/case for *V. cholera* and *S. typhi* infection prevented. From Table 5.3 it can be seen also that: the greater the α value the higher the cost of prevention, that could reach as high as US$13.75 million to prevent a single case of hepatitis A. If it is assumed that all four infectious diseases are endemic and transmitted simultaneously then to prevent all 61 cases/year resulting from the four listed pathogens, it would cost US$27,500,000, i.e. on average, the cost of preventing a single case would be US$451,000. Nevertheless, if the true level of risk associated with the WHO guidelines is closer to the 10^{-6} level, then no detectable reduction of risk would be gained by the additional annual investment of US$27,500,000 required to meet the USEPA/USAID effluent guidelines. These figures are estimated by the less-conservative interpretation of the results of this study. It is questionable whether this level of additional treatment, requiring major extra expenditure, is justifiable to further reduce the negligible low levels of risk of infection and disease that these estimates indicate are associated with the new WHO guidelines.

Let us look at the cost-effectiveness of treating the wastewater to the WHO recommended guidelines for this city of one million as compared to the situation of continuing the irrigation of vegetables eaten raw with untreated wastewater. If the present state of no treatment and irrigation with untreated wastewater were to continue, the community would be faced with some 100,000 annual cases of the four enteric diseases included in this study. By building a treatment plant that achieves the

Table 5.3. The annual cost in a city with a population of one million of preventing a single case of a particular disease caused by a specific pathogen due to eating lettuce irrigated with effluent according to WHO guidelines (1000 FC/100 ml), at a rate of 100 g/day for a total of 150 days.

Pathogen	α	Cases/year	Cost of preventing all cases/year (US$ millions)	Cost of preventing a single case/year (US$ millions)
Rotavirus	0.265	10	27.5	2.75
Hepatitis A virus	0.2	5	27.5	5.5
	0.5	2	27.5	13.75
V. cholera	0.2	23	27.5	1.2
	0.5	6	27.5	4.6
S. typhi	0.2	23	27.5	1.2
	0.5	6	27.5	4.6

WHO guidelines some 99,940 cases of disease could be prevented each year at an estimated annual total cost of some US$12,500,000 or US$125/case of disease prevented. This can be considered reasonably cost-effective and a worthwhile investment in public health disease prevention. However, each community must make its own judgment as to the level of investment it is prepared to make in preventing disease.

It should be recalled, however, that the health burden incurred by the different diseases varies, and that each disease should be considered separately. Accordingly, WHO and the World Bank have developed another method of evaluating health risk by comparing different diseases on one scale, disability adjusted life years (DALY) (Murray and Lopez, 1996).

Disability Adjusted Life Years (DALYs)

In this study the health effects of the four infectious diseases are considered equally, the WHO and the World Bank have developed a new methodology that measures their relative public health burden by comparing the weight of the damage incurred by the diseases (DALYs) rather than by counting the total number of cases of each disease. DALY emphasises the real health weight of the diseases, that might in some cases be fatal and/or cause long-term damage such as liver injury due to hepatitis A or paralysis in poliomyelitis. This integrated measure combines the number of years of life lost (YLL) by mortality with the number of years lived with a disability (YLD). These are standardised by severity weights. DALY is equal to the sum of YLL + YLD. YLL is calculated by multiplying age-specific mortality rates by the life expectancy of the fatal cases that have not developed the disease. YLD is calculated by multiplying the number of cases by the average duration of the disease and a weight factor that reflects the severity of the disease on a scale of 0–1 (death).

As an example, the DALY of two intestinal diseases: hepatitis A and salmonellosis is calculated:

DALY for 1000 cases of hepatitis A

Assuming that:

Average number of days of disability	40
Severity factor	0.5
Death rate	1%
Life-time disability from liver damage	10%

Therefore:

YLD for 40 days is:

$$1000 \text{ cases} \times 40/365 \times 0.5 = 55$$

YLL:

$$1000 \text{ cases} \times 1\% \text{ death} \times 45 \text{ years} = 450$$

(assuming that the person died at the age of 30 and that the life expectancy is 75 years);

YLD for liver damage is:

$$1000 \text{ cases} \times 10\% \times 45 \text{ years} \times 0.5 = 2{,}250$$

Thus the total DALY for hepatitis A is:

$$55 + 450 + 2{,}250 = 2{,}755.$$

DALY for 1000 cases of salmonellosis

Assuming that:

Average number of days of disability (YLD)	4
Severity factor	0.2
Death rate	0%

Thus the total DALY for 4 days of disability is:

$$1000 \text{ cases} \times 4/365 \times 0.2 = 2.$$

Therefore, the ratio of hepatitis A:salmonellosis is 2,755 : 2 = 1,378 : 1

It can be seen that in this example the disease that has real public health burden is hepatitis A and not salmonellosis (the weight of damage of one case of hepatitis A is equal to 1,378 cases of salmonellosis), since hepatitis A causes death or has a life-long effect. Therefore, an approach that considers the number of cases rather than the weight of diseases according to their real damage (calculated in DALY) is less accurate. It is more justifiable to calculate cost-effectiveness based on preventing diseases like hepatitis A or poliomyelitis that cause heavy health damage, rather than salmonellosis or rotavirus infections. The use of the DALY approach is more logical for this type of risk/cost-effectiveness analysis. For example, it might be more reasonable just to estimate the cost of preventing the one important disease (hepatitis A) rather than pooling all the other less-important infectious diseases (Shuval *et al.*, 1997).

Discussion and Conclusions

A model for the assessment of risk of infection and disease associated with wastewater irrigation of vegetables, eaten raw, has been developed based on a modification of the Haas *et al.* (1993) risk-assessment model for drinking water. The modifications include laboratory experiments to determine the amount of wastewater that could cling to such irrigated vegetables as cucumbers and lettuce, and an estimation of the concentration of pathogens that would be ingested by consuming vegetables irrigated with wastewater of different standards. Validation of the model with data from the Jerusalem cholera epidemic and typhoid fever outbreaks in Santiago which, in both cases, were caused primarily by the consumption of wastewater-irrigated vegetables, lends support to the assumption that the risk-assessment model can provide a reasonable approximation of the levels of disease that really can and have occurred due to irrigation with poor-quality wastewater. Risk assessment, using this model of irrigation with treated wastewater effluent that meets the WHO guidelines for vegetables eaten raw (1000 FC/100 ml), indicates that the annual primary infection risk of a disease such as hepatitis A is about 10^{-5} to 10^{-6}, and of diseases caused by rotavirus, *V. cholera*, and *S. typhi* – about 10^{-5} to10^{-6}.

It is worth mentioning that in developing the risk-assessment model, the worst possible scenario was used in order to reduce the uncertainty factor, and that disease transmission due to secondary infection was not taken into consideration. Therefore, the total number of cases may be higher than the number estimated on the basis of primary infection. The USEPA has determined that guidelines for drinking water microbial standards should be designed to ensure that human populations are not subjected to an annual risk of enteric disease infection greater than 10^{-4} (Regli *et al.*, 1991). Thus, this study suggests that the WHO wastewater effluent reuse guidelines provide a safety factor some one to two orders of magnitude greater than that called for by the USEPA for microbial standards for drinking water. Current findings correlated well with those recommended by Blumenthal *et al.* (2000), based on the revised WHO guidelines for treated wastewater used for agriculture (WHO, 1989).

According to the cost-effective analysis, the data suggest that the additional degree of risk reduction that might be attained by meeting the USEPA/USAID guidelines for water reuse (that require no detectable FC/100 ml), would, according to the most conservative estimate, result in expenditure of some US$1.2–5.5 million per case of disease prevented when $\alpha = 0.2$. However, if $\alpha = 0.5$ the cost would be as high as US$13.75 million. It is questionable whether such additional investments in high technology wastewater treatment facilities designed to meet the USEPA/USAID guidelines rather than the WHO guidelines, are justifiable, considering the small degree of additional health protection they might provide. However, the variable health burden incurred by the different diseases calculated as DALYs should also be considered.

Major chapters in this volume are devoted to the views of their authors on the benefits of using untreated wastewater in agriculture. In these authors' estimates the risk of becoming ill with an infectious disease, including very serious diseases with significant death rates and long-term consequences such as hepatitis A, from the consumption of salad crops irrigated with untreated wastewater is very high. It is conservatively estimated that some 20% of the exposed population (those eating raw vegetables) will become ill every year with one of the four diseases included in this study if they eat vegetables irrigated with untreated wastewater. The cost-effectiveness of treating wastewater to the WHO recommended guidelines against continuing to irrigate vegetables eaten raw with untreated wastewater would be about US$125/case of disease prevented. This can be considered a reasonably cost-effective level and a worthwhile investment in public health disease prevention. However, each community must make its own judgment on the level of investment it is prepared to make in preventing disease.

It must be pointed out that the model used in this study estimates the risk of infection and disease only of those who consume raw vegetables irrigated with untreated wastewater. It does not include the health risks to the farmers and irrigation workers exposed to untreated wastewater. Earlier studies (Shuval *et al.*, 1986) have shown that these risks are considerable, particularly in areas where hookworm and other parasitic diseases are endemic. Thus, in the authors' view, irrigating vegetable crops eaten raw with untreated wastewater is not a desirable public health practice. Treating wastewater to significantly reduce the concentration of pathogens along the lines recommended by the WHO appears to be the right way to go. But even somewhat less-rigorous treatment levels that are less costly could provide significant cost-effective health benefits. This study did not evaluate such alternative degrees of treatment.

It should also be noted that one of the common risks associated with present lifestyles is road accidents, which in Israel alone, reach an annual total of 7×10^3 injured. This value is similar to the risk of infection from eating untreated wastewater-irrigated vegetables, which can be lowered by 2–3 orders of magnitude if wastewater is treated to meet the WHO guidelines. Then too, injuries incurred by road accidents are far more serious and lethal than the enteric diseases resulting from the ingestion of vegetables irrigated with wastewater effluent. This example is presented in order to raise the issue that health-protecting investment should bear some rational relationship to the risks involved and the cost-effectiveness of the preventive measures.

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6 Wastewater Irrigation – Hazard or Lifeline? Empirical Results from Nairobi, Kenya and Kumasi, Ghana

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Abstract

The range of factors that determine the quality of wastewater used by different irrigators is described, drawing on case studies from Nairobi, Kenya and Kumasi, Ghana. Not all urban irrigation relies on raw wastewater and it is misleading to consider wastewater as a uniform commodity. Dilution and natural remediation mean that irrigators use a range of water qualities and the authors raise the question of when a dilute wastewater stream is no longer classed as wastewater. World Health Organization (WHO) guidelines for the design of wastewater treatment plants are widely used as standards to judge the quality of untreated irrigation water. However, because of the gap between standards that lead to 'no measurable excess risk of infection' and the actual situation pertaining in many cities, urban planners either condemn all urban irrigators as posing a major health risk to the community, or turn a blind eye. The authors argue that a standard leading to 'no measurable excess risk' to health is an unattainable and unhelpful medium-term goal under the conditions of indirect wastewater use seen in many cities. Instead, there is a need for explicit debate of the levels of risk that may be acceptable to individuals and communities, and the costs and benefits that they bring with them. Informed debate, that is enabled to assess the risks associated with different water qualities and irrigation practice, may lead to the development of local water quality norms and wastewater management that account for the physical and social environments in which wastewater irrigation is actually practised.

Introduction

Types of urban wastewater irrigation

The information presented here comes from a larger study of urban and peri-urban irrigation practices carried out in Nairobi, Kenya and Kumasi, Ghana, from 1998 to 2001. That research aimed to describe and quantify the nature, extent and importance of informal, irrigated agriculture in the urban and peri-urban zones of those cities (Cornish *et al.*, 1999, 2001; Cornish and Aidoo, 2000; Hide and Kimani, 2000; Hide *et al.*, 2001). The research focus was not confined to irrigation with wastewater or the hazards associated with its use. Rather, the intention was to understand the range of practices that exist with regard to water sources, water and crop management, crop marketing, and the contribution of informal urban and peri-urban irrigation to household income and expenditure. The research showed that in both cities a minority of irrigators use the urban potable water

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supply; many use shallow groundwater that is polluted to varying degrees whilst others draw water from streams or rivers that are also polluted to varying degrees by untreated, industrial and municipal wastewater. In Nairobi, 34% of the irrigators sampled diverted untreated sewage from trunk sewers directly onto their land. In Kumasi there is no extensive piped sewerage network and urban wastewater is either collected in septic tanks that are periodically emptied by tanker, or it is discharged directly into the small streams and rivers that drain the urban area. Tankers that empty the septic tanks discharge their contents into derelict waste stabilisation ponds that overflow directly into a river. Thus, whilst there is no direct use of untreated wastewater in Kumasi, many irrigators who draw water from the rivers downstream of the city are using a diluted wastewater stream. Table 6.1 summarises the different water sources used by informal irrigators in the two cities.

Table 6.1. Percentage of urban and peri-urban irrigators sampled drawing water from different sources.

Source	Nairobi (%)	Kumasi (%)
River/stream	51	38
Shallow well	4	46
Sewerage main	34	0
Urban potable water supply	3	3
Other (pool, deep well, etc.)	8	13

In introducing this chapter the following points are emphasised:

1. *Treated* wastewater is not being used for irrigation in either city to the best of the authors' knowledge. Irrigation is informal and irrigators obtain water where they can. In many cases their water source is highly polluted and in Nairobi raw sewage is used. It seems reasonable to presume that informal use of dilute and undiluted, *untreated* wastewater is common in other urban areas in sub-Saharan Africa.
2. It is an over simplification to consider 'urban wastewater irrigation' as a single activity with uniform characteristics, amenable to a standard response from planners, policy makers or technologists. Rather, there is a range of different physical conditions under which urban wastewater irrigation occurs. These conditions influence both the levels of risk to health faced by growers and consumers, and possible interventions that may reduce those risks while maintaining the benefits to irrigators and possibly to the wider environment. Recognition of this variation in conditions is essential to any effective discussion of wastewater irrigation practice, or to the formulation of recommendations regarding its regulation.
3. The issue of mixing, and thus diluting wastewater, with water from a natural water body merits comment: at what point does urban wastewater become simply a polluted water body? Many will know of urban 'rivers' and other water bodies that are little more than open sewers or cesspits. Although some mixing and dilution of wastewater has occurred in these water bodies it seems misguided to exclude them from a consideration of wastewater irrigation as they are characterised by the presence of urban wastewater. There is a need to define a level of dilution at which wastewater becomes polluted 'natural' water, but proposing that definition lies beyond the scope of this chapter.

Figure 6.1 shows the range of factors that determine the nature of wastewater irrigation at any location. The only non-physical factor considered is whether the irrigation takes place in a formal (authorised) or informal (unauthorised) setting. The figure does not include the wider social, economic or institutional factors that influence any given practice, although these are recognised as having an important influence on irrigators' behaviour.

Figure 6.1 may not constitute a formal typology of wastewater irrigation, but it emphasises the range of factors that influence both the physical and biochemical quality of wastewater used for irrigation. The elements of Fig. 6.1 are used to describe three different types of wastewater irrigation practice drawn from sites in Nairobi and Kumasi.

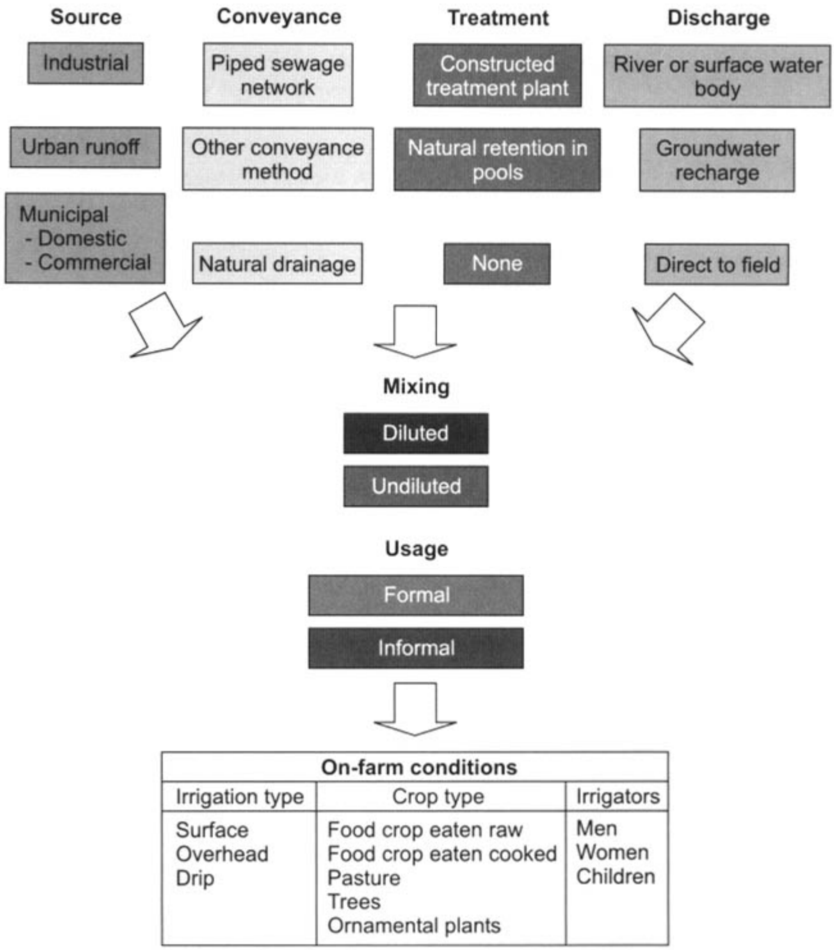

Fig. 6.1. Factors determining the nature of wastewater irrigation. Diluted = Effluent mixed with other water before use in irrigation. Undiluted = No significant dilution of the effluent in a river or other water body before use in irrigation. Formal use = Use of wastewater with a certain level of permission and potential control by state agencies. Informal use = Use of wastewater without permission and control by state agencies.

Physical factors include the source of the wastewater, the means by which it moves from the source to the field, and whether or not any treatment occurs. 'Discharge' describes whether or not the wastewater is discharged into an intermediate water body – surface or groundwater – where dilution occurs before an irrigator obtains it for use. The differentiation between formal and informal (authorised/ unauthorised) irrigation – an institutional factor – is often determined by whether the wastewater is obtained from a small number of potentially controllable locations, or from numerous, unknown locations. The on-farm conditions identified are those considered to have the greatest influence on the level of risk to health for either the irrigators or those consuming the crops they produce.

Types of Wastewater Irrigation in Nairobi and Kumasi

Mau Mau Bridge, Nairobi

Mau Mau Bridge lies upstream of Nairobi's city centre and its industrial zone (see Fig. 6.2). There are irrigated farm plots adjacent to the Nairobi River. Farmers have constructed small dams and weirs in the river to divert water through channels to the lower areas of their farm plots. Using buckets and watering cans, water is drawn from hand-dug ponds at the end of the channels, to irrigate crops at higher elevations in the farm plots. On-farm irrigation methods therefore include surface furrows or basins and overhead sprinkling from cans.

Although Mau Mau Bridge is situated upstream of the main city and industries, slums are located on the slopes above the Nairobi River. Waste and wastewater from the slums are dumped onto the streets and into natural drainage channels from where they find their way into the river. Thus, untreated municipal wastewater mixes with river water and it is this mixed water that the irrigators at Mau Mau Bridge use.

A typical plot size is 60 × 20 m and farmers grow a mixture of vegetables, including tomatoes, cabbage, spinach, maize and French beans. Some of these are eaten raw and others are cooked before consumption. Crops are mainly grown for the local market but small quantities are also consumed by the irrigators' families. All members of the irrigators' families carry out irrigation and other farm work.

Maili Saba, Nairobi

Maili Saba is 15 km east and downstream of Nairobi city (see Fig. 6.2). There are both similarities and contrasts with Mau Mau Bridge in the way wastewater is obtained and

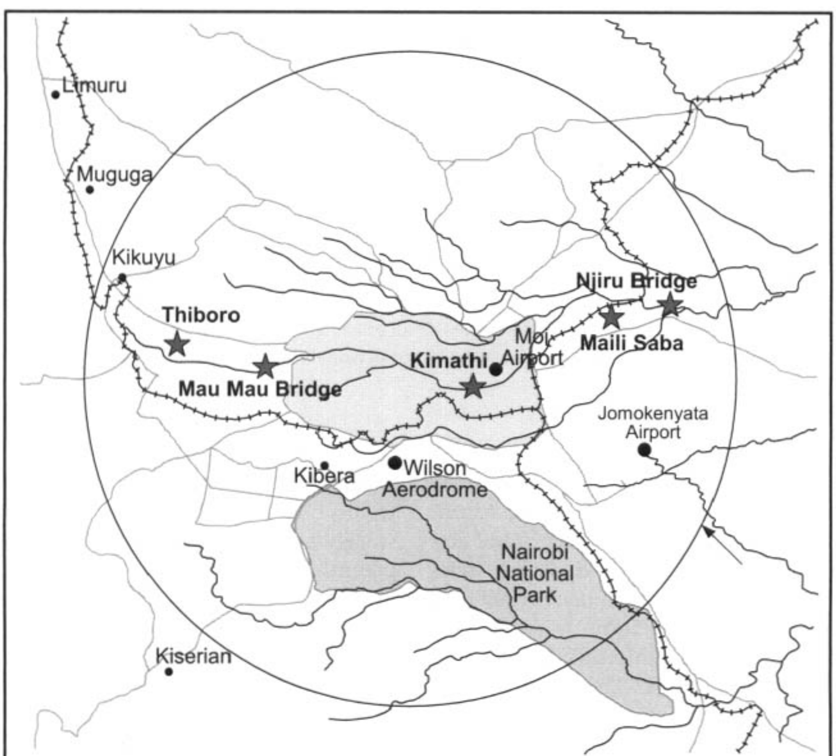

Fig. 6.2. Location of water-sampling sites (★) with a 20 km radius of Nairobi city centre (Hide *et al.*, 2001).

used. At both sites the practice is informal with no government permission or infrastructure provided to support irrigation. However, at Maili Saba farmers remove manhole covers and block the city's main sewer, diverting raw sewage onto their land. Their plots, typically 20 × 40 m, are irrigated by surface irrigation from a hand-dug canal system. Buckets or watering cans are not used. Irrigators grow kale, sweet potato, arrowroot and some green maize – crops that are cooked before being eaten. Much of the production is for home consumption but some is sold at the local markets. Assuming that the produce is well cooked the health risks associated with the use of undiluted sewage are confined to the family members including men, women and children who carry out the irrigation.

Asago, Kumasi

Asago is situated 9 km downstream of Kumasi at the confluence of the Sisa and Oda Rivers (see Fig. 6.3). The Sisa collects untreated and partially treated municipal wastewater and untreated industrial wastewater. The wastewater constitutes municipal and industrial effluent, conveyed to the river by both road tankers and natural drainage flows. Farmers at Asago draw irrigation water from the perennial River Oda either by bucket, or other container or using motorised pumps (hired or owned). Considering the factors identified in Fig. 6.1, wastewater irrigation at this site is informal use of diluted wastewater using river water that has been mixed with untreated or insufficiently treated wastewater from stabilisation ponds.

All farmers use some form of overhead application to irrigate a mix of vegetable crops including tomato, African aubergine (*Solanum integrifolium*) okra and chilli, some of which are always cooked and others eaten raw. Water is applied with watering cans, buckets or perforated tins. Irrigators who use pumps use PVC pipes to convey the water from the pump to a position within their fields and connect a short length of 50-mm lay-flat hose to the final pipe length. A worker then stands and sprays water from the hose-end onto the crop.

The vegetables are mainly grown for the Kumasi market but small quantities are also consumed at home by all members of the family, who carry out irrigation and other farm work.

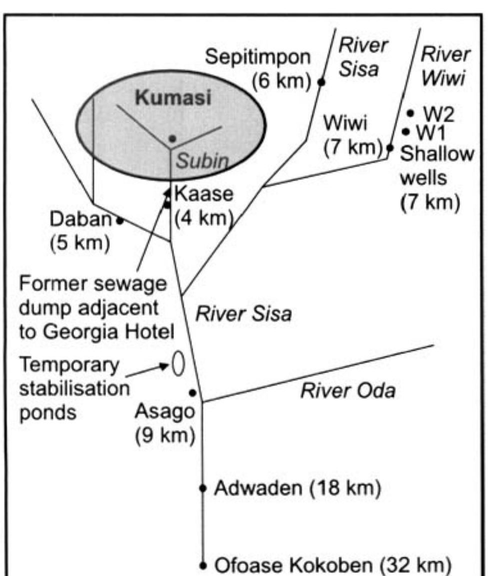

Fig. 6.3. Location of water-sampling sites relative to Kumasi city centre (Cornish *et al.*, 1999).

Variations in Water Quality Between Sites

Field measurements of faecal coliform numbers demonstrate the large variation in microbiological water quality between sampling sites and the danger of considering all urban wastewater irrigation as equal. In all but two of the sites the mean faecal coliform count exceeds the World Health Organization (WHO) *Health Guidelines for Use of Wastewater in Agriculture and Acquaculture* (WHO, 1989) but the degree of exceedence varies widely. The question of whether guidelines, developed for the design of wastewater treatment plants assuming a requirement for 'no measurable excess risk' are appropriate and adequate for making judgements of health risk in diverse field conditions such as these, lies at the heart of this chapter and is examined in more detail below.

Following the example of Westcot (1997) mean faecal coliform count was used as the sole indicator of biological water quality for health risks. It is recognised that helminth infections pose the greatest of the risks associated with wastewater irrigation and that the WHO guidelines specify threshold values for both faecal coliform and helminth egg numbers. However, whilst laboratories and technicians are readily able to measure faecal coliform numbers, procedures for the accurate detection of helminth eggs are more demanding and less widely known. For this pragmatic reason, helminth egg numbers were not measured or reported.

Figure 6.4 shows the mean numbers of faecal coliforms recorded at different locations in a. Nairobi and b. Kumasi. Five samples were collected at 10-day intervals over a 40-day period. The sampling sites included three river sites, one well and one sewerage outlet. Their location relative to Nairobi City centre is shown in Fig. 6.2. The sampling sites in Kumasi included seven river sites and two wells. Their locations relative to central Kumasi are shown schematically in Fig. 6.3. Five samples were collected at 6-day intervals over a period of 26 days. In both cities the sampling period coincided with the dry season, when irrigation is mainly practised.

Most of the data from Nairobi show very high levels of pollution. Numbers of faecal coliform in the Nairobi River at Kimathi and Njiru Bridge, both situated downstream of the city centre, are as high as those recorded in effluent drawn directly from sewerage mains at Maili Saba. This is 10,000 times greater than the limit for unrestricted irrigation recommended by the WHO design guidelines for treated wastewater. Water at Mau Mau Bridge contains faecal coliform numbers that are 10 times greater than the recommended value. Mau Mau Bridge is situated upstream of Nairobi's city centre where the Nairobi River water has only been mixed with municipal wastewater collected and disposed into the river through natural drainage channels. Only water drawn from the shallow well at Thiboro, upstream of Nairobi, yields water that lies within the WHO guideline limits.

In Kumasi levels of pollution are generally lower, with water from the two sites upstream of the city centre lying on or near the WHO threshold value for unrestricted irrigation. Asago, the most highly polluted site, exceeds the guideline by only 2-log. At Asago farmers draw their water from the perennial River Oda. This water is mixed with municipal and industrial effluent conveyed to the river by road tankers and natural drainage flows.

There is clearly great variation in the quality of the water used at different locations. This must be recognised in evaluating the likely health risks. Single threshold values, intended as a guideline in the design of treatment plants, even when they account for different forms of irrigation and crop types say nothing about the different levels of risk posed at these various sites.

Positive Impacts of Urban Wastewater Irrigation

The extent of urban wastewater irrigation and its contribution to food security

The areal extent and the number of households relying on irrigation within the two study areas are shown in Table 6.2. It is important to note that not all of these irrigators are directly reliant on wastewater. The two city studies characterised urban and peri-urban irrigation irrespective of water type. Farmers using shallow groundwater in areas remote from rivers draining the urban centres are not using a wastewater source, although the shallow wells

Table 6.2. Extent of informal irrigation in the study areas.

City	Gross study area (km^2)	Mean irrigated plot area[a] (ha)	Minimum number of households involved in irrigation	Estimated minimum area of irrigation (ha)
Kumasi	5,027	0.94	12,700	11,900
Nairobi	1,257	0.60	3,700	2,220

[a] Estimates are based on sampling of 410 farmers in Kumasi and 158 farmers in Nairobi.

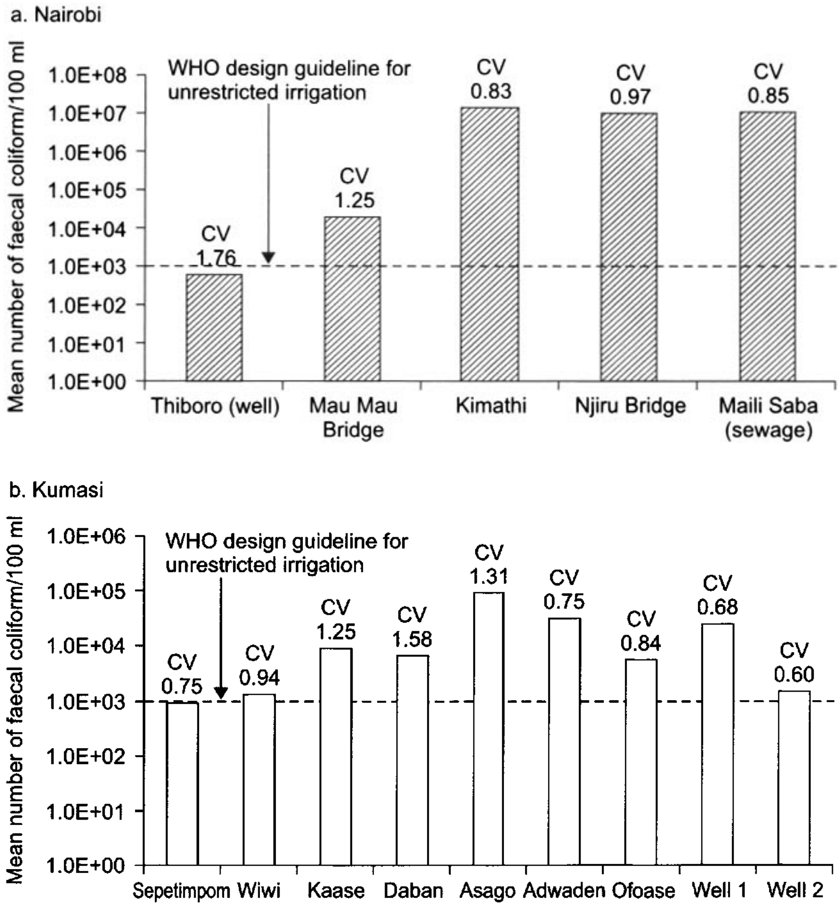

Fig. 6.4. Geometric mean faecal coliform (count/100 ml) and coefficient of variation (CV) at different sites in Nairobi (mean of at least 5 sampling dates (Hide *et al.*, 2001).

sampled in Fig. 6.4 still indicate relatively high levels of faecal coliform contamination in the water they use.

The large area of informal irrigation within a 40-km radius of Kumasi contrasts with the 6,400 ha under formal irrigation reported in the Food and Agriculture Organization's (FAO's) statistics for the whole of Ghana (FAO, 1995). Kumasi alone supports an area of informal irrigation almost twice that of all formal irrigation in the country, and further substantial areas of informal irrigation exist around Accra and Takoradi.

The smaller area of informal irrigation identified around Nairobi was recorded over a much smaller study area. Irrigated crop production is, for many, a relatively new activity. It is quite possible that such wastewater irrigation will continue to expand in the coming years. Figures on irrigated areas in Kenya for 1998 reported by the Ministry of Agriculture and Rural Development (cited by Muchangi in HR Wallingford, 2001) identify only 1,500 ha of urban irrigation for the whole country. This study identified more than 2,200 ha of informal irrigated agriculture within 20 km of the centre of Nairobi. As in Ghana, it appears that the extent and importance of urban irrigation is under-reported in official statistics.

In Nairobi, the average annual revenue per ha from irrigated plots is US$1,770, indicating that from the urban irrigated sector vegetables worth as much as US$3.9 million are being used in Nairobi each year. The seasonal (Nov-

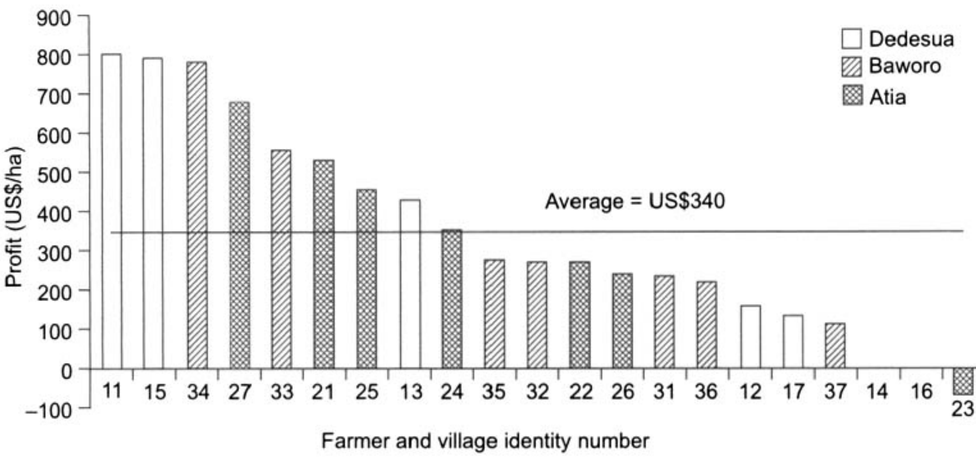

Fig. 6.5. Seasonal (November-May) profits (US$/ha) from irrigated cropping for 21 Kumasi farmers in three villages (Cornish *et al.*, 2001).

ember–May) average revenue per ha for production around Kumasi was US$544 indicating a total value of food production in excess of US$6 million.

The studies did not determine what fraction of the total annual vegetable consumption of the two cities these production figures represent, and did not consider that all of the production does not pass through the main city markets; some is sold in smaller, local markets outside the urban centres. However, it is clear that informal urban irrigation, much of which relies on wastewater sources, contributes significantly to the supply of fresh vegetable produce in both Nairobi and Kumasi.

Contribution of urban wastewater irrigation to the livelihoods of irrigators

Income generation is the main objective for most irrigators in Nairobi and Kumasi. Only a small percentage of the farmers surveyed said that directly supplementing their food supply was their main goal. By generating cash income, urban irrigation is an important means of alleviating poverty and enhancing livelihoods.

The average profit recorded in three different peri-urban villages around Kumasi is remarkably similar, indicating that different sources of water, distance to market, or other factors determined by location do not have a major influence on profit. There is certainly no evidence that water quality influences levels of income in the Kumasi study.

Although average profit in each village is similar, Fig. 6.5 shows that there is a wide range of levels of profit recorded by individual farmers. Numbers on the x-axis identify individual farmers – farmers 11–17 from village 1 (Dedesua), 21–27 from village 2 (Baworo) and 31–37 from village 3 (Atia). Farmers from all three villages are distributed across the whole range of profit per ha. Although the average profit is around US$340/ha, four of the farmers recorded profits of between US$650–800/ha. As the actual plot sizes are much smaller than a hectare the actual profits of these four farmers were in the range of US$220–470.

The situation in Nairobi is quite different. On average, incomes and profits per hectare are higher than in Kumasi, but plot sizes are much smaller. Furthermore, there is a clear trend in the levels of expenditure, income, and profit according to location.

Farmers to the east of Nairobi, at Thiboro operate on a commercial basis, albeit on very small plots, investing heavily in paid labour and other production inputs. Levels of revenue and profit reflect this investment with an average actual profit (from 0.126 ha) of US$607 (US$4,816/ha). At Mau Mau Bridge there is high investment in production inputs, but no use of hired labour. The average revenue during the period of study was low due to a pest attack on a crop of green peppers. This clearly illustrates the relatively high-risk nature of irrigated vegetable production. Average actual profit was just US$86 or US$1,036/ha. The agricultural practices at Maili Saba are more subsistence in nature. Few exotic market vegetables are grown and very few inputs are purchased. Actual average profits were about US$70 (US$1,404/ha) during the study period June–September 2000.

Trade-offs of urban wastewater irrigation

The case studies show that urban wastewater irrigation has a positive effect on the financial capital of the urban irrigators. However, wastewater irrigation potentially bears risks that may weaken the human, natural, and social assets of the irrigators and their families, making them more vulnerable to external shocks. Apart from the direct risk to health, water polluted with industrial effluents may also pollute soil and groundwater, thereby undermining the long-term sustainability of the natural resource base. An analysis of the risks would help to understand the actual trade-offs on the sustainability of the livelihoods of urban irrigators and their families: Do the benefits outweigh the risks and negative impacts of wastewater irrigation, and over what time frame should such benefits and costs be assessed? The recent increases in the numbers of urban dwellers engaging in urban wastewater irrigation in Nairobi and Kumasi indicate that in irrigators' and family members' own assessment the benefits outweigh the risks, at least in the short term.

Whatever the benefits may be for the irrigators, policy makers must safeguard the wider public interest. Although irrigation with untreated wastewater contributes substantially to the availability of fresh vegetables, and under controlled circumstances may be environmentally acceptable and a beneficial means of waste disposal, uncontrolled wastewater irrigation can lead to both chronic ill-health and more serious outbreaks of disease amongst irrigators and consumers. Policy makers and others working in this field need clearer guidance on the levels of risk associated with use of different qualities of untreated wastewater if they are to assess the trade-offs that exist between the costs and benefits. Some types of wastewater irrigation documented in these studies are probably unsustainable and may be regarded as unacceptable by most communities, when given information. However, in the absence of guidelines aimed specifically at the management of untreated wastewater irrigation it is difficult to make informed judgements about the costs, benefits, and trade-offs, associated with different practices.

The Dilemma

At present there are no microbiological irrigation water quality standards that acknowledge the concept of an acceptable level of health risk for irrigators and the wider community, other than zero risk. In the absence of other norms, the WHO microbiological quality guidelines for the design of wastewater treatment plants, where the effluent is intended to be used for irrigation, are used extensively to evaluate the health risks arising from the use of polluted water sources for irrigation (WHO, 1989). These guidelines are designed to ensure **'no measurable excess risk'** of infection attributable to the use of wastewater as evaluated from epidemiological studies and risk assessment models. The guidelines prescribe that for unrestricted irrigation the faecal coliform (FC) count may not exceed 1,000/100 ml and that the helminth egg count should be below 1/l. FAO promotes the use of these guidelines to monitor the quality of water used to irrigate vegetables and other high-risk crops in the absence of other microbiological irrigation water quality standards (Westcot, 1997).

In adopting these guidelines for controlling the quality of water used for irrigation two anomalies emerge. Firstly, water for irrigation must meet a higher standard than that set by the British Government's Statutory Instrument 1991 No. 1597 for coastal and freshwater bodies used for bathing (HMSO, 1991), which sets a limit of 2,000 FC/100 ml. Secondly, and more significantly, a high percentage of the world's freshwater resources do not meet WHO water quality guidelines for unrestricted use, while in practice these waters are diverted for unrestricted irrigation. Data published by WHO (1989) show that 45% of 110 rivers tested around the world have FC levels of above 1,000/100 ml, while 15% have levels over 10,000/100 ml. In China 27% of the river sections monitored have a coliform count of more than 10,000/100 ml. It may be expected that near urban centres the water quality will be poor. Rapid urbanisation is putting further pressure on sanitation and treatment infrastructure that is already inadequate. In developing countries, where the majority of the large cities are located, the costs of necessary investments in water supply, sanitation and treatment facilities are far beyond those countries' present economic potential (Niemczynowicz, 1996). In the foreseeable future, surface water quality close to urban centres is likely to deteriorate further rather than to improve, and irrigators will continue to use it. To insist that only *treated* wastewater be used for irrigation seems an unrealistic goal. What planners and technocrats urgently need is guidance on the levels of risk associated with the use of water whose quality falls below the ideal, 'no risk' threshold set in the present WHO guidelines.

Conclusions

A large number of urban and peri-urban irrigation farmers around Nairobi and Kumasi are using various forms of untreated wastewater for irrigated cropping under unregulated and informal arrangements. In general, both the numbers of irrigators and the volumes of untreated wastewater seem certain to increase in the short to medium term, as urban populations grow and investment in wastewater treatment infrastructure is constrained.

In these two case-study cities the wastewater used for irrigation displays a wide range of microbiological quality depending on location, dilution, and the effects of natural remediation. It is misleading to consider 'wastewater irrigation' as a single activity with uniform characteristics. The various pathways of wastewater acquisition, from source to field, must be identified and differentiation made between them.

Some forms of wastewater irrigation not only offer important financial gain to the growers, they may also represent a low-cost and beneficial means of using and 'treating' wastewater within acceptable and controllable levels of disease risk. However, so long as the focus remains on the management of formally treated wastewater and a policy of 'no measurable excess risk to health', guidance on what might constitute an acceptable risk, the risks associated with different types of practice, and the tools needed to make informed, pragmatic judgements remain lacking.

By using the WHO guidelines to make judgements over the safety of the use of wastewater, without taking the various 'types' of urban wastewater irrigation into consideration, policy makers and technocrats are driven towards inappropriate conclusions. There is inevitably a huge gap between a standard leading to 'no measurable excess risk of infection attributed to the reuse of wastewater' and the situation on the ground. Faced with such a gap, reactions are either to condemn urban irrigators as posing a major health risk to the community or to turn a blind eye because action seems impossible and ignorance is the preferred course. Neither approach is helpful and both are driven by the lack of appropriate standards, inappropriate use of the WHO microbiological quality guidelines for treated wastewater use in irrigation, and a failure to differentiate between different qualities of wastewater flows. In Nairobi, for example, after the publication of studies on informal irrigation in the peri-urban zone, and the wider emergence of 'urban agriculture' as a planning issue, city authorities are now motivated to ban the practice without taking account of the various types of urban wastewater irrigation, and the range of water qualities which largely define the actual risks involved.

As explained by Hespanhol and Prost (1994) guidelines produced by the WHO are intended to provide guidance for making risk-management decisions related to the protection of public health based on current scientific research and epidemiological findings. They provide a common background from which national and regional standards can be derived. However, for the development of national or regional standards the economic, technical, social, cultural and political contexts need to be taken into consideration. Such an approach inherently incorporates a risk-benefit analysis. Shuval *et al.* (1997) describe a risk-assessment model that estimates the risk of infection associated with eating vegetables irrigated with wastewater of varying microbiological quality. The first step in applying risk-assessment approaches is the definition of an 'acceptable' risk of infection. Therefore, there is a need for explicit debate on the levels of risk that may be acceptable to producers and consumers of wastewater-irrigated crops and the costs and benefits that they bring with them. Pragmatic water quality standards based on such an approach that are pertinent only to the use of untreated wastewater, can better inform policy makers and technocrats as they seek to manage the real situation on the ground.

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7 National Assessments on Wastewater Use in Agriculture and an Emerging Typology: The Vietnam Case Study

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Abstract

The use of urban wastewater in agriculture is a common practice for diverse reasons, not least of which are water scarcity, fertiliser value, and lack of an alternative source of water. It is necessary to have a clear understanding of wastewater's importance and significance in terms of extent, agricultural production, and livelihood impacts before appropriate policies, strategies and guidelines for its use in an integrated water management framework are developed. The Vietnam nationwide assessment was the pioneer in a series of such assessments being undertaken by the International Water Management Institute (IWMI). Findings indicate that 75% of domestic wastewater in large cities and 45% in smaller cities are discharged into sewers. Wastewater is used for agriculture or aquaculture in 93% of the cities. On an average wastewater is used in at least 2% of the agricultural land around most cities, predominantly to grow rice. The nationwide total of such irrigation is conservatively estimated at around 9,000 ha. Wastewater aquaculture is carried out in natural ponds which serve the dual purpose of inundation control and as collection sinks for city wastewater. Wastewater agriculture provides a primary or secondary source of income to 1% of the urban population. The corresponding figure for wastewater aquaculture is 0.1%. Factors that influence the use of wastewater in non water-short regions have emerged, showing a possible pattern of wastewater use under these conditions. A key result from this study is the need for a typology that effectively captures all these characteristics, as a prerequisite for a global assessment.

Introduction

The use of urban wastewater in agriculture is a common practice, not only in arid and seasonally arid zones but also in non water-short countries like Vietnam. The reasons for this are diverse and dependent on the situation and local context. For instance, in Pakistan, wastewater is used for its water value even in untreated form, and as a source of plant nutrients. In Ghana it is used because an alternative non-polluted source of water is not available. The added benefit of its fertiliser value is incidental. In Mexico, large areas of land are irrigated with partially treated and/or diluted wastewater.

(eds C.A. Scott, N.I. Faruqui and L. Raschid-Sally)

The reasons for wastewater use, the diverse conditions under which it is used, and its impacts are still not clearly understood and require further research before amelioration techniques and technologies can be suggested.

In most developing countries wastewater is used untreated, partially treated or diluted, but policies governing its use are not adapted to the local contexts. A clear understanding of its importance and significance at a global level in terms of extent, agricultural production, and livelihood impacts would contribute to developing appropriate policy and legal frameworks for wastewater use within an integrated water resources management framework.

The Vietnam nationwide assessment is part of an initiative (part of the Comprehensive Assessment of Water Management in Agriculture) to assess the global extent of wastewater use. There are claims that worldwide more than 20 million ha are irrigated with urban wastewater but at present there is a gap in knowledge about global estimates, and the possible trade-offs between health and environmental impacts, and the livelihoods-related benefits for those using wastewater. A survey of literature on wastewater agriculture indicates that this was the first study of its kind ever attempted at a national level, necessitating the design of a research methodology suitable for this purpose. Documenting the situation in Vietnam provided insights on agricultural wastewater use practices where water scarcity is not always the major consideration. It also served to gain an understanding of the constraints and limitations of such an assessment, and the importance of developing a clear typology for future assessments.

Background

Vietnam is one of the developing countries where wastewater has been used for decades – even centuries – by poor farmers in urban and peri-urban areas for both agriculture and aquaculture. Located in the tropical monsoon belt of Southeast Asia, Vietnam has mean annual rainfall ranging from 1700 mm in the north to 2000 mm in the south with temperatures ranging from 13° to 35°C that are favourable for agricultural production, especially paddy rice cultivation. Its territory of 333,000 km^2, with a population of approximately 77.7 million people in 2000, is officially classified into eight geographical regions, namely: northeast (NE) and northwest (NW) mountainous regions, the Red River delta (RRD), north central coast (NCC), south central coast (SCC), central highland (CH), southeast (SE) and Mekong River delta (MRD).

In spite of *doi moi* (renovation) reforms in 1986, the country is still rated one of the world's poorest with a predominance of poverty in rural areas. Irrigation plays a significant role in agricultural production, which represents approximately 25% of the country's gross national product. Despite the general abundance of freshwater resources, wastewater, both domestic and industrial, is used extensively in some areas, e.g. in the peri-urban areas of Hanoi particularly in the Thanh Tri, and Tu Liem districts, where it contributes significantly to food production and food security in the cities. About 80% of Hanoi's vegetable demand is satisfied from wastewater agriculture (Tran Van Lai, 2000), and the system seems to be generally accepted by consumers.

Survey Design

Scope and sample selection

There are 57 provincial capitals in Vietnam distributed within eight geographical regions, and four cities directly under central government rule. In selecting a sample of cities/towns to be surveyed, the following were left out: those in the mountainous NW region (inaccessible), those that had no known wastewater irrigation (e.g. in predominantly forested provinces), and those in the delta floodplains (difficulty in designating specific wastewater irrigated areas). The sample of 30 cities finally selected represented different city classes that are designated in Vietnam according to population and available infrastructure facilities.

The sample cities covered seven of the eight geographical zones (NW excluded). In MRD only one city, Tanan (in Longan province), located southeast of Ho Chi Minh City, was included. The total population of the cities surveyed was 14.7 million amounting to

Table 7.1. Provincial capital cities selected for Vietnam nationwide survey, roman numerals indicate city class.

North		Central			South	
NE	RRD	NCC	SCC	CH	SE	MRD
Viet Tri V	Nam Dinh II	Thanh Hoa IV	Da Nang II	Buon Ma Thuot IV	Thu Dau Mot IV	Tan An IV
Thai Nguyen I	Ninh Binh V	Vinh II	Quang Ngai IV	Da Lat III	Bien Hoa II	
Bac Giang IV	Hai Duong IV	Ha Tinh V	Tuy Hoa IV	Plei Ku III	Ho Chi Minh I	
Bac Ninh IV	Hanoi I	Dong Hoi V	Tam Ky IV		Vung Tau II	
	Hai Phong II	Dong Ha IV	Quy Nhon II			
	Thai Binh IV	Hue II				
	Ha Dong IV					

approximately 19% of the total population of the country (Table 7.1).

Data Collection and Validation

Data on water supply, sanitation and sewerage infrastructure, wastewater generation (sources, management), wastewater agriculture and aquaculture (areas, production, characteristics), and general social, health, and crop impact were collected from secondary data sources and through a questionnaire survey accompanied by indepth interviews administered to officials of the Department of Land Administration, Statistics, Agriculture and Rural Development, Transportation and Public Works, Science, Technology and Environment, and the Irrigation and Drainage Management Company.

Working on the assumption that most wastewater use would be in urban and peri-urban areas of cities, simplified definitions for the following terms suited to the study were developed.

- **Target study area** – the metropolitan area of each city, including its urban centre and the suburban areas falling within the city boundaries.
- **Urban wastewater** – a combination of domestic effluent (both blackwater and greywater), industrial, commercial and institutional effluent including hospital waste, and other urban and storm runoff. Irrigation and drainage canals and other water bodies, which receive untreated wastewater and are highly polluted, may also be considered as wastewater.
- **Wastewater irrigated area**
  a. When water for irrigation was taken from a *wastewater drainage canal* the whole area irrigated with this water was included in the wastewater irrigated areas, e.g. Hanoi agricultural areas.
  b. When water was taken from an *irrigation and drainage dual canal* that was receiving wastewater, the area designated as wastewater-irrigated was limited to the area close to the receiving point where sensory negative impacts on users, e.g. bad smell, itching were known.
  c. When water was taken from an *irrigation canal receiving city wastewater*, the wastewater irrigated area was calculated as a fraction of the irrigated area within the city limits corresponding to the proportion of wastewater in the canal.
- **Wastewater aquaculture** – the use of natural stabilisation ponds and man-made ponds receiving wastewater to cultivate fish.

A pilot study was conducted in Hai Duong city, to test the questionnaire and its relevance, before launching the full-scale exercise. Maps were used when possible to localise areas, and field observations were made when time permitted. Written materials made available by local authorities were also used. Data validation for five selected cities was conducted either through a further visit or by telephone interviews with authorities. No major discrepancies were noted although it must be understood that some of the data were figures provided by the local authorities, with no independent confirmation. Due to lack of secondary data, e.g. domestic and industrial water demand, etc.

in many instances these had to be estimated by local officials. Data reliability turned out to be a major shortcoming that is likely to plague other attempts at national and global assessments despite clear definitions.

Results and Discussion

Classes of cities and population

The survey covered 50% of the largest cities in Vietnam. These cities account for 19% of the national population. The two largest cities, Hanoi and Ho Chi Minh City, accounted for 54% of the population covered.

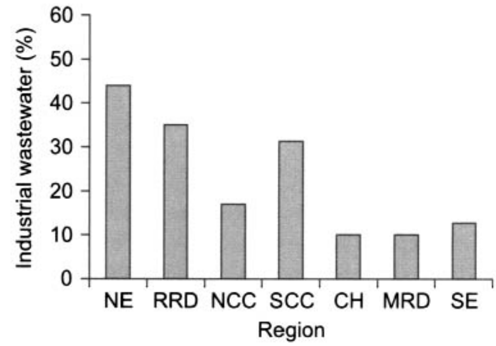

Fig. 7.2. Proportion (%) of industrial wastewater (including hospital wastewater) in total wastewater in various regions (see Fig. 7.1) of Vietnam.

Water supply and sanitation

Surface water provided the sole source of water supply in 12 cities (40% of all those surveyed). Groundwater alone was used in 5 cities (17%). In 13 cities (43%) both surface and groundwater were used. In some cities, although groundwater is the source, the wells are close to the river, e.g. the Red River in the case of Hanoi.

Most cities in Vietnam have some sewerage and wastewater drainage coverage. Sewerage systems are covered networks but the drains carrying city wastewater may be open. Data show that in larger cities about 75% of the domestic wastewater drains into municipal sewerage systems of some sort, and in the smaller cities this figure is 45%.

Industrial wastewater is sometimes discharged into municipal collection systems when an alternative is not available. Industries close to rivers tend to discharge their wastewater directly into the rivers. There is no discernible pattern in the proportion of industrial wastewater to total wastewater that can be related either to the size of the city or the geographic region (Figs 7.1 and 7.2).

In total, out of 2.7 million m^3/d of fresh water consumption in the 30 cities, 77% returns to nature as wastewater; domestic wastewater constitutes between 60–90% of this.

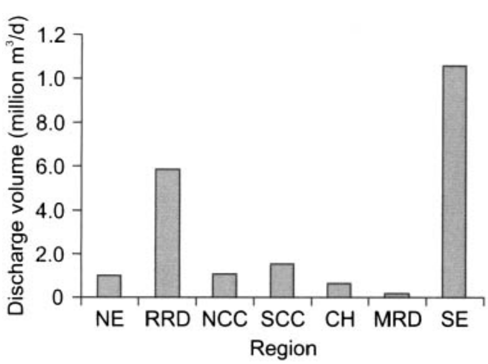

Fig. 7.1. Total wastewater discharge by region in Vietnam. (NE = northeast, RRD = Red River delta, NCC = north central coast, SCC = south central coast, CH = central highland, SE = southeast, MRD = Mekong River delta).

Pattern and extent of wastewater use

In 93% of the surveyed cities (28) wastewater is used for agriculture or aquaculture or both. More cities use wastewater for agriculture (80%) than for aquaculture (63%).

Agricultural land use

According to our definition of target study area, six of the 30 surveyed cities have urban and peri-urban agricultural land areas exceeding 10,000 ha. Three of the four city provinces (Hanoi, Ho Chi Minh, and Hai Phong) have the largest agricultural land areas constituting a high proportion (>45%) of the total land area in each city.

Wastewater agriculture

In the 30 cities surveyed, agricultural land accounts for 35% of the total land area. Wastewater irrigated areas vary from 0.5–5% (average 1.6%) with 70% of the cities falling within the range of 1–2% (Table 7.2).

On a regional basis, the highest proportion of wastewater-irrigated land is in NCC, possibly due to the water scarcity in that area. However, a similar pattern is not observed in SCC, which is also water-scarce but where most of the cities surveyed are coastal either without available agricultural land, or where most wastewater is discharged directly into the sea.

Cropping pattern related to wastewater use

Generally in Vietnam there are three cropping seasons; spring, summer and winter (Fig. 7.3). The predominant crop in both wastewater and non-wastewater areas is paddy rice, also called lowland rice. Rice is grown on 76% of the area in the spring and on 85% in the summer. Vegetables and upland crops (corn, maize, sweet potatoes, groundnut, soybean) are also grown. Wastewater is used markedly less in winter than in other seasons, because paddy rice that requires a lot of water, is not a winter crop.

Reasons for use of wastewater for agriculture

Unlike in many arid and semi-arid countries, where urban wastewater is sought after and used extensively, in Vietnam the underlying reason for its agricultural use is the unplanned

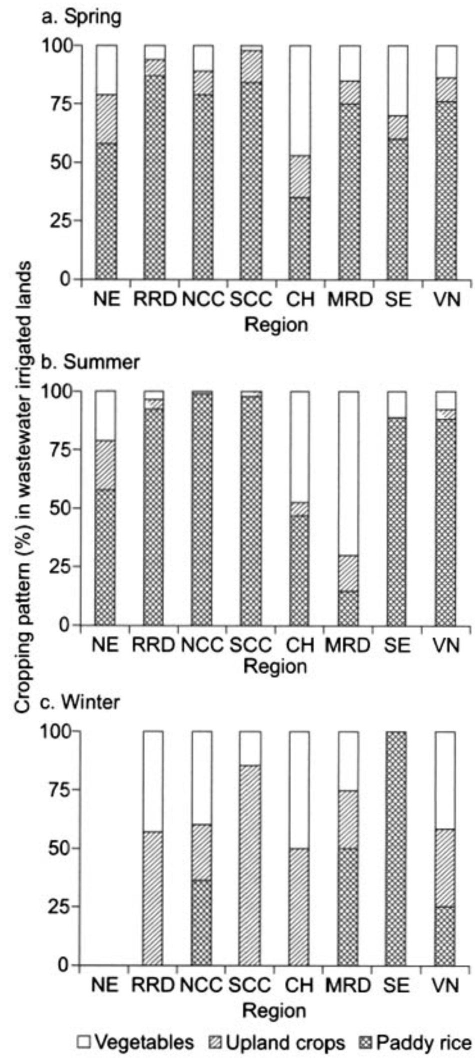

Fig. 7.3. Cropping patterns in wastewater-irrigated areas across regions (see Table 7.1) of Vietnam by season.

Table 7.2. Agricultural land and wastewater-irrigated agriculture by city class in Vietnam (surveyed cities).

City class	Land area (ha)	Agricultural land in city (ha)	Agricultural land as % total land area		Area irrigated with wastewater (ha)	Wastewater-irrigated area as % agricultural land	
			Mean	Range		Mean	Range
I	301,599	140,234	46.5	–	2,561	1.8	1–4
II	397,267	111,798	28.1	8–58	485	0.4	0–4
III	88,172	18,708	21.2	7–40	215	1.1	0.3–3
IV	45,122	25,345	56.1	42–66	1,368	5.4	0–17
V	61,413	17,035	27.7	16–74	243[a]	1.5[a]	0–10
Overall	893,573	313,120	35.0	–	4,871[a]	1.6[a]	–

[a] Excludes Ninh Binh where most of the wastewater used is from a thermal power plant and is therefore not representative.

discharge of wastewater into natural water courses, drainage canals or irrigation canals. However, intentional wastewater use occurs in some instances due to inadequacy of irrigation systems particularly at the tail end. Survey results show that approximately 60% of the cities use wastewater because of its unplanned management that results in discharge into natural watercourses or drainage canals. City officials who were interviewed recognise wastewater's nutrient and water value, but less than 10% of the available wastewater is used. Farmers were not interviewed in this survey, but from the authors' experience in other discussions, farmers value the wastewater particularly for aquaculture. Both officials and farmers are uneasy about using industrial wastewater. Wastewater is generally discharged directly to rivers from riverine cities, taking it away from the metropolitan area.

Nationwide Estimation of Wastewater Agriculture

An attempt was made to extrapolate the data from 30 cities to a national context using city class and regional averages. This approach has its limitations (as seen from Tables 7.3 and 7.4 below) given the wide variation in values within a class or a region.

This extrapolation to the national level gives the following figures for wastewater use in agriculture:

9,410 ha based on class averages,
5,957 ha based on regional averages
6,972 ha (i.e. 446,937 × 1.6% from Table 7.2) based on the overall average

A range of 6,000 to 9,500 ha is indicated as a national figure.

It must be noted that the magnitude of these figures largely depends on the initial definitions

Table 7.3. Nationwide projection of wastewater-irrigated agriculture by city class.

City class	Land area (ha)	Agricultural land in city (ha)	Agricultural land as % of total land area	Wastewater irrigated area (mean) as % agricultural land – based on survey	Calculated wastewater irrigated area (ha)
I	301,599	140,234	46	1.8	2,566
II	416,915	117,573	28	0.4	506
III	168,506	60,634	36	1.1	697
IV	225,617	95,376	42	5.4	5,150
V	147,064	33,118	23	1.5	490
Total	1,259,701	446,937	35		9,410

Table 7.4. Nationwide projection of wastewater-irrigated agriculture by region in Vietnam.

City class	Land area (ha)	Agricultural land in city (ha)	Agricultural land as % of total land area	Wastewater irrigated area (mean) as % agricultural land – based on survey	Calculated wastewater irrigated area (ha)
NE	103,504	24,552	24	2.2	530
RRD	262,248	121,237	46	1.9	2,340
NCC	45,162	15,253	34	4.7	722
SCC	243,192	36,517	15	0.8	299
CH	130,195	29,839	23	1.1	343
MRD	123,996	80,251	65	0.5	369
SE	296,672	132,330	45	1.0	1,284
NW	54,732	6,955	13	1.0	70
Total	1,259,701	446,937	35		5,957

of *target study area*, *wastewater*, and *wastewater-irrigated areas*. This assumes that very little wastewater agriculture takes place outside of the city limits, but this is not so in Vietnam, where the pollution of irrigation canals extends the problems of wastewater irrigation beyond the city boundaries. Furthermore, the proportional method used to calculate the extent of land under wastewater irrigation in schemes served by canals receiving wastewater may have led to an underestimation of the real situation. This confirms the importance of proper definitions and the need for a standard typology if results from different countries are to be compared.

Aquaculture Using Wastewater and the Role of Natural Stabilisation Ponds as Treatment Facilities

Of the 30 cities surveyed, 19 use wastewater for aquaculture. Natural stabilisation ponds, traditionally used for flood inundation control, that are prevalent across the country, are generally used for aquaculture but not exclusively using wastewater. Data were not comprehensive, but from available figures, the annual total fish production from wastewater in the cities surveyed is 6,359 t, of which more than half (3,380 t) comes from Hanoi, by far the largest fish producer using wastewater. Certain districts of Hanoi, e.g. Than Tri and Tu Liem depend almost entirely on wastewater for both agriculture and aquaculture. Five other cities annually produce around 100–200 t. Wastewater aquaculture appears to be more common in the larger cities, i.e. in eight out of the 10 class II cities. Tilapia and carp species predominate.

According to doctors interviewed, it seemed that little information was available in Vietnam about health risks associated with sewage-fed aquaculture (Dalsgaard, 1995).

Of the sample cities, 73% had stabilisation ponds, many of them over 10 ha in size. In many cities, due to the poor collection and disposal infrastructure for wastewater, these ponds serve the additional purpose of bio-treatment. However, the sizing of the ponds does not correspond to the degree of treatment required by the wastewater (Metcalf and Eddy, 1991). Estimates of retention times varied from 1–122 days.

Other than these stabilisation ponds other forms of urban wastewater treatment are virtually non-existent (Ha *et al.*, 2001), but industrial wastewater in some instances undergoes some form of treatment before discharge. The applicability of natural pond systems as a low-cost method for the partial treatment of wastewater for agricultural use may prove useful in other countries, and should be further studied under Vietnamese conditions.

Livelihoods, Health and Environmental Aspects

An attempt was made through this nationwide survey to gather information on the number of households using wastewater as an income source. Data availability was sketchy at this level of assessment, and it was understood that more detailed studies on the livelihoods dimension of wastewater use were needed. In the context of this study livelihoods reflect the number of persons dependent or engaged in wastewater agriculture or aquaculture, using it either as a main or a secondary source of income.

Analysis of available information (Tables 7.5 and 7.6) showed 1% of the population depend on wastewater agriculture as a primary or secondary, but not necessarily sole, income source.

In the CH cities of Buon Ma Thuot and Plei Ku, a higher percentage (5%) of households use wastewater. This may be explained by the very small sizes of plots which allow for more households to cultivate vegetables.

Table 7.5. Livelihoods dependent on wastewater use by city class in Vietnam.

	Number of persons as % of population[a]	
City class	Agriculture	Aquaculture
I	1.0	0.10
II	0.3	0.08
III	5.0	-
IV	0.5	0.03
V	3.6	0.02
Overall	1.0	0.09

[a] The population figure excludes cities where information on households was not available.

Table 7.6. Livelihoods dependent on wastewater use by region in Vietnam.

	Number of persons as % of population[a]	
Region	Agriculture	Aquaculture
NE	–	–
RRD	1.4	0.18
NCC	2.3	0.25
SCC	0.2	0.09
CH	5.0	–
MRD	0.1	0.04
SE	0.4	0.01
Overall	1.0	0.09

[a] The population figure excludes cities where information on households was not available.

The proportion of the population engaged in wastewater aquaculture is only one tenth that of agriculture. In Hanoi however, with an annual fish production of 3,380 t, 0.3% of the population uses wastewater for aquaculture. Dalsgaard (1995) reports that farmers can make a net profit of around US$1,400 through wastewater aquaculture, and employees could earn around US$35/month.

Whilst the figures for both agriculture (1%) and aquaculture (0.1%) may be low in percentage terms, for Vietnam this is equivalent to nearly half a million people. The survey did not attempt to provide exact figures of incomes or the percentage of household income attributable to a wastewater source.

No substantive evaluation of environmental and health impacts was carried out at this stage, but the perceptions of authorities were recorded. Of those interviewed, more than half of the local authorities dealing with wastewater in the surveyed cities were aware of the negative impacts of wastewater use on human health and crops. Local officials based on observation and discussion with farmers, gave importance to such visible medical symptoms as skin irritations, and listed poor crop quality and yields as negative impacts. They stated that they would prefer an alternative water source, but in the meantime, wastewater use did not seem to be actively discouraged, and they did not have plans for developing alternative sources.

Institutions for Wastewater Management

Although a series of legislation and decrees emphasising the State's commitment and outlining the responsibilities for water resources protection and management exists, there is no single fully constituted entity responsible for wastewater management per se in Vietnam.

Prevention and mitigation of negative impacts on the environment are regulated by environmental legislation under the Ministry of Science, Technology and Environment (MOSTE). At the provincial and city level, the Department of Science, Technology and Environment (DOSTE), which reports to the Provincial People's Committee (PPC), is responsible for environmental protection and management [extracted from the 'Law on Environmental Protection' (Vietnamese National Assembly, 1994)].

Operation and management of city sewerage systems is under the authority of the Urban Management and Planning Company (UMPC) by decree. The UMPC is supervised by the Department of Transportation and Public Works, or Department of Construction, but reports to the PPC or to the City People's Committee (CPC). In principle wastewater pipes cannot be connected to the city sewerage systems without the approval of these organisations, and this is subject to toxic substances in wastewater being treated to required standards provided in the legislation [extracted from 'Responsibilities of Ministry of Agriculture and Rural Development (MARD)' (Government of Vietnam, 1999)]. However, these are not always enforced.

The Irrigation and Drainage Management Company (IDMC) manages the ponds and irrigation and drainage canals into which the urban sewerage systems are usually discharged. In cities close to rivers, wastewater is pumped directly into the rivers where possible.

Conclusions and Lessons Learned

Pioneer national assessment

The Vietnam national assessment was conducted to acquire an overview of the importance and significance of wastewater agriculture in terms of extent, agricultural production, and livelihood impacts. Such an overview could contribute to developing appropriate policy and legal frameworks for wastewater use within an integrated water resources management framework for Vietnam. It is the first time that such an assessment to acquire a national perspective has been attempted in any part of the world.

- The assessment showed that 93% of the cities sampled use wastewater for agriculture or aquaculture or both. In larger cities in spite, or because of urbanisation, urban and peri-urban agriculture appears to play a significant role in providing food to urban populations
- Wastewater irrigated areas vary from about 0.5%–5% (average 1.6%) of the total agricultural land in the cities; with 70% of the cities in the range of 1–2%.
- The predominant wastewater crop in Vietnam is paddy rice, grown on 76% of the area in the spring and 85% in the summer seasons
- Extrapolation of these findings to national level gives a range of 6,000–9,500 ha as a national figure for wastewater-irrigated agriculture
- 1% of the urban population derives incomes from wastewater agriculture and 0.1% from wastewater aquaculture. Whilst these figures may be very low in terms of percentage, for Vietnam this represents close to half a million people
- Stabilisation ponds serve the dual purpose of inundation control and *de facto* biotreatment. The latter is not very effective as the ponds were not primarily designed for this purpose. These ponds are also extensively used for aquaculture especially in the larger cities.

It must be noted that the magnitude of these figures largely depends on the initial definitions applied to target study area, wastewater, and wastewater-irrigated area. It assumes that very little wastewater agriculture takes place outside of city limits, which is not necessarily the case in all situations in Vietnam, where the pollution of irrigation canals extends the problems of wastewater irrigation beyond city boundaries. Furthermore, the proportional method used to calculate the extent of land under wastewater irrigation in schemes served by canals receiving wastewater, may have been an underestimation of the real situation.

For all these reasons the importance of developing a typology before proceeding to a global assessment clearly emerges.

Factors for rationalising wastewater use

Another reason for carrying out a national survey was to gain a clearer understanding of the reasons behind the use of wastewater in a national context in order to identify key factors that influence such use. Such information is not only useful for national policy, but also provides more generic information for application at a global level. The survey elicited the following:

- In Vietnam the underlying reason for its agricultural use is the unplanned discharge of wastewater into natural watercourses, drainage canals, or irrigation canals. This is unlike the situation in many arid and semi-arid countries, where urban wastewater is sought after and used extensively for its water and nutrient value. In some water-scarce areas of Vietnam, or under poorly maintained or managed irrigation systems, intentional wastewater use is noted
- 77% of the city's freshwater supply returns as wastewater, of which the domestic content varies between 60 and 90%. These figures provide first estimates of possible wastewater return flows in Vietnam and similar countries in the region
- Data show that in larger cities about 75% of the domestic wastewater drains into municipal sewerage systems of some sort and for the smaller cities this figure is 45%. These figures are indicative of the situation in many similar less-developed countries and could be used as the starting point for global estimates of available 'channelled' wastewater that can be put to other uses
- In riverine and coastal cities, both industrial and domestic wastewater is discharged directly to the rivers or to the sea and is not usually used by farmers
- Rice and vegetable cultivation are the highest consumers of wastewater. Both may have substantial impact on human health particularly the possible presence of heavy metals in wastewater-irrigated rice systems.

Emergence of a typology and its requirements

A key lesson from this survey is the realisation that a more descriptive typology (or a classification of the most common forms of wastewater use in irrigation) is a prerequisite to the global assessment of wastewater agriculture, providing a framework to describe different practices and defining what is included in the assessment. A typology that can effectively capture these characteristics will ensure that those involved in this field are aware of the important differences that exist, and are able to identify where a given research finding, policy instrument or technical intervention will or will not find relevant application (Cornish and Kielen, Chapter 6, this volume; van der Hoek, Chapter 2, this volume).

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8 Wastewater Use in Pakistan: The Cases of Haroonabad and Faisalabad

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Abstract

Untreated wastewater is used for irrigation in over 80% of all Pakistani communities with a population of over 10,000 inhabitants. The absence of a suitable alternative water source, wastewater's high nutrient value, reliability, and its proximity to urban markets are the main reasons for its use. Two case studies in Pakistan studied the impact of untreated wastewater use on health, environment, and income. The results showed a high increase in hookworm infections among wastewater users and a clear over-application of nutrients through wastewater. Heavy metal accumulation in soil over a period of 30 years was minimal in Haroonabad, a small town with no industry, but showed initial signs of excess levels in soil and plant material in Faisalabad, a city with large-scale industry. The impact of wastewater irrigation on household income was considerable as wastewater farmers earned approximately US$300/annum more than farmers using freshwater. Both case studies showed the importance of wastewater irrigation on local livelihoods. The lack of financial resources at municipal and provincial levels for wastewater treatment calls for other measures to reduce the negative impact of untreated wastewater use on health and environment, for example to manage groundwater, regular (canal) irrigation water, and wastewater conjunctively, and regular deworming treatment of those exposed to wastewater.

Introduction

Pakistan has a population of over 140 million and is one of the few countries that is almost completely dependant on a single river system for all its agricultural water demands. The Indus river and its tributaries provide water to over 16 million hectares of land, situated in the mainly arid and semi-arid zones of the country. A rapidly growing population, saline groundwater, a poorly performing irrigation distribution system, and recurrent droughts have led to increased water shortages. Under these conditions, the use of untreated urban wastewater for agriculture has become a common and widespread practice.

Preliminary results from a country-wide survey in the four main provinces showed that untreated wastewater was used in 50 out of 60 visited cities. The three main reasons for the use of wastewater were the high salinity of groundwater, recent droughts that have led to a decline in groundwater tables, and the nutrient value of wastewater. Other important

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reasons were the proximity of urban markets and the reliability of wastewater, which unlike regular irrigation water is not subjected to a rotational schedule. In more than half of the visited cities some sort of fee was paid by farmers to either the municipality or the local wastewater utility for the use of wastewater. For example, in the city of Quetta, 212 farmers cultivating 800 ha collectively paid US$12,000/annum for the right to use wastewater. This was 2.5 times more than the fee for regular irrigation water. Land rent in all cities reflected the importance of wastewater with the rent for land that had access to wastewater being at least double and in some cases up to six times that of land without access to wastewater. In the city of Quetta, the average annual rent for land with access to wastewater was US$940/ha, compared to US$170/ha for land irrigated by freshwater.

This chapter presents two ongoing case studies in progress since January 2000 in a small town without major industry (Haroonabad) and a large industrialised city (Faisalabad). The objective of both case studies was to study wastewater use in a holistic way, looking at environmental and health risks together with the economic benefits and costs for a household. To this end, a number of study components were implemented including a cross-sectional health survey to estimate the prevalence of intestinal nematode infections among exposed and unexposed farmers, a nutrient and water balance, an evaluation of the irrigation and nutrient application of wastewater irrigation, a soil and crop survey looking at soil and crop heavy metal concentrations and potential human food chain contamination risks, an entomological study looking at the potential of wastewater bodies to support the life cycle of disease transmitting mosquitoes, and an economic survey comparing the income of households with access to wastewater to that of households without access to wastewater. At both sites, the impacts on water quality and heavy metal uptake were studied by examining locations where untreated wastewater was used exclusively, where freshwater and wastewater were mixed, and where freshwater was used exclusively.

Background

Haroonabad

The town of Haroonabad is located on the edge of the Cholistan desert in southern Punjab province, close to the Indian border. In 1998 the population was 63,000 (Population Census Organization, 2001) and apart from the small-scale seasonal, cotton-related industrial activities such as washing and ginning (separation of seeds and fibre), there was no major industry in the town. The arid climate, with an annual average rainfall of 160 mm, potential evaporation of 2500 mm, and temperatures ranging from 0°C in January to 48°C in July, make agriculture without irrigation virtually impossible. Shortly after the construction of a sewerage system in 1965, farmers started using untreated wastewater pumped from the newly constructed disposal station for irrigation. In 1979 more pumps were installed in and around the town to dispose of blocked wastewater, after the sewerage system had collapsed because of heavy monsoon rains. This resulted in the development of more wastewater-irrigated sites. Currently there are three main sites with a total irrigated area of over 130 ha. The main crops grown with wastewater are vegetables (in particular cauliflower) cotton, and fodder.

Faisalabad

The city of Faisalabad has a population of just over 2 million and is the third largest city in Pakistan. Centrally located in the heart of the Punjab province it was founded in 1900 as an agricultural market town, but has since then rapidly developed into a major agro-based industrial centre. Over 150 different industrial units have been identified by the local Water and Sanitation Agency (WASA), most of which are involved in such cotton processing tasks as washing, bleaching, dying and weaving.

The use of wastewater for agriculture was common, a survey showed that at least nine different sites could be identified, differing in size from a few ha to almost 1,000 ha. Two main sites can be distinguished, the Narwala Road site and the Channel 4 site. Farmers at the first site used wastewater of primarily domestic origin, while farmers at the latter site used a mixture of industrial and domestic wastewater. Common crops at both sites were fodder, wheat, cotton and vegetables (cauliflower, spinach, and aubergine). The aquifer underlying the city was highly saline and could not be used as a source of irrigation or drinking water. Temperatures ranged from 48°C to −4°C, while annual rainfall has varied between 198 mm and 615 mm over the last 40 years.

Water Quality, Crops and Cropping Intensities

Wastewater used for irrigation in Haroonabad and at both sites in Faisalabad (Table 8.1) was not fit for unrestricted irrigation according to microbiological guidelines set by the World Health Organization (WHO) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* (WHO, 1989). However, the WHO guidelines state that the guidelines can be relaxed when vegetables are eaten cooked, and in this case, the main vegetables cultivated, cauliflower, spinach and aubergine, are almost exclusively eaten cooked. The high values of electrical conductivity and total nitrogen loads of the wastewater placed medium restrictions on the use of this wastewater for agricultural production as its use could result in limited crop growth and hence yield reductions (Pescod, 1992).

During the course of the studies farmers mentioned that they were limited in their choice of crops, though some crops considered unsuitable by one farmer were grown by another. There seemed to be a consensus among farmers that such root crops as carrots, radishes, onions and potatoes were unsuitable for wastewater irrigation, because as a result of their foul smell, poor colour, and in the case of carrot and radish, the development of several short, not single straight roots, these could not be sold in the local market. The main crops grown were fodder sorghum (*Sorghum bicolor*), cauliflower, spinach, cotton, wheat, tomatoes and aubergine. The number of crops grown on the same land each year on wastewater-irrigated sites in Faisalabad and Haroonabad was three, compared to less than two grown in fields irrigated with freshwater.

Farmers interviewed along the length of Channel 4 encompassing fully, mixed, and

Table 8.1. Water quality parameters of wastewater used for irrigation in Haroonabad and at the Narwala and Channel 4 sites in Faisalabad, Pakistan.

		FAO and WHO		Faisalabad	
Parameter	Unit	guidelines	Haroonabad	Narwala Road	Channel 4
Electrical conductivity (EC)	dS/m	< 3	4.4	3.1	5.8
Faecal coliform (FC)	Count/100 ml	1000	6.3×10^7	$>10^8$	$>10^8$
Helminth eggs	Number/l	< 1	100	763	
Sodium adsorption ratio (SAR)		< 9	4.5	6.3	16.9
Total nitrogen (N)	mg/l	< 30	78.3	41.6	35.7
Total phosphorus (P)	mg/l	8.6	6.0	5.7	
Total potassium (K)	mg/l	34.7	20.0	35.1	
Manganese (Mn)	mg/l	0.20	0.07	0.14	
Chromium (Cr)	mg/l	0.10	0.23	0.05	
Lead (Pb)	mg/l	5.0	0.04	0.24	
Nickel (Ni)	mg/l	0.20	0.14	0.03	
Copper (Cu)	mg/l	0.20	0.35	0.09	
Cobalt (Co)	mg/l	0.05	0.06	0.08	
Cadmium (Cd)	mg/l	0.01	0.01	0.00	
Iron (Fe)	mg/l	5.0	0.22	0.16	
Zinc (Zn)	mg/l	2.0	N.D	0.14	

non-Channel 4 water users indicated that 'excess' application of Channel 4 water to wheat and sorghum seedlings less than 30 days after emergence resulted in severe 'burning' of crops and frequently resulted in expensive re-planting. Further, the long-term application of Channel 4 water has resulted in a significant breakdown in soil structure and visible indicators of soil salinity. In addition, the formation of a compact surface layer has resulted in the delayed emergence of both wheat and sorghum. Prior to reliance on Channel 4 water, the emergence time for wheat was 5–7 days. After relying on Channel 4 water for 5–16 years, emergence now takes place after 15 days.

Nutrient and Water Balance

The original research question about water and nutrient use in both Haroonabad and Faisalabad was whether wastewater was applied according to the plants' water and nutrient requirements. At both sites, nutrients were over-applied when compared to fertiliser standards set by the Ministry of Food, Agriculture and Livestock, Federal Water Management Cell (1997). Table 8.2 shows the example of cauliflower irrigated with wastewater in Haroonabad and Faisalabad. The differences in nitrogen ratios (N applied/N recommended) between Haroonabad and Faisalabad can be explained by daily and monthly fluctuations in the quality of wastewater.

The over-application of wastewater was reflected in low irrigation performance, as over-application of wastewater led to high percolation (Ensink *et al.*, 2002). In addition, the nitrogen ratio results for both Haroonabad and Faisalabad, indicated a significant 'inefficient' over-application of nitrogen (Table 8.2). This resulted in high levels of nitrates, nitrites and *Escherichia coli* in groundwater under the wastewater-irrigated sites. These levels of nitrates, nitrites and *E. coli* would be of concern if groundwater were to be used for drinking water purposes [World Health Organization (WHO) *Guidelines for drinking-water quality*] (WHO, 1993) but the natural salinity of this groundwater has prevented such use.

Heavy Metals

Haroonabad

The results for Haroonabad indicate that because the pH of the soils analysed ranged from 7.72–8.30, the levels of copper (Cu), nickel (Ni), lead (Pb), and chromium (Cr) are within European Economic Community (EEC) maximum permissible (MP) levels (Table 8.3). No MP levels are established for cobalt (Co) and manganese (Mn). However, a significant accumulation of Pb and Cu can be observed within the top 0–15 cm of the 100% wastewater-irrigated soil profiles (Table 8.3). In contrast, Ni, Co, Cr and Mn remained relatively uniform irrespective of depth with mean (n=6) concentrations of Ni 30.2 (±0.4), Co 12.3 (±0.5), Cr 56.3 (±9.5) and Mn 256.3 (±18.4) mg/kg (Table 8.3).

As with the 100% wastewater-irrigated field, Pb and Cu levels were elevated at the soil surface (0–5 cm) of the conjunctively irrigated field (Table 8.3). However, the surface accumulation of Pb and Cu was restricted to 0–5 cm soil depth compared to 0–15 cm for the 100% wastewater-irrigated field. It is suggested that the elevated levels of Pb could be attributable

Table 8.2. Total nitrogen (TN) application, nitrogen ratios and total amount of wastewater applied to cauliflower in Haroonabad and Faisalabad, Pakistan.

	TN/cropping season (kg/ha)	Nitrogen ratio[a] (%)	Total water applied (mm)
Haroonabad	546	440	314
Faisalabad	192	160	321

[a] Nitrogen ratio: $\frac{\text{Total N applied}}{\text{Recommended N}} \times 100\%$

Table 8.3. Vertical distribution of heavy metal concentrations in soil (mg/kg) at varying soil depths in relation to type of irrigation water used at three sites in Pakistan.

	Concentration (mg/kg) at various soil depths[a]							
Type of irrigation water	Pb	Pb	Cu	Cu	Ni	Co	Mn	Cr
100% wastewater	(0–15 cm)[a]	(15–90 cm)	(0–15 cm)	(15–90 cm)	(0–90 cm)	(0–90 cm)	(0–90 cm)	(0–90 cm)
	19.4	9.2	86.9	71.1	30.2	12.3	256.3	56.0
	(2.3)[b]	*(1.2)*	*(1.4)*	*(2.4)*	*(0.4)*	*(0.5)*	*(18.4)*	*(9.5)*
Conjunctive use	(0–5 cm)	(5–90 cm)	(0–5 cm)	(5–90 cm)	(0–90 cm)	(0–90 cm)	(0–90 cm)	(0–90 cm)
	13.4	6.4	77.3	58.7	26.9	12.4	231.9	46.5
				(2.0)	*(1.1)*	*(0.9)*	*(12.5)*	*(4.6)*
Freshwater	(0–90 cm)		(0–90 cm)		(0–90 cm)	(0–90 cm)	(0–90 cm)	(0–90 cm)
(Hakra 4/R)	7.9		21.9		22.5	11.2	185.7	64.2
	(1.7)		*(4.4)*		*(3.3)*	*(1.0)*	*(16.1)*	*(11.0)*
EEC MP[c] levels	50–300		50–140		30–75			100–150

[a] Sampling depth in parentheses.

[b] Standard deviation in parentheses and italicised.

[c] The range of European Economic Community (EEC) maximum permissible (MP) levels for Pb, Cu and Ni given in Table 8.3 correspond to soil pH. The lower value given corresponds to a soil pH < 5.5 and the higher value a soil pH >7.0.

to deposition from petrol fumes as the 100% irrigated wastewater site is located next to the central bus station. Other metal concentrations remain relatively uniform with depth with mean (n=6) concentrations of Ni 26.9 (±1.1), Co 12.4 (±0.9), Cr 46.5 (±4.6) and Mn 231.9 (±12.5) mg/kg.

In contrast, both soil Pb and Cu in the Hakra 4/R (freshwater-irrigated) fields were significantly lower than in the wastewater-irrigated plots (Table 8.3). In addition, no surface accumulation of Pb or Cu was observed. In comparison to the wastewater-irrigated plots, levels of Ni, Co, Mn and Cr remained relatively uniform irrespective of soil depth.

Faisalabad

During April–May 2002 soil and wheat samples were collected from pre-selected fields at 1-km intervals along the length of Channel 4 to evaluate the impact of wastewater use on soil heavy metal accumulation. As a control, samples were also collected from fields receiving freshwater irrigation from the Dhudi Wala Minor. The results indicated that for both the Channel 4 and Dhudi Wala Minor irrigated fields, soil Cd, Pb, Zn, Ni, Cr, and Cu concentrations are all below EEC MP levels irrespective of sampling site (Table 8.4). However, elevated levels of Zn were observed at the 0.2 and 1.3 km sampling locations with values of 90.6 mg/kg at 0.2 km and 92.6 mg/kg at 1.3 km. In addition, elevated levels of Cd were observed between the 1–3 km sampling site with a mean Cd value of 0.40 ± 0.03 mg/kg compared to a mean Cd concentration of 0.14 ± 0.04 mg/kg for the 4–9 km sampling site. Lead, Cr, Ni, and Cu concentrations were relatively uniform irrespective of sampling site and irrigation source.

The wheat grain results indicate trace (<0.05 mg/kg) concentrations of Pb, Cr, and Ni in grain, which reflected the relative immobility of these elements in soils and translocation in the plant. Wheat grain Cu and Zn concentrations for both the Channel 4 and Dhudi Wala Minor irrigated fields were at concentrations indicative of optimum yields (Wells *et al.*, 1996). The wheat grain Cd concentrations exceed the Joint FAO/WHO Expert Committee on Food Additives (JECFA) Codex Committee on Food Additives and Contaminants (CCFAC) draft provisional maximum level (ML) for Cd in wheat grain of 0.1 mg/kg (Codex Alimentarius Commission, 2002). However, Chaney *et al.* (1996) suggested that a Cd:Zn ratio of <1.5% effectively provides protection against Cd-induced health impacts. For the Channel 4 and Dhudi Wala Minor wheat samples, the Cd:Zn ratio ranged from 0.28–1.05%. Health risks are therefore effectively prevented at this time.

In summary, with the exception of the surface accumulation of Pb and Cu in 100% wastewater and conjunctively irrigated fields in Haroonabad (Table 8.3) heavy metal accumulation in Haroonabad was of minor concern. However, monitoring programmes should be established and the source of contamination confirmed and managed to prevent soil Cu and Pb reaching levels that may prove toxic to crop growth and soil biological functions. In Faisalabad the source of Cd contamination should be identified and managed, monitoring soil and edible portions of crops is essential to ensure protection of the food chain from elevated levels of Cd.

Health Impact

Intestinal nematodes

Preliminary results from a health survey in Faisalabad and a completed study in Haroonabad (Feenstra *et al.*, 2000) show a similar trend (Table 8.5).Wastewater farmers had a 4 to 5 fold higher risk of hookworm infection than a group of non-wastewater users. There was no difference in risk of hookworm infection between children of wastewater farmers and children of non-wastewater irrigators.

Studies in Mexico identified *Ascaris lumbricoides* as the main source of intestinal nematode infections among wastewater farmers and their children (Blumenthal *et al.*, 2001). Although *A. lumbricoides* eggs were found in large numbers in wastewater, the studies in Faisalabad and Haroonabad showed very low prevalence of *A. lumbricoides* among wastewater farmers and their children for as yet unexplained reasons.

Table 8.4. Soil and wheat grain heavy metal concentrations (mg/kg) in relation to irrigation source, Faisalabad, Pakistan.

Metal	Sample type	Channel 4	Dhudi Wala Minor
Cd	Soil (0–20 cm)	0.23 ± 0.13[a] *(0.08–0.44)*[b]	0.21 ± 0.00 *(0.21–0.21)*
	Wheat grain	0.16 ± 0.04 *(0.10–0.23)*	0.11 ± 0.00 *(0.11–0.12)*
Pb	Soil (0–20 cm)	10.5 ± 1.7 *(8.5–15.2)*	11.6 ± 0.1 *(11.5–11.6)*
	Wheat grain	Trace < 0.05	Trace < 0.05
Zn	Soil (0–20 cm)	50.8 ± 15.2 *(32.1–92.6)*	44.5 ± 4.8 *(41.2–47.9)*
	Wheat grain	28.0 ± 9.4 *(15.0–47.9)*	29.6 ± 4.8 *(41.2–47.9)*
Cr	Soil (0–20 cm)	26.3 ± 3.4 *(20.7–35.4)*	24.1 ± 1.8 *(22.8–25.4)*
	Wheat grain	Trace < 0.05	Trace < 0.05
Ni	Soil (0–20 cm)	33.8 ± 4.1 *(27.1–40.4)*	35.2 ± 0.98 *(34.5–35.9)*
	Wheat grain	Trace < 0.05	Trace < 0.05
Cu	Soil (0–20 cm)	21.6 ± 2.3 *(17.18–28.30)*	22.8 ± 0.09 *(22.70–22.83)*
	Wheat grain	6.5 ± 1.1 *(5.6–10.2)*	6.0 ± 0.04 *(6.0–6.0)*

[a] Values in mg/kg ± 1 standard deviation.
[b] Range of concentration given in parentheses and italicised.

Vector breeding

Vector studies in Haroonabad and Faisalabad revealed that wastewater stabilisation ponds and other wastewater bodies favoured the breeding of *Anopheles* and *Culex* mosquitoes. Within the wastewater-irrigated zones, each vector species was found to be associated with specific breeding site types and environmental characteristics. The presence of potential vectors of human diseases such as malaria, filariasis, West Nile fever, and Japanese encephalitis indicated that wastewater systems could contribute to vector-borne disease risks in addition to other associated health risks among poor human communities that depend on wastewater use for their livelihoods. However, this potential role of wastewater

Table 8.5. Hookworm prevalence among wastewater-irrigating farmers and their children compared to a group of unexposed farmers, labourers and their children at two locations in Pakistan.

	Hookworm prevalence			
	Exposed (%)	Unexposed (%)	Odds ratio	95% confidence interval
Haroonabad				
Adults	75 (51/68)	41 (48/118)	4.4	2.3–8.5
Children (age <13)	20 (26/130)	21 (55/261)	0.9	0.6–1.6
Faisalabad				
Adults	15 (24/165)	3 (7/243)	5.7	4.9–6.6
Children (age <13)	6 (18/305)	5 (26/478)	1.1	0.7–1.8

stabilisation ponds to serve as breeding sites for mosquito vectors of human disease has received little attention. Poorly managed wastewater treatment ponds have thick emergent vegetation and floating solid waste along their margins. The vegetation and floating waste offer ideal habitats for the breeding of mosquitoes by attracting them to oviposit and also by providing them with protection against predators. The creation of such perennial water bodies close to large urban areas in an arid environment could pose a significant health risk for communities living around such treatment schemes.

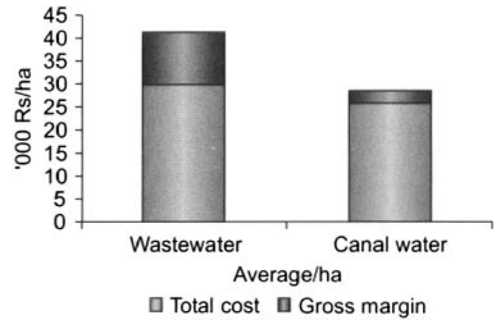

Fig. 8.1. Total cost and gross margin ('000 Rs/ha) for a wastewater farmer and a regular canal water farmer in Haroonabad, Pakistan (Rs.58 = US$1).

Household Income and Livelihood

In Haroonabad wastewater farmers spent more money on insecticides, labour and land rent than farmers using regular canal water. The major input cost for regular farmers was for fertiliser and although this was a substantial cost, on average the total costs for regular farmers were less then those for wastewater farmers. However, the average gross margin for a wastewater farmer, about US$173/ha (Rs 10,000/ha), was substantially higher than for a freshwater farmer using canal water, about US$43/ha (Rs 2,500/ha) because of higher cropping intensities and the ability to cultivate crops with higher market values (Fig. 8.1).

Conclusion

Untreated wastewater irrigation poses serious health risks that cannot be ignored. While the risks to consumers may not be excessive, as most vegetables grown in land irrigated with wastewater are eaten cooked, the risks to farmers practicing flood irrigation cannot be ignored. The studies in Faisalabad and Haroonabad show a 5-fold increase in the risk of hookworm infection among wastewater farmers. However many of these farmers have no other option or do not want to use other water. This was illustrated by some farmers in Faisalabad who had access to treated and untreated wastewater but opted for the untreated (black) wastewater as it was considered less saline and better for their crops.

In the present situation there seem to be clear gains for both farmers and municipalities. Farmers are willing to pay high water fees, which in turn are used by municipalities to finance the maintenance and operation costs of drinking water and sewerage services. However, the long-term sustainability is at risk as farmers are limited in their choice of crops and heavy metal uptake by wheat as measured in its grain is getting close to critical levels. Groundwater contamination due to extensive irrigation with wastewater has not been an issue for Faisalabad and Haroonabad because the natural saline groundwater there means they have no alternative irrigation water source, but it would be an important issue in cities and towns in the fresh groundwater regions.

Although the use of wastewater is likely to become increasingly important for Pakistan as a combined strategy for water conservation and pollution prevention, management of this resource is in the hands of local farmers and municipalities. There seems to be little awareness of the risks involved in the use of untreated wastewater among local municipalities where the opinion of many is that 'the farmer knows best'.

It is unlikely that Pakistan will be able to treat all wastewater currently used by farmers up to WHO guideline standards. Enforcement of crop restrictions will deprive many farming families of their livelihoods and there is therefore a need to look at options other than full wastewater treatment or the enforcement of crop restrictions. The need for ways to reduce health and environmental risks while at the same time safeguarding positive impacts on household income is evident. The WHO guidelines offer such other options as partial treatment for irrigation of vegetables eaten cooked, as is predominately the case here, and the use of deworming medication, which could be appropriate for the economic and environmental situation prevailing in Pakistan. Although these strategies have not been implemented, as full wastewater treatment has always been considered the norm, deworming campaigns, with or without partial wastewater treatment, could potentially be very successful, as they have shown to be in programmes established for school children (UNICEF, 1998).

Encouraging farmers to wear footwear and other protective gear, such as gloves and long trousers, has been suggested as a possible additional measure to protect farmer health. Many farmers might consider footwear and gloves impractical and uncomfortable under field conditions, and therefore the acceptability of such an intervention needs to be investigated prior to its implementation.

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9 Agricultural Use of Untreated Urban Wastewater in Ghana

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Abstract

In Ghana, urban sanitation infrastructure is poor and only a small portion of the (primarily domestic) wastewater is collected for treatment. The bulk ends up in drains and nearby water bodies and is used by urban and peri-urban vegetable farmers for irrigation. Open-space urban and peri-urban vegetable farming is market-oriented and depends on water availability. It not only supports the livelihoods of many farmers and traders but also contributes significantly to the supply of perishable vegetables to cities. However, high contamination levels, especially pathogens, have been recorded in most irrigation water sources as well as on irrigated vegetables. Because wastewater irrigation is illegal, farmers are periodically expelled from their plots. As any significant improvement of the urban sanitation infrastructure is financially constrained, research into strategies for safe wastewater use that considers both health risks and farmers' livelihoods is in progress. The aim is to contribute to the sustainability of urban vegetable production systems and their benefits in West Africa.

Background

Ghana lies at the shores of the Gulf of Guinea in West Africa. To the north, it borders Burkina Faso, Togo to the east and Côte d'Ivoire to the west (Fig. 9.1). It has a population of about 19 million, growing annually at the rate of 2.7%. About 44% of Ghana's total population lives in urban areas. Some urban centres have annual growth rates as high as 6%, more than twice the country's average rate (Ghana Statistical Services, 2002). This includes 'Mega Accra' that encompasses Accra, Tema and Ga districts with 2.7 million inhabitants and Kumasi with 1.0 million inhabitants. The overall national population density is 79 persons/km^2 (Ghana Statistics Services, 2002). Agriculture is the mainstay of the Ghanaian economy, contributing 36% of the gross domestic product (GDP) and employing 60% of Ghana's labour force. The average annual *per capita* income of those employed in agriculture is estimated at US$390.

Annual rainfall ranges from 800 mm in the coastal areas to 2,030 mm in the southwestern rainforests. Table 9.1 summarises climatic conditions in the synoptic stations of Accra (southern belt), Kumasi (middle belt) and Tamale (northern belt) (Agodzo, 1998). The country's surface hydrology comprises three main river basins: the Volta basin that covers about three-quarters of the country's surface, the southwestern and the coastal basin systems.

 Wastewater Use in Irrigated Agriculture (eds C.A. Scott, N.I. Faruqui and L. Raschid-Sally)

Fig. 9.1. Map of Ghana and its administrative regions.

Status of Urban Wastewater Disposal and Treatment in Ghana

Sanitation and wastewater generation

About 63% of Ghana's population has sanitation coverage, which is more than the West Africa average of 48% (Fig. 9.2) and similar to the average of eastern (62%) and southern Africa (63%) (WHO *et al.*, 2000). While most countries in West Africa (like Senegal) show a very high disparity in provision of sanitation services between rural and urban areas, Ghana has a good balance with 62% coverage in urban areas and 64% in rural areas. According to Agodzo *et al.* (2003) the total amount of grey and black wastewater currently produced annually in urban Ghana has been estimated as 280 million m^3. This wastewater is derived mainly from domestic sources as Ghana's industrial development is concentrated along the coastline where wastewater, treated or

Table 9.1. Mean annual climate data of Accra, Kumasi, Tamale.

Location	Rainfall (mm)	Temperature (°C)	Relative humidity (%)	Sunshine duration (hours)	Wind velocity (km/day)	Solar radiation ($MJ/m^2/day$)	Potential evaporation (mm)
Accra	810	27.1	81	6.5	251	18.6	1,504
Kumasi	1,420	26.1	77	5.4	133	17.0	1,357
Tamale	1,033	28.1	61	7.3	138	19.6	1,720

Source: Agodzo, 1998.

untreated, is disposed of into the ocean. In Ghana, collection and disposal of domestic wastewater is done using:

- Underground tanks such as septic tanks and aqua-privies, either at industrial facilities or at the community level and then transported by desludging tankers to treatment works or dumping sites
- Sewerage systems
- Public toilets
- Pit and improved latrines.

Less than 5% of the households in Accra and Kumasi are connected to piped sewerage systems, while 21% use floodwater drains (gutters) as open sewerage that ends up in nearby water bodies. Some of the urban dwellers discharge their faecal waste into septic tanks while kitchen and other wastes from the home are usually directed into the nearest open drain. As the majority of the urban drains are open, they often serve as defecating areas for households that do not have adequate sanitation facilities. According to the national population and housing census carried out in 2000, one third of all households in Ghana use public toilets, reflecting the absence of toilet facilities in many dwelling places. Pit latrines continue to be used in 22% of all households but an improved version, the Kumasi Ventilated Improved Pit (KVIP), is being promoted and its use is expected to rise from the current 7%. Bucket latrines (4%) are being phased out because they are not hygienic. It is quite striking that more than 25% of all households in Ghana have no toilet facilities, with numbers increasing to about 70% in the three northern regions. Water closets (WCs), considered to be modern toilet facilities, are used by only 9% of the households, most of them located in Accra and Kumasi.

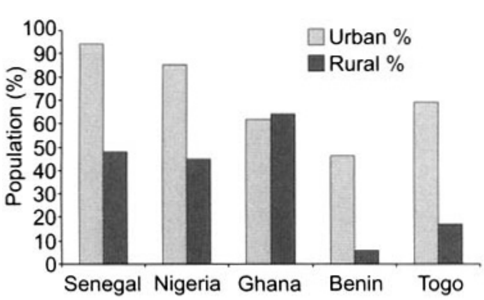

Fig. 9.2. Regional sanitation coverage in five West African countries.
Source: Adapted from WHO *et al.*, 2000.

Thus, the majority of the population in urban Ghana does not have appropriate means to manage wastewater and the costs of putting in place the required infrastructure to effectively collect and dispose of all urban wastewater are excessive.

Wastewater Treatment

More than half of all wastewater treatment plants in Ghana are in and around Accra (EPA, 2001). Two administrative regions (Brong Ahafo and Upper West, Fig. 9.1) have no treatment plant, despite having several important cities and towns. But even where treatment plants are available, less than 25% (primarily in the Greater Accra, Ashanti and Eastern regions, and mostly small-capacity and/or privately owned plants) are functional (Fig. 9.3).

A few years ago, a large modern biological treatment plant started operation at Accra's Korle Lagoon; but, it handles only about 8% of Accra's inner-city wastewater from domestic and industrial sources. The system has a capacity three times greater than that it currently uses, but is constrained by the small urban sewerage network. Only about 10% of the Accra's wastewater is collected for some kind of treatment.

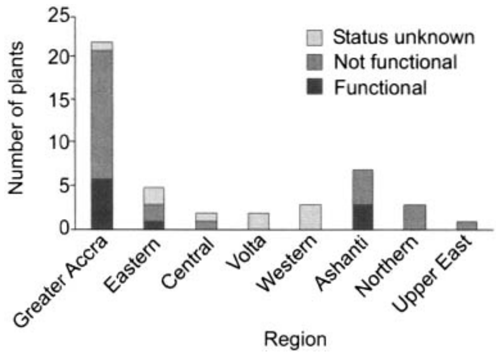

Fig. 9.3. Status of wastewater treatment plants in Ghana. Source: Adapted from EPA, 2001.

Equally disastrous is the situation of septage and night soil treatment. There are only a few low-capacity treatment facilities (usually stabilisation ponds) functioning in most cities. To cite just a few examples: Over the last few years, Kumasi's main faecal sludge treatment plant was receiving an average of 180–500 m^3/day, which is less than 5% of the total faecal sludge produced in the city. The Waste Management Department attributes this low percentage mainly to vehicle breakdowns. However, the treatment ponds have been filled beyond capacity for years, often without desludging for many months and with faecal sludge overflowing to nearby rivers without treatment. The situation is similar in Accra with two sites loaded beyond capacity. The ocean is the third semi-official site, receiving about 40% of the excreta produced in the city. In Tamale, the first plant is still under construction while faecal sludge continues to be dumped in natural depressions.

In Kumasi, a new plant has been built at Buobai, but it can only handle 200 m^3/day and is already reaching its limit. Another pond facility is in preparation near a new landfill site. It is apparent that city sanitation services cannot keep pace with the high urbanisation rates (Keraita *et al.*, 2003b). The general situation causes the authorities concern as shown in Kumasi's 1996–2005 Sanitation Strategic Plan (Box 9.1).

Quality of Irrigation Water Used in Farming

Wherever space allows, urban and peri-urban agriculture take advantage of any water source, be it polluted or not, for dry-season or annual irrigated farming. As most of the wastewater is of domestic origin, faecal coliforms are the contaminants of primary concern. Heavy metal levels in water bodies in and around Ghana's urban centres are not elevated (McGregor *et al.*, 2001; Mensah *et al.*, 2001; Cornish *et al.*, 1999). These studies also showed that inter-seasonal variations of water quality especially after the first heavy rains can be high, hence the need for long-term monitoring.

The main focus of the on-going water quality monitoring by the International Water Management Institute (IWMI) has therefore been on nutrients and microbiological contaminants in irrigation water sources, which in most cases exceed the WHO guidelines significantly (Keraita *et al.*, 2003b). In Kumasi, faecal coliforms typically reach values of 10^6–10^8/100 ml while total coliform levels often range from 10^8–10^{10}/100 ml. Lower faecal

Box 9.1.

The current system of human waste management in Kumasi is inadequate; waste removed from the public and bucket latrines ends up in nearby streams and in vacant lots within the city limits creating an unhealthy environment. Many government offices, schools and private institutions require improved sanitation facilities. Industrial effluent from the breweries, leachate from sawmills and waste oil spillage from the vehicle repair complex at Suame are also discharged into receiving waters without treatment. The stormwater drainage system is essentially an open sewer, which discharges into the Subin, Aboabo and Sissai rivers, and as a result the beneficial uses of these rivers (domestic water supply, irrigation, livestock watering and recreational activities) are adversely affected for a number of miles downstream.'

Source: Waste Management Department, 1996–2005 Sanitation Strategic Plan, Kumasi, Ghana.

coliform counts of 10^4–10^6/100 ml were measured at some urban farming sites in Accra and Tamale. At one site in Accra piped water is available for irrigation; at another, water from a small treatment pond[1] is used. In Tamale water from a broken sewage treatment plant is used for irrigation.

The use of polluted irrigation water threatens public health. Market surveys by IWMI in Kumasi, Accra and Tamale showed that it is very difficult to find any irrigated vegetables (e.g. lettuce, spring onions, cabbage) that are not contaminated with faecal coliforms. Helminth eggs are also commonly found on such vegetables. Coliform contamination levels of vegetables are often almost the equivalent of a similar amount of fresh faeces (Keraita *et al.*, 2003b). The nutrient concentration in the water is comparatively less excessive due to wastewater dilution. In and around Kumasi, for example, the total nitrogen applied via 1,000 mm of annual irrigation ranges between between 10 and 15 kg/ha upstream of the city and up to ten times that value downstream. Phosphorus values range between 7–11 kg P_2O_5/ha. Potassium ranges between 50 and 80 kg K_2O/ha. Salinity is low (EC <1 dS/m) and pH ranges from 6.8–7.2, which is in the normal range for irrigation (IWMI, unpublished).

Use of Polluted Water in Urban Agriculture

It was estimated that if only 10% of the 280 million m^3 of wastewater from urban Ghana could be (treated and) used for irrigation, the total area that could be irrigated with wastewater alone could be up to 4,600 ha. At an average dry-season farm size of 0.5 ha, this could provide livelihood support for about 9,200 farmers in the peri-urban areas of Ghana (Agodzo *et al.*, 2003). However, as described in the previous sections, there is inadequate sewage conveyance capacity. In Accra, as in the other cities directly located on the coast, most wastewater flows into the ocean for lack of any land physically available for agriculture. In other cities and towns, such as Kumasi, wastewater flows from drains into streams, which are usually used for irrigation. Thus wastewater is mostly used in a diluted form mixed with surface runoff and/or stream water (Cornish *et al.*, 2001).

However, there are also cases where farmers use wastewater directly from drains and broken sewers without further dilution, especially in the dry season. For simplification, all these water sources are referred to as 'wastewater' in the following sections, unless a differentiation is required.

Open-space Vegetable Farming

A common picture in both urban and peri-urban areas of Ghana is the cultivation of such cereals as maize in the rainy seasons and of irrigated vegetables in the dry seasons. More than 15 kinds of vegetables are cultivated, all of which are sold. The most perishable (often non-traditional) vegetables, such as lettuce, are usually grown in the city and often harvested 11 times during the year (with only supplementary irrigation during the rainy season) (Table 9.2). Less-perishable vegetables, such as aubergines (locally known as garden eggs) are typical of dry-season irrigation in peri-urban areas. Here, staples like maize and cassava for subsistence are preferred in the rainy season.

Due to the high food prices in the dry season, the highest-value land sites have access to water. They are located on river banks, next to drains, in valley bottomlands, and if possible close to the city to reduce transport costs.

The use of polluted water for vegetable farming is more widespread in the more populated cities where safe water is scare and is used for domestic purposes. From a general survey among open-space farmers carried out in 2002, it was found that about 84% of nearly 800 farmers farming in and close to Accra and almost all 700 farmers in Tamale used polluted water for irrigation, at least during the dry seasons.

Typical urban farm sizes range from 0.1–0.2 ha and they increase in size along the urban–

[1] This is the only site in the country where 'treated' wastewater is used by six farmers. The quality of the water, however, is not much different from other (polluted) sources.

Table 9.2. Features of selected open-space urban agriculture sites in Accra.

Location in Accra (local name)	Farmers (number)	Irrigated area (ha)	Soils	Sources and quality of water	Crops	Marketing
Marine Drive (Independence Square)	98	4	Clay, gravel	Drain water, FC$<10^{6-7}$/100 ml); Irrigation with watering cans	Lettuce, green pepper, spring onion, cucumber etc.	Farm gate (trader buys crops bed-wise on the farm)
Dzorwulu/ Power line, Plant Pool	180	18	Clay, gravel	Water from river Onyasia (FC$<10^{5-6}$); irrigation with watering cans; in part pipe water (FC$<10^{1}$); irrigation with drag hose or watering cans	Lettuce, cucumber, cabbage, cauliflower, onion, Chinese cabbage, spring onions, radish, spinach etc.	Farm gate
Korle Bu Hospital	80	10	Clay, sandy soil	Drain water; shallow wells; irrigation with watering cans (FC$<10^{8}$)	Lettuce, cabbage, spring onions, local vegetables (*ayoyo*, *aleefi*), beans etc.	Farm gate
La Fulani	111	65	Sandy clay, clay	Water from stream (FC$<10^{6}$); furrow irrigation, on a small site water from a military camp treatment pond (FC$<10^{6}$)	Water melon, tomatoes, pepper, bean, okra, lettuce, spring onions, green pepper etc.	Farm gate

rural gradient. As production is market-oriented, farming is input- and output-intensive, particularly in terms of the use of water and such other farm inputs as poultry manure, pesticides and fertilisers. In Ghana, most farmers use watering cans to irrigate, while motor pumps are more common in Togo (Keraita *et al.*, 2003a). Only a few farmers with larger holdings in peri-urban areas use motor pumps. The promotion of treadle pumps started only very recently. Farmers fall into different age groups, but the majority are between 20 and 40 years old. Most of those engaged in urban agriculture are migrants from rural areas, often from the Islamic northern regions, and have experience in farming. For many urban or peri-urban farmers agriculture is the main source of household income, although not the only one.

In contrast to vegetable farmers, almost all crop and vegetable sellers are women. Many of them buy vegetables on-farm from field beds and often order in advance (Danso and Drechsel, 2003). Otherwise, open-space vegetable farming is more than 90% male-dominated especially in urban areas, usually with a large distance between the home and the actual farm plot. The reasons mentioned by farmers of both genders for the dominance of men in vegetable production, are the arduous tasks including irrigation with two heavy 15-l watering cans and traditional work sharing with women responsible for food preparation, small businesses and/or hawking. As one moves to the rural areas, however, the number of women assisting in vegetable farming increases slightly. Most undertake such activities as carrying irrigation water in buckets as 'head-loads' to the fields, weeding, and harvesting delicate vegetables. While almost all men do vegetable farming purely to generate income, women also use the produce (except for non-traditional crops) to feed their families.

Irrigation Water Requirements and Application Rates

The amount of irrigation water required depends on the effectiveness of rainfall in any given location. For the vegetables grown, the crop water requirements range between 300 and 700 mm depending on the climatic conditions and the season of the crop at the location (Table 9.3). For some farming activities that coincide with the major rainy season, irrigation water requirements are minimal. On the other hand, in the drier months in urban areas located in the dry savannah areas, irrigation water requirements per growing season could be as high as 600 mm as shown in Table 9.3. For farmers in the urban centres that depend on water from the drains, there may be insufficient water to meet their crop requirements (Agodzo *et al.*, 2003), especially if crops are grown all year round. Tap water is only available on one open-space site in Accra (Table 9.2). With up to 11 lettuce harvests per year (manual) application rates between 600 and 1,600 mm are common.

Socio-economic Benefits of Wastewater Irrigation

Individual benefits

Preliminary cost/benefit analyses have been carried out for urban and peri-urban vegetable farmers in and around Kumasi (Danso *et al.*, 2002a; Cornish and Aidoo, 2000). Year-round, open-space urban farmers can achieve annual income levels of US$400–800/ha (Table 9.4). These levels are achieved due to the intensive nature of farming made possible partly by the free and reliable supply of water. However, being successful in this way requires careful observations of market demand in the lean season in order to properly plan for the required inputs, particularly seed (Danso and Drechsel, 2003). Also, dry season peri-urban vegetable farming is seen as a significant source for income generation, since during the wet season staple crops are also grown for household consumption.

Table 9.3. *Crop water requirements for seasonal vegetable production in and around Accra, Kumasi and Tamale.*

Location	Crop	Cropping season	Crop water requirements (mm)	Irrigation water requirements (mm)
Accra	Tomato	Jul – Nov/Dec	527	327
	Pepper	Sep – Dec/Jan	464	325
	Okra	Mar – Jun/Jul	367	23
	Aubergine	Sep – Dec/Jan	508	364
Kumasi	Okra	Dec – Mar/Apr	568	504
	Aubergine	Jan – Apr/Jul	521	140
	Water melon	Dec – Feb/Mar	298	166
Tamale	Tomato	Oct – Jan/Feb	668	604
	Onion	Nov – Feb/Mar	678	581
	Okra	Nov – Feb/Mar	487	450
	Cabbage	Oct – Jan/Feb	590	na

Source: Agodzo *et al.* (2003). The data presented are for irrigation projects near each city.

Table 9.4. Revenue generated in different farming systems.

Farming system	Typical farm size (ha)	Net annual revenue (US$/ha)	Net annual revenue (US$/actual farm size)
Rainfed maize or maize and cassava	0.5–0.9	350–550	200–450
Dry-season vegetable irrigation only: aubergine, pepper, okra, cabbage, etc.	0.4–0.8	300–350	140–170
Dry-season, irrigated vegetables and rainfed maize	0.7–1.0	500–700	300–500
All-year-round irrigated vegetable farming lettuce, cabbage, spring onions, etc.	0.1–0.2	2,000–8,000	100–800

Source: Danso *et al.* (2002a).

A detailed survey carried out by Cornish and Aidoo (2000) in peri-urban Kumasi showed the profitability of different crops (Table 9.5). Based on actual farm size, average profits ranged in villages between US$140–170 per farmer. Irrigation practised here is either manual (watering can) or by motorised pumping. Farmers with motor pumps have higher production costs, but revenues were not commensurately higher (Cornish *et al.*, 2001). If the daily *per capita* income is calculated, only households engaged in urban agriculture (see Table 9.4) could move above the poverty line of US$1 per day (Danso *et al.*, 2002a).

On average, farm income from all vegetables amounts to about US$1,440/ha but a more conservative estimate considering actual crop mix could be US$500/ha (Cornish *et al.*, 2001). Most of the vegetable crops are grown in the dry months of November to February. The authors estimate the actual peri-urban area under informal irrigation within a 40-km radius of Kumasi as 11,500 ha. This is more than the total area reported under formal irrigation in the whole country. The annual value of this production has been estimated as US$5.7 million. A significant part of this (downstream of Kumasi) is produced with wastewater.

As mentioned above, vegetable marketing is the exclusive domain of women, be it in big markets or kiosks in residential areas. Inner urban area production means not only fresh produce but also lower transportation costs and higher profits.

Table 9.5. Income per commodity in peri-urban Kumasi.

Crop	Average crop area/ farmer (ha)	Total crop area (ha)	Total income (US$)	Average income (US$/ha)
Cabbage	0.35	18.5	83,954	4,551
Carrot	0.24	2.9	4,671	1,614
Aubergine	0.47	84.1	135,018	1,606
Cucumber	0.23	4.7	7,169	1,539
Tomato	0.51	99.3	133,324	1,343
Hot pepper	0.49	55.6	69,049	1,242
Okra	0.51	77.7	94,681	1,219
Green bean	0.19	1.7	1,585	948
Onion	0.29	2.0	1,813	896
Water melon	0.81	4.1	3,388	837
Green pepper	0.21	3.5	2,607	743
Ayoyo	0.51	5.1	1,061	210
Lettuce	1.03	16.4	2,705	165
Spring onion	0.19	1.1	174	153
Total		376.5	541,198	

Source: Cornish and Aidoo (2000).

Aggregate Benefit to the City

The value of wastewater irrigation should not only be seen from the perspective of livelihood support, employment, and income generation given that the actual (sometimes small) numbers of open-space farmers might not attract the attention of municipal authorities. The overall (aggregate) benefit to the city should also be highlighted. An example is the dependence of the city on irrigated urban vegetable production. Due to the lack of refrigerated transport and storage, the supply of perishable vegetables to urban dwellers depends significantly on this kind of agriculture (Nugent, 2000; Smith, 2002). In Senegal, for example, about 60% of the vegetables consumed in Dakar are produced within or close to the city (Niang *et al.*, 2002), mostly with wastewater. The specific contribution of urban agriculture to aggregate city supply and its complementarity to peri-urban and rural production has also been quantified for selected cities of Ghana and Burkina Faso (Cofie and Drechsel, 2004). The analysis, that excludes backyard subsistence production, revealed that urban agriculture is a crucial supplier of the most perishable vegetables to the cities' markets. Peri-urban production appears to be an important supplier of tomatoes and aubergines, while the majority of common staple crops like cassava, plantain, maize and rice in the city markets derive from rural areas or are imported (Fig. 9.4).

There is high demand for urban produce especially from low-income households and the large number of small (street) eating places (locally known as 'chop-bars') because it is fresh and they have limited possibilities for storage. Thus, most of the chop-bars benefit from wastewater irrigation.

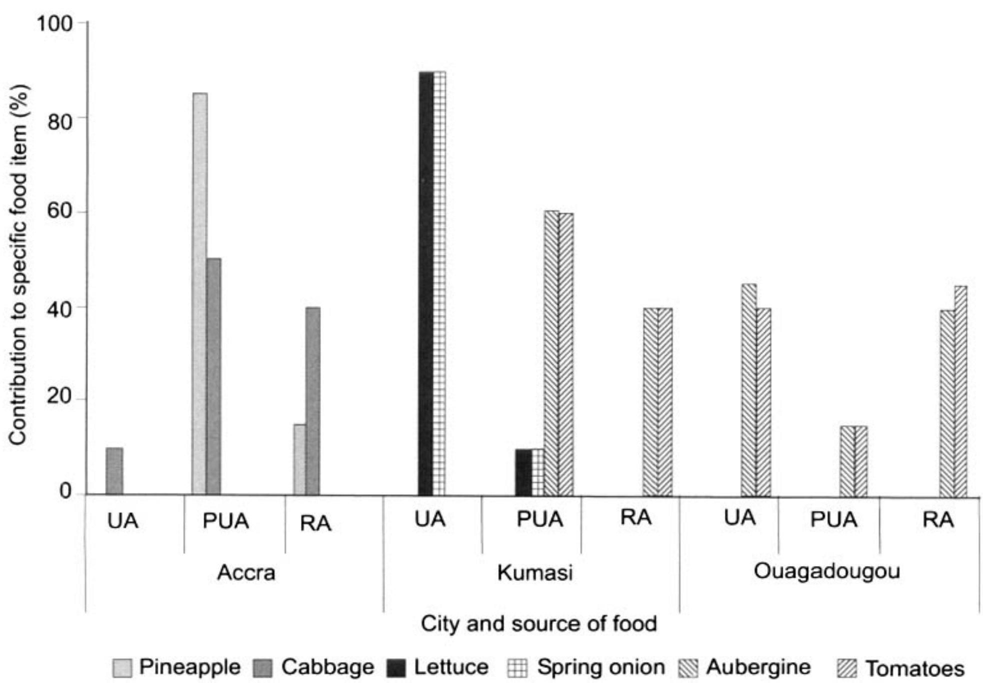

Fig. 9.4. Contribution of urban (UA), peri-urban (PUA) and rural (RA) agriculture to urban vegetable supply in three West African cities.

Source: Cofie and Drechsel, 2004.

Institutional and Perceptional Issues on Wastewater Use in Urban Agriculture

According to one of its bylaws the Accra Municipality allows the production of crops in the city. In contrast to backyard farming, open-space production (or livestock keeping) requires registration with the Medical Officer of Health. Also the Land Title Registration Law accommodates the notion of multiple rights and interests on a single plot, which provides a legal framework for urban agriculture although a distinct corresponding land-use policy does not yet exist (Flynn-Dapaah, 2002). However, as a result of Ghana's decentralisation efforts, there is a Directorate of Food and Agriculture within all metropolitan assemblies. The corresponding Metropolitan Directors of Agriculture work at the interface between the Municipality and the Ministry of Food and Agriculture with their own extension service. During Ghana's annual 'Farmers Day' celebrations they honour – like their rural colleagues – the best farmers from all administrative districts and regions, including the best Metropolitan and peri-urban farmers. All this supports the status of urban agriculture in Ghana. Despite these positive signs the problem of crop contamination raises significant concerns, not only among the health directorates of the same assemblies, but also in the media. This is supported by a municipal bylaw stating, 'No crops shall be watered by the effluent from a drain from any premises or any surface water from a drain which is fed by water from a street drainage'. This bylaw targets those vegetables and fruits likely to be eaten raw (Local Government, 1995). Although authorities expel farmers from time to time, water analysis is expensive and bylaw enforcement weak. Thus irrigated urban agriculture remains informal without any cross-sectoral support by authorities. And as farmers at most locations have no alternative to polluted water, they continue to use it. The interviews also showed that farmers in general place lower priority on the possible nutrient value of the wastewater than on its value simply as a reliable water source, especially in the dry season.[2] Thus the amounts of manure and fertiliser applied to crops are not reduced, even where water is highly polluted. A similar picture has been found with respect to farmers' awareness of pathogen contamination. Cornish and Aidoo (2000) found that only one in four peri-urban farmers would not drink the water he/she used for irrigation. Urban farmers are more often confronted by authorities (and researchers) with the water–health problem and are decreasingly willing to discuss the issue. In general, however, they do not perceive it as a major problem. Those who speak freely usually say that they see no harm in the practice. As one put it, "Ever since I was born, my father has been doing this work and it is the same drain water we have been using with no health problem" (Obuobie, 2003). In fact, the source of the water or its quality is of little concern. More important to the farmers is its uninterrupted availability and that they do not have to pay for it (Obuobie, 2003). A similar low level of concern is found for the use of pesticides, which are usually considered as 'plant medicine'. The most acutely perceived problems are access to credit, markets and water supply in peri-urban areas (Cornish and Lawrence, 2001), as well as land and water access, seed availability and low farm-gate prices in urban agriculture.

As consumers do not ask for 'safe' but 'fresh' and 'clean' products, neat appearance of the crops is most important for sellers. Refreshing and cleaning vegetables with water often of as bad quality as irrigation water is thus normal practice in markets (Drechsel *et al.*, 2000). As mentioned above, many vegetable sellers in the city buy their crops on urban farms and are often aware of the water source, but also prefer not to discuss it, particularly not with customers. The general awareness level for environmental and health issues is low (Danso *et al.*, 2002b) or of less importance than other concerns affecting consumers' livelihood and health (food security, malaria, etc.). When complaints about vegetable appearance were raised by expatriates, however, sellers tried to satisfy customer demand by extra cleaning efforts (Drechsel *et al.*, 2000).

[2] In other places, e.g. Nairobi, farmers showed more awareness of the nutrient value of wastewater (authors' observations).

Conclusions

As in other principal urban centres in developing countries, the sanitation infrastructure in Ghana's main cities has been outpaced by population increases, making the management of urban wastewater ineffective. Large volumes of partially or untreated wastewater adversely affect both water bodies and the urban and peri-urban farmers using these water bodies as sources of irrigation. High levels of pollution, specifically microbiological contamination, have been measured in irrigation water and on crops. This has raised concerns, especially on the part of local authorities as they pose heath risks to farmers and the general public. In order to protect consumers from contaminated vegetables, authorities in Accra have banned the agricultural use of polluted irrigation water. Enforcement, however, would not only affect the livelihoods of urban farmers and vegetables traders but would also reduce the continuous supply of traditional and non-traditional vegetables in the city. In this context, the implementation of the WHO irrigation guidelines appears impossible, as improved water treatment appears unviable. Similarly, there are few (tenure) possibilities or market incentives for farmers to grow crops that are not easily contaminated (like tree crops) or to use, for example, drip irrigation. In view of this, other approaches which take into account both public health risks and farmers' livelihoods need to be devised (Drechsel *et al.*, 2002). These should focus on low-cost options for risk reduction not only on farms (mini-sedimentation ponds, water filters), but also in markets and especially in households. Unless wastewater collection and treatment are generally improved, stakeholder education through awareness campaigns, e.g. on the importance of washing vegetables carefully before consumption will remain crucial to addressing the problem.[3]

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10 Untreated Wastewater Use in Market Gardens: A Case Study of Dakar, Senegal

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Abstract

Urban vegetable production in Dakar plays a significant role in fighting poverty, as it provides both income to farmers, and a source of nutritious food for the poor. However, the irrigation of these crops is cause for concern, as many farmers prefer untreated wastewater to freshwater due to the higher profits stemming from its greater availability, reduced fertiliser costs, and higher yields and production. While using such water, few take precautions to protect their health, and 60% are infected with intestinal parasites. The practice also poses a risk to public health, as three of the main crops produced (lettuce, tomatoes, and onions) are often or exclusively eaten raw. Thus, while there is a growing willingness among policy-makers to encourage urban agriculture (UA), there is also the recognition that current irrigation practices are unsafe. Authorities looking to decentralise wastewater treatment need reassurance that community-level systems can be proven efficient and sustainable. It is recommended that action research be conducted that includes finding effective treatment systems, and that tests the feasibility of other management options such as increasing public awareness, using safer irrigation methods, and practising restricted irrigation. Additional research on the economic importance of UA is also necessary to encourage donors to fund research and development initiatives. Ultimately, action must be taken soon, or a repeat of the 1987 typhoid epidemic in Dakar could lead to backlash among consumers and policy-makers, with devastating consequences for both poor farmers and poor consumers.

Introduction

Senegal ranks 156th out of 175 countries on the United Nations Human Development Index (UNDP, 2003), although its per capita gross domestic product (GDP) is US$1,500. Measures taken in 1994 to liberalise the economy, including currency devaluation and elimination of subsidies, have attracted investment and stimulated economic growth, but have also hit the poor hard. Real wages have declined, and a quarter of the population lives below the internationally recognised poverty line of US$1/day.

Furthermore, recent droughts have decreased the production of groundnuts, an important commodity that uses 40% of the cultivated land, employs 1.5 million farmers and makes up 10% of Senegal's export earnings. The sector saw significant declines in the 1990s until 1999–2000, when it bounced back.

On average, Senegal receives 1400 mm annual rainfall but during the 1980s, rainfall declined significantly before stabilising in recent years (Gommes and Petrassi, 1996). The south receives more rainfall than the north, where only about 300 mm fall each year. The city of Dakar receives about 450 mm rainfall each year (RADI, 2002). However, 80% of this is concentrated in 4 months – July to October.

All of these factors – removal of subsidies on basic foodstuffs, unemployment arising from low commodity prices, and recent droughts – have threatened the food security of the poor. Poor rural migrants looking for work increasingly find themselves in Dakar, the largest city with a population of 1.9 million people, and the centre of economic power. With a growth rate of 4%, Dakar's population is expected to reach 3.8 million by 2015. Although 80% of Senegal's industry is located in Dakar (RADI, 2002), the city still has a 25% unemployment rate. Thus, to generate income and food, more and more people have set up market vegetable gardens, which provide income, and fresh, nutritious food for the urban poor. Because it is often more convenient, reliable, and profitable, many farmers use untreated wastewater for irrigation.

Since 1999, the International Development Research Centre (IDRC) has supported Environnement et Dévéloppement–Tiers Monde (ENDA) and the Institut Fondamental de l'Afrique Noire (IFAN) to study wastewater use and urban agriculture in Dakar. IDRC first supported pilot research to identify which types of natural wastewater treatment systems would work best in Dakar. A second phase of the research project, upon which this case study is based, focused on developing two community-scale wastewater treatment plants, and a better understanding of the nature and impacts of urban gardening in Dakar. The team used GIS and aerial photos to outline the extent of UA in Dakar. For the entire production cycle, from on-site field plots to transport to the markets, the team gathered data using surveys including individual interviews and focus group discussions. Fifty farmers on three different sites were surveyed. Samples of UA produce, human waste (stool, urine) and blood of farmers were taken to assess health impacts. The study encompassed all three seasons in Dakar and analysed sites using groundwater (as a control) and untreated wastewater to make comparisons. The research results are presented in this chapter, which first describes the nature and extent of urban farming in Dakar and then outlines its health and environmental effects. This is followed by an analysis of the socio-economic factors involved, a description of the institutional and legal context, and a breakdown of other constraints to production. Finally, management and policy recommendations are outlined, and future research needs are identified.

Urban Agriculture in Dakar

Location, size, principal crops

Vegetable production in Senegal centres on the *Niayes* – shown in Fig. 10.1, a long, narrow fertile zone of land that stretches 250 km along the coast from Dakar to St. Louis. Its annual output is more than 100,000 t, worth US$18 million, and accounting for 80% of the country's total vegetable production (Touré Fall and Salam Fall, 2001).

As shown in Fig. 10.2, within Dakar there are several major sites where urban gardening takes place. This study focused on the urban farmers in Pikine, which, with a total area around 650 ha, constitutes the largest urban agriculture site in or around Dakar. Known as *les poumons de la ville* (the lungs of the city), this large green space exists within the city as a result of policies first implemented by Leopold Sedar Senghor, the first president of Senegal. Despite its importance, the zone is threatened by both urban development and saline intrusion, and has shrunk by 56 ha (10%) over the last 30 years.

The primary crops grown are lettuce, tomatoes, onions and eggplant or aubergine. While some fruits are cultivated, vegetables are preferred because they grow faster and are more profitable. The total annual production is 39,000 t and constitutes 60% of the vegetables consumed in the city (ENDA–IFAN, 2002).

Of the vegetable plots in Dakar, 80% cover between 0.01 ha and 0.1 ha with an average of 0.05 ha, or 500 m^2. These smallholder plots are traditionally farmed using such hand tools as pitchforks, hoes and shovels (Touré Fall and Salam Fall, 2001).

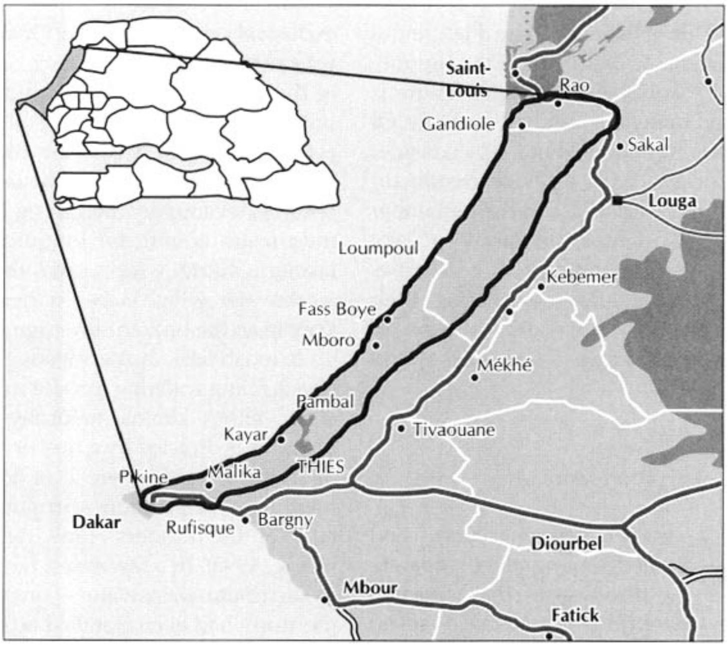

Fig. 10.1. The Niayes of Senegal.

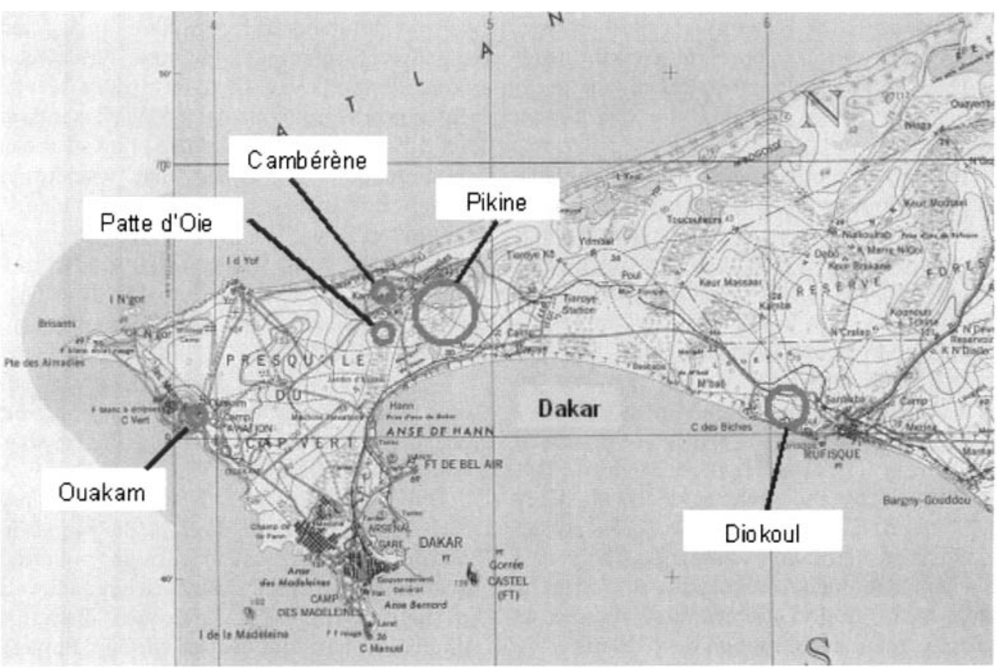

Fig. 10.2. Urban gardening in Dakar, enlarged from Fig.10.1.

Although Dakar has an Urban Plan and a 1964 Loi du Domaine National (LDN) [Republic of Senegal (National), 1964] land tenure is precarious, and many use land without title. Of the 380 farmers in Pikine, about 40% consider themselves owners with legal or customary title to the land, 6% lease it, and the remainder farm without any right to the land – a risky proposition. In 1999, municipal authorities expelled 50 farmers after discovering their plots near the airport. Also, without security of tenure, most farmers invest little in the land they cultivate.

Irrigation sources

Water supply, wastewater collection, and treatment are divided among three separate entities under the direction of the Ministère Hydraulique. Distribution has been privatised and devolved to Sénégalaise des Eaux (SDE). Operation and maintenance is controlled by Société National pour l'Exploitation des Eaux (SONES), while the Office Nationale de l'Assainissement (ONAS) operate sewerage services. SDE provides two main sources of water for Dakar – 20% comes from Lac de Guieres, where it is screened, clarified, and chlorinated, and 80% comes from groundwater at Thies, 80 km northeast of Dakar, where it is chlorinated before entering the distribution system.

A few farmers use water from the potable distribution network, but this is too expensive for most. The main sources of irrigation water are therefore *céanes* and untreated wastewater. *Céanes* are large, shallow hand-dug wells up to 3 m deep and 5 m in diameter, and are highly saline due to their close proximity to the coast. Untreated wastewater is often accessed by breaking into the mains that carry untreated wastewater, 180,000 m^3 of which are generated daily in Dakar. Of this, about 66,000 m^3, or 40%, is collected by the sewerage network. Only 4,000 m^3, or a mere 6% of the collected wastewater is treated before discharge. The rest is discharged through cesspools and unlined septic tanks to the ground and eventually the sea, or directly into the sea through open drains.

The irrigation source varies at each site, depending on access. At Cambérène, farmers exclusively use *céanes*, but at Ouakam, untreated wastewater is the only source. In Pikine, some of the farmers have access to both *céanes* and untreated wastewater, and the wastewater actually helps to access the *céane* water. The deeper the *céanes* are dug, the more saline they become, eventually becoming so saline that their water is unfit for irrigation. Thus, some farmers dilute water from the *céanes* with wastewater, which is less saline, by channeling flow from the broken sewerage mains.

In most cases, farmers wade directly into the *céanes*, filling watering cans for irrigation. Wastewater either drains naturally from broken pipes, or is directed by a hose into a depression or a *céane*, from where it is collected. Using these manual techniques, irrigation takes up to 60% of the farmers' time (Navez, cited in Niang, 1999). In a few cases, farmers use hoses to distribute wastewater – one rare farmer in the study had even installed an electric pump.

Analysis of the raw wastewater at each site showed expected results (Table 10.1) with some variance mainly due to the condition of the mains, i.e. how much storm water was in the system. Not surprisingly, the number of faecal coliform (FC), an indicator of pathogenic bacteria, far exceeded the 1000 FC/100 ml of water WHO standard required for unrestricted irrigation. Furthermore, the raw wastewater contained the larvae, eggs, or cysts of several protozoa or worms – above the WHO standard of 1/l. Some of the *céanes* also showed faecal contamination, suggesting that wastewater from the broken sewer mains is infiltrating into the groundwater. The most commonly found parasites are *Ascaris lumbricoides* (roundworm), *Entamœba coli* (which causes amoebic dysentery) and *Strongyloides stercolaris* (threadworm) (ENDA–IFAN, 2002).

Only trace amounts of most heavy metals were found, except for copper (Cu) and zinc, (Zn) which had levels only slightly higher than recommended (Rodier, 1996).

The characteristics of the wastewater vary markedly on separate days of the week. In Senegalese culture, certain days are preferred for laundry, and on these days, detergent levels are high. On Fridays, mosques discharge ablution water from *Jumma* (Friday Prayer), resulting in increased dilution and lower concentration levels for all parameters.

Table 10.1. Water quality[a] from various sources in parts of Dakar, Senegal.

Location	Water source	TSS (mg/l)	COD (mg/l)	K (mg/l)	NO_3 (mg/l)	NO_2 (mg/l)	P_2O_5 (mg/l)	FC (/100 ml)
Pikine	Deep well	28	300	132	14	0	1.49	N/A
	Shallow wells (*Céanes*)	438	282	100	37	4.5	80	17×10^3
	Raw wastewater	3,891	1,350	247.2	0.33	2.96	167	
Ouakam	Raw wastewater (rainy season)	1,299	367	65	0.4	1.02	57	47×10^4–47×10^5
	Raw wastewater (winter)	933	317	96	0.08	0.48	55	47×10^4–47×10^5
Patte d'Oie	Raw wastewater (rainy season)	7,491	1,606	136.8	0.54	0.72	147	N/A

[a]TSS = total suspended solids; COD = chemical oxygen demand; K = potassium; NO_3 = nitrate; NO_2 = nitrite; P_2O_5 = phosphate; FC = faecal coliform.

Crop productivity using wastewater

Depending on the growth period of their crops, farmers on average needed only 10 mm/day of wastewater for irrigation, compared to 12 mm/day for *céane* water (Gaye and Niang, 2002). Although the vigorous plant growth resulting from the nitrogen in wastewater would generally require even more water, this need is offset by the increase in soil organic matter that boosts its water-holding capacity.

The study found that, except for lettuce, most crops produced higher yields when watered with untreated wastewater without the addition of artificial fertilisers, than when farmers used piped potable water with added artificial fertilisers. For farmers using artificial fertilisers, these costs represent an average of 23% of their total farming costs (ENDA–IFAN, 2002). Possibly for this reason – higher yields from the same plot size – farmers who use raw wastewater have an average plot size of 0.02 ha, compared to 0.05 ha for those who use *céanes* water (ENDA–IFAN, 2002).

Table 10.2. Parasite prevalence at Ouakam and Pikine.

	Ouakam (raw wastewater) (%)	Pikine (*céanes* and raw wastewater) (%)
Prevalence	60	41
Type of parasites observed		
Ascaris	35	21
Entamoeba coli	28	35
Endolimax nana	25	0
Other	13	44

Moreover, the results also show that wastewater irrigation reduces the growth period for crops. For example, the typical period of maturity for lettuce is approximately 30 days, but drops to 20–25 days when using raw wastewater. Given that the usual growing season is November to April, this makes nine harvests possible instead of six – an increase of 50%. One drawback is that although wastewater-grown lettuce is larger, it is also less dense, yielding only 40 t/ha compared to 45 t/ha. Additionally, such lettuce spoils faster and must be sold within 24 hours of harvest (Faruqui, 2001). Similar results were found with aubergines.

About 75% of urban farmers farm year-round – the remainder work on their gardens 10 months of the year. However, 99% of farmers using wastewater practice their trade year-round. One reason for this is that wastewater-irrigated lettuce is more resistant to insects and the plant disease they cause – both of which are more prevalent during the wet season – and thus it can be grown successfully year-round. It is not yet known whether other crops exhibit this characteristic.

For all of the above reasons, the farmers interviewed have a definite preference for using raw wastewater, as it simply translates into higher annual profits. Those using wastewater reported earning very good profits during the dry season, when the price for lettuce is high due to limited supply. One farmer in Patte d'Oie said: "If I could have a permanent supply of raw wastewater for irrigation ... without being bothered by the health authorities, I could feed (support) more than 30 people."

Health and Environmental Effects

Health effects

Many farmers suffer from ill health because of their direct contact with wastewater – the lack of footwear or gloves makes them vulnerable to infection by parasites, transmitted either orally (placing unwashed hands in the mouth) or through the skin (parasites burrowing directly into the body).

At Ouakam, where only wastewater is available, 60% of farmers were infected with intestinal parasites. At Pikine, where water sources are mixed, the level of infection was lower – about 40%. The most common parasites found were *Ascaris ascaris* (roundworm), *Trichuris trichiura* (whipworm), and *Strongyloides stercoraltis* (threadworm). The eggs or larvae of all three worms, which live in the intestine, are passed through the faeces. In the case of roundworm and whipworm, reinfection is then oral, by ingesting food contaminated by the infective eggs. Threadworm, like hookworm infects by penetrating the skin of the feet or hands of farmers working in fields irrigated with wastewater.

A high density of *Plasmodium falciparum*, a parasite that causes malaria, was found in four farmers who irrigated *céanes* at Pikine. Malaria is endemic to the area, with many *Anopheles* mosquitoes present. Farmers using raw wastewater for irrigation were not infected, probably because raw wastewater is usually too dirty for mosquito larvae to thrive.

Sanitary quality of products

Recently harvested wastewater-irrigated plants for sale were found to be contaminated with amongst other pathogens, *Amoebae*, *Ancylostoma*, and *Ascaris* which cause amoebic dysentery, hookworm, and ascriasis (roundworm), respectively (Niang, 1999). Given that some of the farmers are also infected with whipworm (see above), eggs of this pathogen are also present in produce irrigated by wastewater. In the past, even more serious pathogens have been found on produce for sale in Dakar. The 1987 epidemic of typhoid caused by *Salmonella typhi* made 400 people in Dakar seriously ill. The disease originated from the consumption of vegetables contaminated with untreated wastewater, and mostly affected urban farmers who had used insufficiently treated wastewater for irrigation.

Almost half of the farmers indicated they were aware of the health risk posed by working with wastewater. However, only a handful used precautions such as wearing boots and gloves, or avoided direct contact. Furthermore, less than 15% were aware that the 1987 outbreak was caused by untreated wastewater use – in fact, many argued it was caused by other factors. Some of those unaware of the health risks are also under the impression that when water is clear, it must be clean.

For consumers, the main concern is over lettuce, onions, and tomatoes, which are most often eaten raw. Without close examination, it is impossible to tell the difference between products irrigated with water from different sources that are sold side by side. Rinsing is insufficient protection – health risks must be mitigated either by disinfecting, using a solution of sodium hypochlorite (bleach) or potassium permanganate, or by cooking. According to the ENDA–IFAN survey, a surprisingly high percentage of consumers (about 70%) are aware of health risks, and either disinfect or eat only cooked vegetables, although other surveys have found only 44% disinfect their vegetables (ENDA–IFAN, 2002). Of course, these solutions also carry risks if too high a concentration of disinfectant is used. Moreover, even using the higher figures of the more recent study, a significant minority of consumers (30%) are unaware of the risks, or take no protective measures.

For people living near the pilot wastewater treatment plants in Castor and Rufisque, an equal concern is the potentially negative health impacts from the treatment plants. To assuage these concerns, the research team carried out epidemiological studies on people, including children, living near the sites. The results found no significant differences in their health from that of the general population. The main concern is diseases transmitted by mosquitoes, including malaria, yellow fever and elephantiasis. During the study period, mosquito species causing malaria (*Anopheles gambiae*) or yellow fever (*Aedes aegypti*) were not present in the ponds, although *Culex* mosquitoes, which transmit elephantiasis, were found. Mosquitoes tend to be associated with the last pond in the series of basins that make up the treatment system, where the water is cleaner. Possible solutions to reduce mosquitoes include placing fish to eat the larvae in the last basin, or adding an additional shallow pond with a gravel bed.

Environmental effects

Very little data exist on other environmental impacts of untreated wastewater irrigation, such as impact on soils or drinking water. Certainly, most of the shallow groundwater is contaminated with pathogens. However, this is because less than 40% of Dakar is connected to the sewerage network, and even the existing infrastructure is in disrepair. Wastewater is also unlikely to affect drinking water, since the *céanes* are too salty to serve as a drinking water source.

Somewhat surprisingly, the research team collected no data establishing reduced yields, and only minimal data on soil damage associated with a build-up of oil, grease and suspended solids arising from repeated, long-term wastewater irrigation. This is probably due to the nature of the sandy or peat soils, which have large interstices between their soil particles. Nevertheless, over time this could prove to be a problem – only 27% of farmers were aware that repeated wastewater irrigation can impede infiltration by blocking pores between soil particles, eventually modifying soil structure.

Given that the majority of the catchments showed very little industrial waste in wastewater, scarce evidence of heavy metals such as cadmium (Cd), mercury (Hg), chromium (Cr^{6+}), nickel (Ni), or manganese (Mn), and only moderate levels of Cu and Zn, there is no evidence yet of other serious associated long-term health or environmental effects. The one known exception is in Rufisque (the location of the IDRC-supported treatment systems), where discharges from the Marisel tannery have increased salinity in the wastewater to the point where it is unusable for irrigation. Levels of discharged Cr^{6+} may also be high, although this has yet to be detected.

Socio-economic Characteristics of Urban Farming

Socio-economic profiles of farmers

Almost 90% of the surveyed farmers are men, mostly under 45 years old, and the primary wage earners in their families. This is in contrast to other African cities where urban farmers are mostly women. However, Dakar female family members do help during the harvests and act as intermediaries, selling crops in the market.

Of the urban gardeners 58% are former farmers who migrated to Dakar from rural areas, and they farm because it is familiar and profitable. For 75%, it is their main occupation. All ethnic groups are represented and the practice is not restricted to the poorest groups.

The farming systems differ widely, showing wide variability in plot size, intensity, and profit, and depend on various factors, including access to water or wastewater, socio-economic level, proximity to markets, land tenure, soil quality, and whether or not farming is the principal occupation.

Urban farmers in Dakar are partially organised, as some are associated with or part of the Groupes d'intérêt economique (GIE). GIEs are community-based economic associations that work to develop small-scale enterprises. GIEs help collect funds to operate the sewerage system in Castor and Rufisque, and help organise some of the UA farmers in Pikine.

Benefits

Crops are largely intended for the market, but a significant amount is for home consumption. The researchers were challenged in trying to make estimates of the economic value of this production, because while the farmers interviewed stated they earn reasonable profits, they were either unable or unwilling to give precise figures. Based on the average response (through oral surveys), the farmers earn net revenues (profit) of about FCFA 43,000 (US$73)[1] per harvest. Given that each farmer's plot is on average 0.05 ha, the profit per harvest is about US$1460/ha.

Using the four most common crops, the study found that on average farmers harvest five crops per year. The net average annual profit for each farmer is then FCFA 215,000 (US$365), or FCFA 589 (US$1)/day – equal to the international poverty line. While this figure may seem low, the profit generated may be less important if urban farmers become completely self-sufficient in vegetables. Considering that food purchases by the poor in the urban areas of developing countries can be as much as 80% of their income, this is a considerable improvement in family wealth (Egziabher *et al.*, 1994). Furthermore, if the farmers are among that quarter of the population already at the international poverty line, the profit earned essentially doubles their income. However, these figures probably underestimate their income. Some of the urban farmers indicated they earned profits of up to FCFA 300,000 (US$510) per harvest, or FCFA 1.5 million (US$2,552) annually, and it is likely that their annual net revenues are closer to this figure. In addition, it is unlikely that farming provides the sole contribution to household income, as some farmers may undertake other activities, and other family members may also be working.

In addition to direct income benefits from UA, there are also indirect economic spin-offs. Although not yet directly estimated, anecdotal evidence indicates that urban gardening generates a variety of other economic activities related to food production, marketing, and the sale cycle. This helps create demand in sectors that produce such goods as tools and seeds, and such service sectors as transport.

Costs

As with benefits, it was difficult to assess input costs due to the informal nature of urban gardening and the reticence of some farmers to respond to surveys. A preliminary estimate of cost per farmer per plot per harvest (both for those using raw wastewater and water from *céanes*) is:

- Soil preparation – FCFA 8,682 (US$15)
- Equipment – FCFA 10,300 (US$17)
- Fertiliser and pesticides – FCFA 4,021 (US$7)
- Seeds – FCFA 7,140 (US$12)

A total cost per farmer per plot per harvest is thus about FCFA 30,000 (US$51), or, using an average estimate of five harvests/year, US$255/year. As noted earlier, farmers who do not use wastewater pay up to 23% of their total input costs for pesticides and fertilisers. In this example, it would amount to about FCFA 9,200 (US$16) – or twice what farmers using wastewater pay for fertiliser.

Furthermore, labour, except for that involved with soil preparation, is not fully accounted for above. Working backwards from the profit figures presented earlier, the estimated average gross revenue based on farmer's responses may be in the order of US$255 (costs) + US$365 (net income), or US$620 annual gross income.

Institutional and Legal Framework

Notwithstanding problems of land tenure, the practice of UA is generally encouraged in Senegal. In 1984, the State began incorporating horticulture into national economic plans and development strategies, and this culminated in 1994 in the creation of the Department of Horticulture. Its aim is to support small-scale agriculture through credit programmes, training, and access to tools, fertilisers, and pesticides; but actual financial support has been negligible and the activity remains firmly in the informal sector. At the municipal level, seven mayors (including Pikine's) and city councillors from West Africa signed the *Dakar Declaration* in March 2002 (IDRC, 2002), which stated their explicit support of UA. Although the *Declaration* specifically noted the widespread practice of wastewater use and its health risks, the municipalities are not yet able to regulate UA,

[1] Based on 17 July 2003 exchange rate of US$1 = CFA Francs 587.76.

or to provide management options for mitigating risks.

While UA is theoretically encouraged, unrestricted wastewater use is not, and is banned by the National Health Act (1983) and the Environment Act (2001). The Health Act (Article L–41) stipulates that the 'deposit of waste, septic tanks discharge, garbage, sludge, faeces are prohibited on all lands where fruit and vegetables consumed fresh and cultivated and where edible parts come into contact with this waste'. Moreover, organic fertilisers like manure and compost can only be placed on crops up to one month prior to harvest. Previously, both national and municipal officials had attempted to enforce the law, but efforts proved futile and not much is done now. For example, at the behest of health officials, ONAS repaired pipes, but farmers simply broke them again.

However, there is evidence that both state and municipal authorities are willing to confront the reality of wastewater use. For instance, the Ministère Hydraulique's Projet Eau Long Terme (PLT) 5-year plan for 2002–2007 recognises the potential of wastewater use as an effective instrument for managing water demand. Notably, ONAS has also recognised its value, and is prepared to support decentralised wastewater use systems, so long as health risks are minimised. ONAS has envisioned creating 160 small-scale, community-operated wastewater treatment systems, and 60,000 on-site treatment systems in the country – with the caveat that it first needs to be convinced of the efficiency and sustainability of such systems. Similarly, the *Dakar Declaration* explicitly recognises both the benefits and risks of widespread wastewater use. All of these developments contribute to a policy climate from which viable approaches to protect farmers and the public health could emerge.

Constraints to Sustainable Urban Agriculture Production

Environmental and public health issues

Environmental effects may become a growing problem, but significant restrictions would also arise from a serious health crisis such as the 1987 typhoid epidemic – global public awareness of health impacts will spread faster and reach more people than in 1984, due to the advances in information and communication technologies made in the last 20 years. In effect, such an episode would quickly generate worldwide publicity through the Internet, and magnify local knowledge of the issue (witness the 2003 SARS outbreak) – making a backlash more likely to occur.

This blowback could result in a possible crackdown on producers by health inspectors, and a temporary repair of broken sewers by ONAS which could have devastating impacts on urban farmers and the urban poor.

Insecurity of land tenure

Short of a major health epidemic, a far greater obstacle to UA is insecurity of land tenure. Large, green, city spaces within developing countries are rare, and Dakar's situation is threatened by the development of a new golf course and private homes adjoining the site of Technopole, a business park already built on the aquifer recharge zone of the *Niayes*. Furthermore, another part of the *Niayes*, east of National Highway 1 and west of the Dalifort neighbourhood is being developed by two urban development agencies – Société Nationale des Habitats à Loyer Modéré (SNHLM) and Société Centrale d'Aménagement des Terrains Urbains (SCAT–URBAM).

As urban planning and programming of the city does not include UA, small-scale producers are aware their land may be expropriated at any time by the state for projects in the 'public interest', and thus do not invest heavily in their land. Although La Loi sur le Domaine National (LDN) suggests that 'la terre appartient en premier lieu à celui qui la cultive' (those that cultivate the land have first rights to it), economic interests sometimes override the law (ENDA–IFAN, 2002). Also, development sometimes provides low-income housing – an acute need in Dakar. This limits the possibilities for maintaining UA plots in the *Niayes*, and means planners face the challenge of moderating competing interests over the productive green areas of Dakar.

Recommendations

Dakar is now at a crossroads, as authorities search for feasible and effective ways to regulate existing irrigation practices and to reduce their harmful effects. The opportunity to implement guidelines from the World Health Organization (WHO) for the treatment and safe use of wastewater for agriculture (Mara and Cairncross, 1989) should now be explored together with other management options.

Treat wastewater

The main recommendation is to treat domestic wastewater to meet WHO guidelines for unrestricted use. Non-functioning treatment plants, abandoned due to a lack of capacity and funds, already exist at Pikine and Patte d'Oie. Parts of these plants could be reused in a simple, low-cost system. Furthermore, at Pikine there are large *mares* or ponds that could be used as reservoirs to allow pathogens to die off, thus rendering the wastewater suitable for unrestricted irrigation (Redwood and Faruqui, 2002).

Over the last 3 years, IFAN has been pilot testing two aquatic treatment systems: one using water lettuce (*Pistia stratiotes*) in Castor, and the other using bulrushes (*Typha* spp.) along with tilapia in Diokoul. Research progress has been slow due to external conditions, but results so far have been encouraging – the natural treatment plants are clearly more robust than mechanical systems. First built in 1994, they survived for 5 years without maintenance or harvesting of the aquatic plants, and they continue to operate, albeit at less than optimal efficiency. In contrast, a mechanical treatment plant would probably have experienced complete failure over such a long period.

Results are also promising in terms of both biochemical oxygen demand (BOD) and total suspended solids (TSS) removal, since heavy metal levels in the influent of both plants are safe. The main problem is pathogen levels, which pose the greatest threat to public health. In both Castor and Diokoul, faecal coliform levels in the effluent exceeds 1000 FC/100 ml, and intestinal pathogens are present, meaning the wastewater should not be used for unrestricted irrigation, although it could be used for restricted irrigation. This stems from inadequate residence time for pathogen die-off, and a second phase of the research project will focus on bringing the existing treatment systems in line with the WHO guidelines.These include a different orientation to increase hydraulic retention time. One important aspect of this study will be to map potential industrial contamination that may be preventing the re-growth of aquatic plants.

While initial results are encouraging, and capital and operations and maintenance costs to date have been low, this is no guarantee that the proposed treatment systems will be cost-effective and sustainable in achieving a water quality suitable for unrestricted irrigation. That possibility notwithstanding, it is still recommended that some level of treatment be provided to reduce health risks, and remove oil, grease, and suspended solids that could harm plants and ultimately modify soil structure. However, this does necessitate an investigation of other means to lower risks.

Other management options

The benefits and costs of the following proposed non-treatment management options will be studied in the next phase of the research project.

Increase public knowledge and awareness

Education programmes for farmers, the public, and municipal officials are essential complements to other risk-reduction tools. The findings in this paper could form the basis for awareness-raising strategies that focus on benefits, risks, and mitigation strategies, designed in line with WHO guidelines. In order to ensure that wastewater management is relevant and has a lasting effect, awareness strategies need to be comprehensive and broad-based, i.e. using such tools as schools and media campaigns, along with non-secular tools.

Culture, including religion, clearly influences how people perceive and manage a resource, and this is increasingly recognised by such organisations as the United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO) and the WHO, which have drawn on this connection for programmes in Afghanistan and Jordan. The degree to which people are influenced by religion varies among and within countries, but given that Senegal's population is predominately Muslim, there is an opportunity to use Islamic teachings to encourage safe irrigation practices. In Dakar, one of the main zones of wastewater use, Ouakam, is close to La Mosquée de la Divinité, and more than 40% of the children in the area attend Islamic school. As indicated in *Water Management in Islam* (Faruqui *et al.*, 2001), explicit support for water conservation is found in Islamic religious texts that place a great premium on cleanliness; wastewater use is allowable, but only when it has been treated sufficiently to protect public health.

Socio-cultural beliefs may also provide indirect opportunities, as farmers could be asked not to irrigate on laundry day (or the day after) because of the high levels of detergent in the water. Instead, they could try to irrigate on Fridays (after *Jumma*) when the water is more diluted following ablutions at the mosques. In Jordan, an IDRC-supported project on greywater use is reusing the *wudu* wastewater to irrigate olive trees in the mosque's courtyard. There is no reason why *wudu* water cannot be used from every single mosque in the world with a patch of land, including those in Dakar.

Use safer irrigation methods

Irrigation methods can affect both the degree of plant contamination and the types of precautions farmers can take to protect their own health. The current method of irrigating with watering cans intensifies the risk of contamination because droplets touch the plant leaves. The research project confirmed that lettuce watered this way is more contaminated by faecal coliforms and *Streptococcus* than lettuce irrigated by furrow (ENDA–IFAN, 2002). However, hose use depends on topography unless farmers install pumps. Where feasible, distribution lines could be fitted with drip irrigators so the wastewater wets the root zone directly without contacting the plant leaves. As an added benefit, this also reduces water consumption per unit area, but probably not in aggregate terms if the irrigated area expands.

In terms of implementation, micro-credit schemes exist in Dakar that could help make such basic tools as trickle irrigation systems, small pumps, and protective gear available to urban farmers. The Department of Horticulture could become more active in propagating these low-tech preventative methods. However, insecure land tenure means that farmers are reluctant to make greater investments in their enterprises, even though improved irrigation methods would improve their personal health.

The timing of wastewater use can also reduce impacts on health. WHO guidelines recommend that wastewater irrigation should be stopped 2 weeks before harvest (Mara and Cairncross, 1989). For those without an alternative water source, irrigation should be stopped at least 2 or 3 days before harvest, because this reduces pathogens on the leaves of produce. The use of setbacks (up to 300 feet) should also be considered for larger plots within urban areas (OAS, 1997).

To protect farmers, health authorities could make wearing boots and gloves when irrigating mandatory – the problem however is that farmers do not like wearing gloves in hot weather, and most *céanes* are deeper than boot length. Under the current passive method of collection and distribution, i.e. allowing wastewater to drain into the *céanes* and watering with cans, wearing gloves and boots is unlikely to be feasible, although even now, farmers could at least wear shoes when walking in their fields. As an alternative, wastewater could be pumped up to raised treatment and storage tanks, from where it could flow into the fields via hoses or furrows or be collected in watering cans from standpipes. However, until the feasibility of decentralised treatment is proven, this approach will be limited to the IDRC pilot test during the next phase of research. This example however, illustrates the point that treatment options and other management options are not mutually exclusive – in fact they depend on each other.

Crop restrictions

Given that many of the crops watered with wastewater are some of the most profitable, it may be difficult to enforce crop restrictions. Nevertheless, until viable treatment systems are in place, this practice should be discouraged, even if focusing on vegetables, such as aubergine that are eaten cooked, lowers profits. However crop restrictions alone have proven impractical in other jurisdictions, so such measures must be combined with a methodical public awareness and farmer education programme. Additionally where regulation fails, markets may succeed, as there may be reduced consumer demand to purchase wastewater-irrigated raw vegetables, if consumers realise the hazards.

Improve institutional coordination

The current research has identified a lack of collaboration between such non-governmental institutions as the farmers themselves, groups representing them, e.g. Groupes d'Intérêt Economique (GIE), and governmental organisations such as municipalities (the Commune of Dakar), and national departments such as the Ministries of Agriculture, Health, Urban Planning, and SONES. An important part of the next phase of the project will be regular meetings bringing all stakeholders together to brainstorm for mutually satisfactory solutions.

Treat infections

Another potential solution is medical treatment for farmers to assuage chronic health problems such as bacterial and worm infections (RUAF, 2002). Granted, such an approach is reactive rather than preventive, but until other solutions are better advanced, it may be the only way to protect farmers' health. The benefits and costs of this approach will also be assessed during the next phase of IDRC research.

Conduct research

The informal and quasi-illegal nature of UA activity, and the cost and time required to do methodical research, means many findings only probe the surface. Although they provide qualitative data or trend directions, they do not fully answer questions, and indeed, raise new ones. Because of this, some of the above recommendations are tentative. As already noted, key research gaps must be addressed by meaningful research before such recommendations can be significantly implemented. These gaps include:

- Designing efficient and sustainable natural wastewater treatment systems
- Finding the best institutional policies and framework to help municipal and national institutions work together in support of urban farmers and to protect public health
- Testing the feasibility of non-treatment management options.

In addition, in order to attract increased donor and state funding (see below), the following information is required:

- Better economic estimates of the value of UA to emphasise its importance for poverty alleviation to donors and policy-makers
- More accurate estimates of the economic value-addition of wastewater use in urban agriculture.

Increased donor/state funding

Finally, donor and state funding is essential to help policy-makers strike a balance between protecting the public interest, the farmers, and the urban poor. ONAS in partnership with UN Habitat and the World Bank suggest that decentralised treatment and use is a serious option for wastewater management in Senegal. However, without additional funding, neither the treatment, nor other management options can be implemented. A real opportunity exists to seriously mitigate risks, provided funds are forthcoming.

Conclusions

Farmers prefer using wastewater to freshwater for irrigation, as they immediately see higher profits. However, few take precautions to protect themselves, and as a result, 60% of them are plagued with intestinal parasites. Additionally, the practice poses a significant public health risk, as three of the main crops are most often eaten raw. Urban agriculture itself is constrained by the insecurity of land tenure, as the constant threat of losing their land makes farmers unwilling to commit to major investments. Thus the potential for safer and more convenient irrigation methods, such as hoses fitted with drip irrigators, is limited.

While policy-makers have largely ignored UA in the past, they are increasingly encouraging its practice, while simultaneously attempting to discourage its dangerous use of raw wastewater. Policy-makers such as ONAS are emphasising treatment and are prepared to decentralise wastewater treatment to the community level, so long as efficient and sustainable systems can be identified. It is recommended that action research be conducted that balances both private and public needs, including testing for effective treatment systems. At the same time, the feasibility of such other management options as increasing public awareness, using safer irrigation methods, and practising restricted irrigation should also be explored. These treatment and non-treatment options are complementary, and unless action is taken soon, a repeat of the 1987 typhoid epidemic could lead to a backlash among consumers and policy-makers, with devastating consequences for both poor farmers and poor consumers.

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11 Wastewater Irrigation in Vadodara, Gujarat, India: Economic Catalyst for Marginalised Communities

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Abstract

Wastewater is gaining popularity as a source of irrigation water in different countries around the world. This is especially true in India, where it has been in use for a long time. Its economic benefits and its importance as a coping strategy for the poor have had little recognition. The rural areas downstream of Vadodara in Gujarat, India, present an interesting case where wastewater supports annual agricultural production worth Rs. 266 million (US$5.5 million). Both food crops and cash crops are irrigated by domestic wastewater and industrial effluent. In this area one of the most lucrative income-generating activities for the lower social strata is the sale of wastewater (and renting pumps to lift it). The lack of alternative sources of water has generated viable markets for wastewater. Increased disposable incomes have resulted from the catalytic use of wastewater that was formerly not socially acceptable, i.e. the farmers considered it unhealthy and unclean. The use of wastewater to grow food crops poses uncertain risks to the health of both consumers and those who actually handle the wastewater. Livestock, land and groundwater resources are also at risk. City planners and administrators view wastewater as a disposal problem. They are not concerned with the impact on the livelihoods it presently generates or with the health of the stakeholders. Politics and corruption play an important role in the decision to construct expensive treatment plants that often fail to function properly, if at all, once they are commissioned. The dynamics of agricultural wastewater use and a potential roadmap for optimal productivity are presented in this chapter.

Background

Worldwide the role of wastewater in agriculture has become increasingly important. Its agricultural use is not limited to arid areas. Humid regions like Vietnam (Raschid-Sally *et al.*, Chapter 7, this volume) also make efficient use of wastewater. As both industry and populations continue to increase and freshwater availability decreases, wastewater becomes an important regional planning variable.

In India, wastewater irrigation is increasingly used for such crops as vegetables, fruits, cereals, flowers and fodder. Kolkata (formerly Calcutta) has a long history of using wastewater stabilisation tanks for aquaculture. An estimated 2.4 t/ha (Gopal *et al.*, 1991) of fish is produced annually in Kolkata from about 3200 ha of ponds with inflow of about 3 m^3/sec Throughout India industries recycle wastewater to reduce the requirements for freshwater. This trend is led by industries in

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Saurashtra, Gujarat and Chennai, Tamil Nadu. Vadodara is the third largest city in Gujarat and growing rapidly. At present, water there is used by three major sectors. Industrial use began in the 1950s and 1960s with oil, chemical and pharmaceutical plants. It is concentrated in such peri-urban areas as Nandesari, Bajuva, Ranoli and Makarpura, where a separate effluent channel handles much of the industrial effluent. Domestic water supply serves a population estimated at about 1.5 million in 2001. A large agricultural area extends well beyond the peri-urban limits into the rural areas to the southwest of the city. Municipal sewage is used to grow vegetables, wheat, paddy rice, and flowers along an 80-km stretch of the rivers Jambuva, Vishwamitri and Dhadar [termed the municipal sewage use area (MSU area), in this chapter]. Effluent is also used for irrigation along a 56.3-km stretch of the Effluent Channel Project (termed the ECP area).

Annual rainfall in the region averages approximately 800 mm, but, there was a 3-year drought in 1999–2002. Flat land that slopes gently towards the sea characterises the topography. Due to proximity to the sea, saline water ingress is a problem that limits the availability, discharge, and duration of operation of wells for exploiting groundwater. The region is classified as a 'No-Source Zone' by the State Ground Water Board, signifying that there are no new freshwater sources that could be tapped. The very high degree of urbanisation assures farmers of stable and lucrative markets.

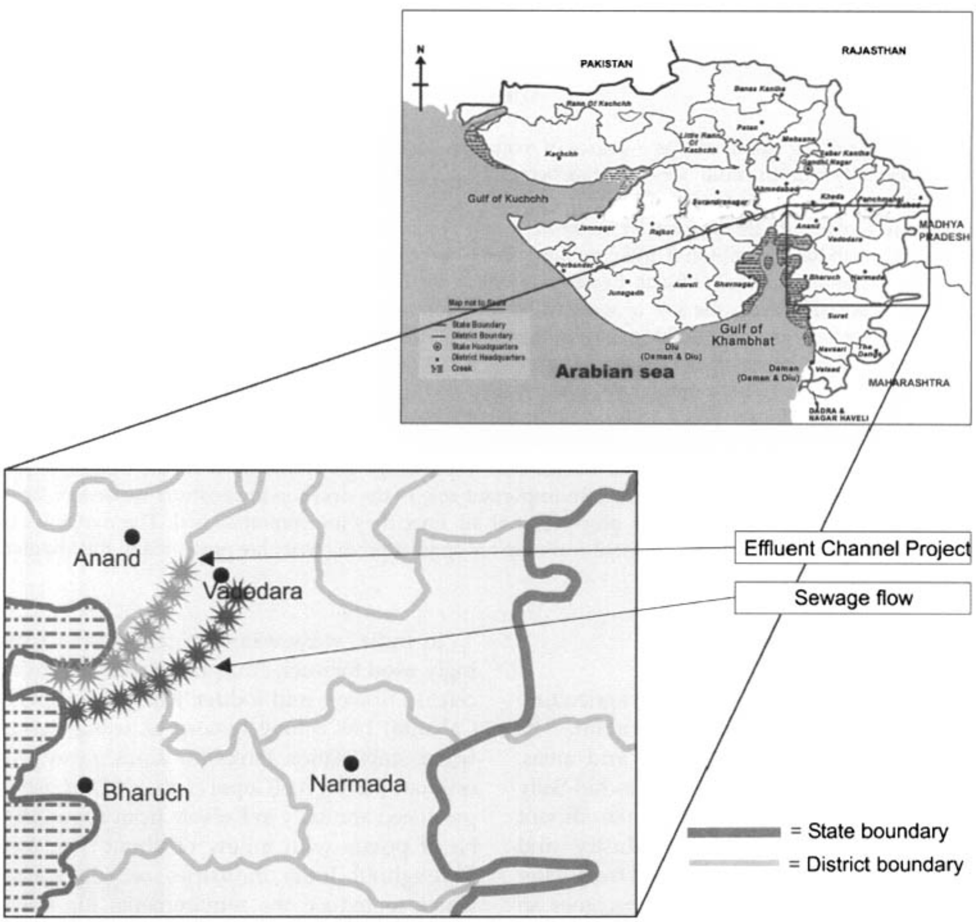

Fig 11.1. Map and sketch showing the wastewater irrigated area (Effluent Channel Project and municipal sewage use areas) around Vadodara, Gujarat, India.

The ECP is a concrete-lined covered channel 56.3-km long. It disposes 18 million gallons/ day (MGD) of treated effluent into the Cambay Channel leading to the Gulf of Cambay. The ECP follows guidelines and procedures developed by the National Environmental and Engineering Research Institute (NEERI) at Nagpur. Nine industries joined together to plan, promote and execute the project that was commissioned in 1983 at a cost of Rs.130 million (approximately US$14 million in 1983). Wheat, tobacco and pearl millet production characterise the agriculture in the region. Untreated effluents are illegally and flagrantly released by erring industries into the last few kilometres of the channel, and cause widespread land degradation and crop loss.

In 1962, the city was divided into three drainage zones, each equipped with a collection system and a sewage treatment plant (STP). The effluent from the treatment plants discharges into the Ruparel Kaans, then into the natural seasonal river system of the Vishwamitri to the southwest of the city, and finally joins the Dhadar River and runs into the sea.

At present none of the three STPs is fully functional. The oldest, Gajrawadi STP, is now beyond repair. It receives close to 85 million litres per day (MLD) of sewage. At the Atladra STP, only the primary settling tank is in working condition, and only partially treats 27 MLD. The Tarsali STP utilises obsolete oxidation ditch technology. Although it receives 40 MLD of sewage, according to a report submitted to Vadodara Municipal Corporation for the future planning of a sewage collection system (AIC Watson Consultants Ltd, 1999), it only has a capacity of 9 MLD. In the village of Kapurai, farmers buy municipal sewage from the municipality to use for irrigation.

Methodology

The methodology for the study comprised a combination of the following:

- Exploratory visits to the area that were necessary to comprehend the region and the issues involved.
- Preliminary group discussions that were helpful in sample design and planning, for the selection of study tools and for qualitative analysis.
- The sample design which involved selecting five villages along the ECP area and 10 along the MSU area. Villages were chosen from along each bank, maintaining a uniform spread over the whole area. For the MSU area this sample comprised eight villages along the river Dhadar, and one village each along the rivers Vishwamitri and Jambuva (where the flow length is short). In the ECP area, the area was divided into six sample sites depending on the intensity and cropping pattern of agriculture. A village was chosen from the centre of each of five sites. The sixth site was excluded, as the Effluent Channel Project Limited (ECPL) authorities permit little or no use of effluent for irrigation there.

Through group discussions the extent, type and interlinkages involved in the use of wastewater for irrigation were estimated.

Three questionnaire surveys were carried out at the farmer and household levels. One questionnaire dealt with agriculture-related information and included a minimum of eight farmers from each group using wastewater, groundwater and rainfed agriculture, totalling 25 in each village. The second questionnaire pertained to the health impacts of water use and covered 25 households from each village including a significant number of households that use wastewater. The third questionnaire captured the dynamics of water markets for irrigation and was administered to three wastewater and two freshwater sellers in each village. The questionnaires consisted of structured closed-ended and open-ended questions supported by informal discussions with respondents and non-respondents alike.

Data on crop economics were collected at the village level and aggregated by crop for the study area. This was done to reduce the error due to direct extrapolation from field to study area level. The statistical package for social sciences (SPSS) and Excel were used to determine the averages, variations and correlations. The results were confirmed through the focus group discussions with the farmers and interviews with the farmers in the villages.

Results and Discussions

Municipal sewage use (MSU) area

About 200 years ago the Dhadar was a perennial river but over time became seasonal, carrying water only during the monsoon. Municipal sewage started flowing in 1962 when the three STPs were commissioned. Since then the perennial flow in the Dhadar has been restored, albeit with municipal sewage. Only twice in its 41 years of wastewater conveyance has the river dried up (70 km downstream of Vadodara city beyond Amod) (Bhamoriya, 2002). The characteristics of water use including wastewater, groundwater and rainfed farming in the MSU area are presented in Table 11.1.

Group discussions elicited the fact that rainfed farmers marginalised by failing rains were an important group that had converted to wastewater irrigation. Wastewater farmers have been using municipal sewage for about 7–8 years on average. Because wastewater is available, farmers have been able to bring a significant area of land under cultivation and irrigation. Wastewater agriculture has thus become an attractive livelihood option in the area.

Three cropping seasons are possible. The most common crops grown with wastewater irrigation are:

- Rainy season (*kharif*): Pearl millet, tobacco, rice and elephant grass
- Postrainy season (*rabi*): Wheat, tobacco, banana and elephant grass
- Summer: Pearl millet and elephant grass.

ECP area

The effluent channel conveys treated industrial effluent for 56 km before discharging into the sea. The extent of the wastewater-irrigated area along the channel is less than that of the MSU area. There is intensive agricultural use of effluent close to the channel itself, but there is systematic under-reporting on its prevalence, because it is illegal to lift effluent to irrigate fields.

Prior to using wastewater, farmers had no source of irrigation water. About 8–9 years ago they discovered the benefits of wastewater irrigation (although some farmers claim to have been using it since 1983). They would prefer to use freshwater but this is not an option here. The recent drought years have seen an increase in the use of effluent for a variety of other purposes, like drinking water for cattle, and for washing utensils and clothes, thus exposing the population to undocumented health hazards.

The farmers reported pH variations in the effluent ranging from 2 to 11, which can be very detrimental to crops, so they steal pH-measuring strips from nearby factories to check the pH of the effluent, and only use it when the pH is between 6.5 and 8.5.

Downstream of Uber untreated wastes brought in by trucks from as far away as Jagadhia and Bharuch are discharged into the

Table 11.1. Comparison of wastewater and groundwater (tubewell-irrigated) and rainfed agriculture in the MSU area.

	Wastewater	Tubewell	Rainfed
Family size (number)	4.9	4.4	4.6
Total landholding (ha)	3.5	3.4	2.6
Off-farm wage earning members (number)	1.7	1.3	1.6
Income from off-farm sources (Rs./month)	1756	1513	1890
(US$/month)	(36.58)	(31.52)	(39.38)
Years since first use of wastewater	8.3	~0	0.1
Distance from source of irrigation (m)	160	175	–

Table 11.2. Comparison of wastewater and tubewell-irrigated and rainfed agriculture along the Effluent Channel Project (ECP).

	Wastewater	Tubewell	Rainfed
Family size (number)	4.98	4.54	4.95
Total landholding (ha)	2.7	3.1	2.4
Other earning family members (number)	1.4	1.3	1.8
Income from other sources (Rs./month)	1,835	1,927	1,715
(US$/month)	(38.23)	(40.15)	(35.73)
Years since first use of wastewater	8.6	0.7	0.4
Distance from source of irrigation (m)	90	75	230[a]

[a] Some critical protective irrigation can be given by a few to their *kharif* crop when the rains fail, hence this value appears.

ECP channel. From this point downstream, the effluent flow is totally unfit for agriculture. Even upstream along the ECP channel, many farmers who took up wastewater irrigation now find that their land has become infertile or they have incurred heavy crop losses, and as a result have been forced to leave agriculture.

Coping with Poverty: Creating A New Social Order

From information collected mainly through the focus group discussions supported by survey data it became clear that the region has suffered from unemployment as a direct result of water shortage in an area with a large population dependent on agriculture. The following social order existed before wastewater was used for irrigation, in order of incomes and economic opportunities:

- Tubewell owners
- Tubewell water buyers
- Well owners
- Employees of a factory or other unit
- Shopkeeper/Trader in village
- Rainfed farmer
- Agricultural labourer

The top three groups represented irrigating farmers but well owners had limited available water and were dependent on rainfall to recharge their wells. As education and skill levels were low, employment was not very remunerative. Shopkeepers had limited markets within the villages. Rainfed farmers and agricultural labourers lived with the high risks and vulnerability of uncertainties linked to water availability for agriculture. A combination of accelerated pumping and erratic rainfall resulted in wells drying up and increasing groundwater salinity. The rural economy was unable to keep up with the larger processes of economic growth fuelled by industry and urbanisation.

In this crisis, some rainfed farmers rented pumps and applied wastewater to their fields to save their parched crops. This proved a revolutionary step. The stigma attached to wastewater use proved a barrier for the so-called 'well-to-do' to take up sewage as an irrigation option. This resulted in sewage use being self-selecting towards the poorer and marginalised sections of the society who had no options but to use it or face drought and poverty.

Sewage and industrial effluent flows have hardly any seasonality in quantity, and therefore are reliable and assured sources of irrigation. Farmers clearly indicate that wastewater is an excellent resource for poverty alleviation.

Besides the direct benefits to farmers who irrigate with wastewater, an indirect benefit has been the sale of wastewater. The data for water selling in Table 11.3 shows higher incomes (despite under reporting) for wastewater sellers (diesel pump owners) than for tubewell owners. This is partly based on the fact that the average pumping time for wastewater (11.25 hours/day) is twice that for groundwater tubewells (6.6 hours/day).

The increased income for wastewater sellers is because there are more customers and larger areas irrigated per diesel pump lifting

Table 11.3. Gross and net monthly incomes [Rs.(US$)] of different groups of water sellers.

	ECP area		MSU area	
	Gross monthly income	Net monthly income	Gross monthly income	Net monthly income
Tubewell water sellers	5,850 (121.88)	2,688 (56.00)	8,050 (167.71)	3,685 (76.77)
Pump-renting agents selling wastewater	10,642 (221.71)	3,467 (72.23)	10,810 (225.21)	4,167 (86.81)

Note: Rs.48 = US$1.

wastewater than those using groundwater from deep tubewells. This is despite the fact that diesel pumps cost more to run than electric pumps.

Wastewater has catapulted wastewater irrigators into the higher economic strata of irrigating farmers and pump owners (water sellers), which are the most remunerative agricultural occupations in the region. This process has benefited the poor and has helped to reduce social inequality.

In the ECP area there have been some interesting cropping shifts. Sugarcane that was not grown prior to the availability of effluent has been introduced. All the sugarcane farmers interviewed were irrigating their crops with effluent. The tubewell owners (groundwater irrigators) do not plant sugarcane because they do not have enough water. A similar trend is cultivation of banana, another remunerative cash crop. Amla (*Phyllanthus emblica*) (fruit) and drumstick (*Moringa oleifera*) trees whose edible seed pods are used as a vegetable are gaining popularity among wastewater irrigators as they provide a good source of revenue with less irrigation than sugarcane, thereby saving the cost of diesel needed to pump wastewater.

Agricultural Value and Impacts

Table 11.4 presents the cropped area derived from the field studies and calculates the value of agricultural production sustained by wastewater (both municipal and effluent).

Note that ECP and the MSU areas were estimated by extrapolating from irrigated area data collected at the village level (through focus group discussions) based on the total number and area of villages along the channel reaches known to receive wastewater. The average irrigation depth applied was calculated by dividing the total estimated wastewater irrigation volume by the gross cropped area.

Despite using only one-third of the municipal area and higher cropping intensity the value of produce from the ECP area is lower than that

Table 11.4. Estimated value of wastewater irrigation, Vadodara, Gujarat.

	ECP area	MSU area
Net cropped area (km^2)	14.8	39.7
Gross cropped area (km^2)	40.7	96.8
Cropping intensity	2.75	2.44
Total annual irrigation applied (cm)	292	198
Average irrigation depth applied (cm/crop)	106	81
Value of annual agricultural production (Rs.)	23,612,000	242,214,000
Total value	Rs.265,826,000 (US$5,538,000)	

from MSU area, because farmers under report fearing legal action against them for using effluent. The above calculations show that from 100 villages in the area the value of annual agricultural production is Rs.266 million (US$5.5 million).

In the MSU area there is no correlation between the horsepower of the pumps used and the area they irrigate, indicating that the irrigation depth applied is variable. However, there is a correlation between the horsepower of a given pump and the number of customers served, suggesting that higher discharge pumps are used in areas with small land-holdings. On the wastewater-irrigated farms fertiliser use has gone down, but pesticide use and labour inputs have increased in the past few years. The farmers recognise the fertiliser-saving benefit of wastewater and also the need for more pesticides because municipal sewage also contains plant pathogens.

Observations and Recommmendations

Agricultural production of net annual value Rs.266 million (US$5.5 million) is generated by wastewater irrigation in and around Vadodara. This substantial sum accrues to 100 villages – an annual average of Rs.2.66 million per village. Wastewater is now being used in an unregulated and sub-optimal manner. The health risks to humans and livestock exposed to sewage and industrial effluent are poorly understood, but undoubtedly have significant economic implications. There is a trade-off between sustaining the economic agricultural activity of 100 villages that have few other options than to irrigate with wastewater and the risks related to its use.

Wastewater is not viewed as a resource by civic authorities. City planners and administrators see it as a disposal problem, with no concern for the livelihoods it presently generates and little recognition of the health risks of stakeholders who use it. Planners and administrators need to identify wastewater as a critical input for agriculture and integrate this into wastewater management and disposal planning. Based on the very real threats to the consumers of wastewater-irrigated food products and to farmers directly and indirectly exposed to it, a research and management agenda must be developed in order to optimise wastewater use and balance its social costs and benefits.

The uncertainty associated with water availability for agriculture, particularly for marginalised farmers without access to groundwater, could be overcome to some extent with planned use of wastewater. Whilst wastewater irrigation represents the only agricultural production option for many farmers, there is increasing awareness of the benefits it brings if optimally used, particularly the opportunities it provides for marginalised groups. In order to achieve greater social gains, there is a need to improve users' knowledge of trade-offs and risk-mitigation strategies.

The present quantity of wastewater flows applied to agricultural land in Vadodara is sufficient to give 81 cm irrigation to each crop in the MSU areas, and 106 cm to each crop in the ECP areas. This signifies grossly inefficient use of wastewater for irrigation given that wheat, a prevalent winter crop in the region, needs only 49 cm of irrigation.

A planned initiative is needed to maximise the benefits that could be derived from waste-water resources. It will be necessary to develop knowledge-based agriculture, focusing on farming and irrigation practices suited to wastewater use systems to generate the maximum benefits.

A number of farmers are increasingly using wastewater conjunctively with other sources of water as a coping mechanism against water quality and scarcity problems. This group of farmers represents a potential 'regular user' group in that many of the current regular users started off using mixed water sources. The increasing number of users requires that the agricultural and planning authorities address the issue of wastewater agriculture on an urgent basis.

The ECPL faces the problem of not having enough funds to carry out even routine monitoring functions properly, as evidenced by the alarming pH variations of 2 to 11. They have to manage with composite samples rather than point samples which can help single out defaulters in treatment standards. The Pollution Control Board needs to develop ways to support the ECPL.

Sale of wastewater by pump owners who rent out their equipment is an indirect benefit of wastewater agriculture in the region. Particularly because of the low lift and associated energy costs, renting out pumps to lift wastewater is more remunerative than selling groundwater. The further development of wastewater markets could have far-reaching impacts on the use and development of this resource as a vehicle for economic prosperity. It might be feasible for the municipality to levy a fee on pump owners and a sewage discharge fee (sewerage cess) that could be used for pollution abatement and management, particularly through wastewater treatment and improved irrigation practices.

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12 The Use of Wastewater in Cochabamba, Bolivia: A Degrading Environment

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Abstract

In Cochabamba, Bolivia, wastewater is extensively used in urban and peri-urban agriculture. Both vegetable and fodder crops are irrigated with polluted water, i.e. diluted or partly treated municipal and industrial sewage containing high concentrations of pathogens, heavy metals and salts. Specifically in the downstream La Mayca area, where the farmers have an agreement with the municipal water and sewerage company, soil degradation has forced farmers to increasingly replace vegetable crops with more salt-tolerant fodder crops. In other areas around the city, cultivators deny using readily available wastewater, pointing to nearby wells as their water source. However, many wells are probably also polluted and do not yield enough water for the irrigated area served. Farmers state they are not confronted with specific health problems related to the use of polluted water, contradicting reports from local health workers. Low surface water flows and low rainfall, along with high (industrial) pollution and low wastewater treatment capacity mean that most of the water available to the farmers is of poor quality. Reduction of (industrial) pollution, increased treatment capacity and an integrated water management (IWM) approach, in which nearby good-quality groundwater could be used as a water source for blending with wastewater, represent options for improvement. However, strong traditional water rights, lack of urban planning, and weak institutions are constraints to the improvement of wastewater management in Cochabamba.

Introduction

In urban areas of many (developing) countries, urban and peri-urban agriculture depends, at least to some extent, on wastewater as a source of irrigation water. The quality of the water and the conditions under which this water is used vary greatly. In poor countries this water may, in extreme cases, take the form of diluted raw sewage, even if this is considered illegal.

(eds C.A. Scott, N.I. Faruqui and L. Raschid-Sally)

Lack of infrastructure results in uncontrolled wastewater flow. Legislation on wastewater discharge and use is either poorly developed or not enforced. Partial treatment at secondary level, typical of overloaded treatment plants, and natural treatment before agricultural use are more common. In general, irrigation with effluent that has been treated up to secondary level can be considered a cost-effective and environmentally safe way of handling domestic wastewater.

In countries where legislation and control are strict and where the economic conditions allow, industrial wastewater is separated from domestic wastewater. Domestic wastewater may receive secondary and sometimes tertiary treatment before it is made available for crop production. Even then, legislation can restrict the type of crops that are allowed to be grown and the irrigation technology to be used. For vegetable crops that are consumed raw, the most stringent conditions are applied.

Bolivia is a typical example of a country where, due to poverty and lack of planning and management capacity, uncontrolled use of wastewater takes place. Cochabamba, the regional capital of the agricultural centre of the country, is a typical example of untreated wastewater irrigation resulting from a shortage of freshwater resources, high levels of pollution from industrial and domestic origin, and insufficient water treatment capacity.

Bolivia

Bolivia, a land-locked country in Latin America, can be divided into three ecological regions. The western part of the country (the Altiplano) is 3,800 m above sea level, cold and relatively dry (300–600 mm annual rainfall). The capital La Paz (almost 1.6 million inhabitants) is situated in a valley of the Altiplano. The sub-Andean region, with Cochabamba (855,000 population) as a major departmental capital, is situated between the Altiplano and the eastern lowlands. Here, average temperatures are between 15° and 18°C and annual rainfall from 380–700 mm. The eastern lowlands (the Llanos) cover about 57% of Bolivia's total area. Their average temperature is high at 23°C and annual rainfall between 1,100–1,900 mm. The biggest city here is fast-growing Santa Cruz (1.5 million).

In the major cities, the urban population has increased by a yearly average of 3–6% in the last 50 years and is estimated now at 62% of the total population of 8.3 million compared to 42% in 1976. For Cochabamba the urbanisation rate rose from 38% in 1976 to 59% in 2001 (Durán *et al.*, 2003).

La Paz discharges all its wastewater, without any treatment, into the Choqueyapu river that runs through the city. Water from this river is used downstream for agriculture, including vegetable production.

Cochabamba is situated in the valleys between the Altiplano and the lowlands. Irrigated agriculture is focused on the production of fodder crops, including fodder maize and alfalfa, although many other crops, including vegetables, are grown for farmers' own consumption. The city has one central wastewater treatment plant (WWTP) with a capacity of 400 l/s. Its effluent, that is of low quality due to overloading of the plant, is used for irrigation. In housing areas there are a large number of septic tanks and Imhoff tanks for primary treatment. However, few of them are functioning properly.

Santa Cruz, the second largest city of Bolivia after La Paz, has three WWTPs with a total design capacity of about 380 l/s, which is low given the population. The WWTP discharge is not used for irrigation, as the immediate surroundings receive sufficient rainfall to meet farmers' needs.

In some other cities in Bolivia, the wastewater is of extremely poor quality, due to industrial activities. Such wastewater is discharged, without any treatment, into evaporation ponds, without any form of subsequent use.

Sewerage coverage is limited in Bolivia, particularly in comparison to other Latin American countries (World Bank, 1999). Yet, from Table 12.1 it can be seen that these coverage figures have increased enormously in the last 25 years, even more impressive if population growth in this same period is considered.

Table 12.1. Increase in access to water supply and sanitation in urban and rural Bolivia, 1976–97 (World Bank 1999).

		Coverage (%)		
		1976	1992	1997
Urban	Water supply	74	81	93
	Sanitation[a]	47	63	79
Rural	Water supply	9	24	37
	Sanitation[a]	4	17	33
Total	Water supply	39	58	72
	Sanitation[a]	22	43	61

[a] Data on sanitation facilities include domestic connections to a sewerage network, latrines and septic tanks.

Actual Use of Wastewater in Bolivia

Wastewater use can be defined as direct or indirect and be characterised as formal or informal:

- In the case of **direct use,** untreated discharge from the sewer or effluent from the treatment plant is directed to the crops. This includes discharge released by intentional ruptures of the sewer pipelines by farmers. The wastewater, treated or untreated, is not diluted before being used. This is a common phenomenon in the areas where water is scarce, e.g. Cochabamba.
- **Indirect use** refers to the use of surface water that is polluted with wastewater, raw or partly treated. In this case the wastewater is diluted before use, certainly in the wet season. In Bolivia, indirect use of wastewater takes place in almost all rural and peri-urban areas downstream of the urban centres.
- In the case of **formal use** a convention or other type of agreement supports the use of (treated) wastewater. There is only one such case known in Bolivia. In Cochabamba, the irrigator's organisation has an agreement with the municipal water and sewerage company (SEMAPA) for the use of their effluent.
- **Informal use** is not supported by any agreement. This is the case in most parts of Bolivia.

Table 12.2 gives an overview of the characteristics of wastewater use in Bolivia's main cities. Most wastewater use is indirect and informal, and is limited to the arid and semi-arid regions: the Altiplano and the Valleys. In the case of the Llanos region, where the rainfall is high, crops do not require irrigation and the wastewater is simply discharged into the rivers that are an important source of fish for indigenous people living downstream in the forests.

When wastewater in Bolivia is used directly the irrigators have at least some insight or

Table 12.2. Characteristics of wastewater use in peri-urban areas of the main cities in Bolivia (Durán *et al.*, 2003).

Departmental capital	Population ('000) (2001)	Characteristics of wastewater use
Cochabamba	855	Direct use of the effluent of the WWTP. Indirect use of polluted water from the Rocha river
La Paz El Alto	1,550	Indirect use from the Choqueyapu river, into which untreated wastewater is discharged. Indirect use through the Seco river where the effluent of the Puchuckollo WWTP is discharged
Santa Cruz	1,543	No wastewater use, high rainfall zone
Oruro	237	No wastewater use, WWTP discharges into a saline prairie
Beni and Pando	265	No wastewater use, high rainfall zones
Tarija	248	Indirect use of polluted water from Guadalquivir river
Sucre	217	No data available
Potosi	238	No data available

opinion about the advantages (availability, nutrients) and disadvantages of such use. In the situation of indirect use, however, the irrigators consider that the pollution of the river damages their agricultural activities.

Wastewater Use in and Around Cochabamba

The downstream area of Cochabamba known as La Mayca is served by the Sistema Nacional de Riegos No. 1 (SNR-1) Irrigation Scheme. Before 1980, this Scheme received its irrigation water from the Angostura Dam and partly from the small Rocha river that crosses Cochabamba. Since the construction of a new airport, part of SNR-1 was cut off from these supply sources. To solve this, the farmers agreed with SEMAPA to irrigate with effluent from the Alba Rancho facultative stabilisation pond treatment plant, constructed in 1986 that has a design capacity of 400 l/s. Other farmers depend more on the water from the Rocha river and from two smaller rivers, the Tamborada and the Valverde. These rivers, however, have increasingly been polluted due to the growing urban population and the uncontrolled discharge of industrial and domestic wastewater. Actually, in the dry season the natural water flow of the river is virtually zero, which means that almost all the discharge is domestic and industrial wastewater.

The irrigated area downstream of Cochabamba can be divided into several zones, each of which uses a different mix of water, depending on location, season and general water availability (Fig. 12.1 and Table 12.3). Most water flows by gravity, although in some places it is pumped to irrigate fields located higher up the valley. Some farmers have a choice between water sources, including wells, depending on water availability.

In the entire area surface flood irrigation is practised. Average farm size ranges from 1–5 ha. The farms have a relatively high cattle density at 12 animals per family. The milk is mostly delivered to Cochabamba dairies although farmers increasingly process part of their milk production into cheese.

Apart from alfalfa and fodder grass (*Lolium* sp.), maize, potato and beans are cultivated. However, due to increasing salinisation in the area, farmers are increasingly shifting to *Lolium* fodder grass that is salt-tolerant. Some plots are no longer cultivated because of soil degradation.

Because all farmers do not use rubber boots and gloves for protection during irrigation, this results in infections. Farmers in this area do not

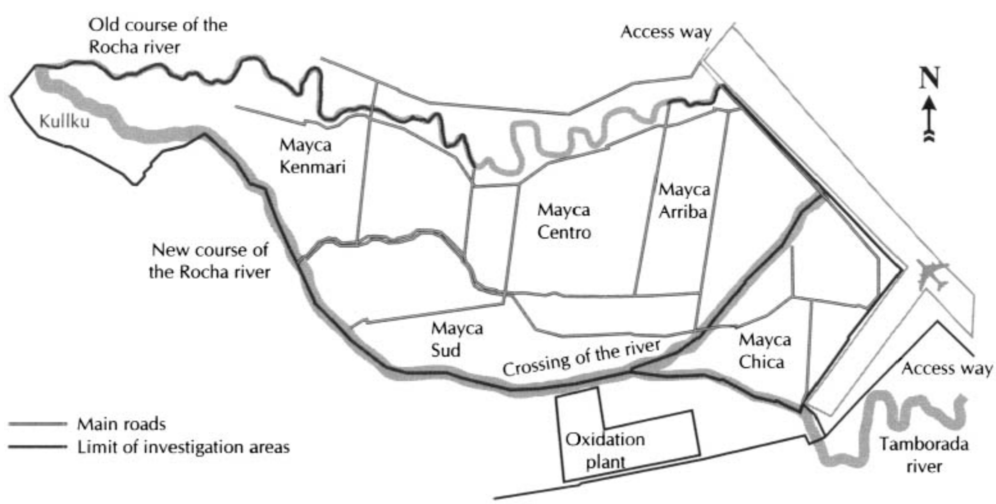

Fig. 12.1. Map of the La Mayca irrigated area downstream Cochabamba, Bolivia.

Table 12.3. Area irrigated (ha) from different sources depending on water availability in La Mayca, Cochabamba.

	Water source					
	Angostura Dam	Treated water from	Rivers			Total irrigated
Community	(1st choice)	Alba Rancho	Tamborada	Rocha	Valverde	area
Monte Canto	10	30				40
Champarrancho	0–8	0–8	0–8			8
Tamborada B	0–15	0–15	0–15			15
Tamborada C	0–17	0–17				17
Mayca Chica	–	0–10		140–150		150
Mayca Sud	11–143	0–110		0–22		143
Mayca Quenamari	0–77	0–77			0–77	77
Media Luna	–	21				21
San José	0–38	0–38				38
Albarrancho	0–114	0–114				114
Kullko	–	57				57
Mayca Norte	60–400	0–100		0–160	0–80	400
Mayca Central	160–350	0–50		0–140		350
Pampa López		28				28
Quenamary		42				42
Sumunpaya	22–77	0–55				77
Total	253–1,249	178–772	0–23	140–472	0–157	1,578

Source: Consultora Galindo Ltda., 2001.

Table 12.4. Quality of water from different irrigation sources in La Mayca, Cochabamba.

	Allowed limits	Sample[a]					
Parameter	(Bolivian standards for water pollution)	Rocha river + sewage M - 1	Rocha river – sewage M - 2	Rocha river + WWTP M - 3	Rocha river + WWTP + sewage M - 4	WWTP M - 5	SNR N1 Angostura Dam M - 6
Electric conductivity (mhos/cm)	Not specified	1057	798	1508	1809	1594	391
$N - NO_3$ mg/l	< 5	0.016	n.d.[c]	n.d.	0.013	n.d.	n.d.
$N - NH_3$ mg/l	< 5	102.3	26.4	n.d.	93.7	n.d.	n.d.
Cr^{6+}[b] mg/l	0.05	< 0.02	< 0.02	< 0.02	n.d.	n.d.	n.d.
BOD_5 mg O_2/l	< 2[d] < 5[e]	319	71	176	96	109[f]	n.d.
Total coliform MPN/100 ml	Not specified	4.4×10^6	3.5×10^6	4.3×10^6	8.6×10^6	1.5×10^7	3.9×10^4
Faecal coliform MPN/100 ml	< 1000	3.2×10^6	1.9×10^6	4.1×10^6	5.8×10^5	3.5×10^5	1.0×10^3

Source: Agreda, 2000.
[a] Samples taken at different dates during the dry season: September–November, 1999.
[b] The analyses for heavy metals included those for lead and cadmium. These metals were not detected.
[c] No data available.
[d] For crops consumed raw.
[e] For processed crops and fodder.
[f] Data from SEMAPA.

complain about their health, yet 80% of them are known to have skin mycosis (Agreda, 2000).

The data in Table 12.3 show that, of a total irrigated area of 1,578 ha almost 50% is wastewater-irrigated in dry years and up to 40% with polluted surface water from small rivers. Only 16% of the area (253 ha) is assured of freshwater from the Angostura Dam in a dry year.

Table 12.4 gives water quality data as measured in this region. Farmers complain about the quality of irrigation water, specifically, about the degradation of their plots through salinisation. The industrial discharge (from tanneries) and the increasing use of wastewater might well be a cause for this, although the effects of the poor internal and external drainage of the area and the excess water applied to the fields should also be considered.

The inflow to the treatment plant exceeds the design capacity by almost 50%. The high inflow load and poor dilution of waste concentrations resulting from the low *per capita* average daily water consumption of 80 l result in the poor quality of the WWTP effluent.

Even though there are strict by-laws that forbid this, industries discharge their wastewater without treatment into the domestic sewerage system or directly into the surface water. This is an important environmental threat, and has already led to a build up of heavy metals in the soil profile, with extremely high concentrations of cadmium (Cd), chromium (Cr^{6+}), and lead (Pb) (Table 12.5).

During a field visit in October 2002 it was observed that wastewater is also used in the upstream parts of the city, immediately downstream of some housing areas that have been provided with communal primary treatment facilities (Imhoff tanks) at some distance from the housing. The main objective of an Imhoff tank is to reduce the suspended solids load in the receiving surface water. Because of the design of the Imhoff tank system there is no further treatment of waste at the secondary level. The local community was asked to assign and pay a person to maintain these primary treatment systems. But, the community has no incentive to maintain the systems, and consequently they malfunction. As a result, sewage water is now being discharged into open drains and subsequently used for small-scale irrigation, including vegetables.

Institutional Aspects

The use of (treated) wastewater in (peri-)urban agriculture is directly linked to urban water supply, sanitation and wastewater treatment capacity since water-supply organisations are also usually responsible for sewerage and wastewater treatment. In Bolivia, different institutions have a role to play (Durán *et al.*, 2003):

- The Ministry of Housing and Basic Services (Ministerio de Vivienda y Servicios Básicos) includes among its responsibilities: the definition of sector policies and priorities, formulation of norms and regulations for the sector, planning sector development, promotion of research and human resources development programmes, channelling of financing and investments, the establishment of a sector-wide information system, and the supervision of the Superintendent of Basic Sanitation (see below).
- The Ministry of Sustainable Development and Planning (Ministerio de Planificación y

Table 12.5. Occurrence of heavy metals (mg/kg dry soil) in soil of the La Mayca area, Cochabamba, Bolivia (Agreda, 2000).

	Mayca area soil profiles					
	A-102		A-104		A-105	
Sample depth (cm)	0–29	29–60	0–28	28–51	0–23	23–40
Cadmium	93	118	38	31	124	120
Chromium	22	14	12	11	12	14
Lead	1500	1313	806	1235	687	1076

Table 12.6. Estimated wastewater production in 2020, based on population data for various Bolivian cities (Durán *et al.*, 2003).

City	Growth (%)	Urban population ('000)		Wastewater discharge (l/s)[b]		Annual volume (Mm^3)	
		2001	2020[a]	2001	2020	2001	2020
Cochabamba	4.2	855	1,865	634	1,382	20	44
Sucre	4.2	217	472	161	354	5	11
La Paz	2.8	1,550	2,629	1,147	1,948	36	61
Oruro	0.7	237	272	176	202	6	6
Potosi	1.0	238	286	176	212	6	7
Tarija	4.8	248	599	183	444	6	14
Santa Cruz	4.9	1,543	3,816	1,143	2,827	36	89
Beni	3.1	244	439	181	325	6	10
Pando	8.0	21	91	16	68	<1	2
Total		5,153	10,470	3,817	7,762	122	244

[a] Authors' estimate.
[b] Estimated discharge $Q = cPD/86400$ where: c = discharge coefficient (0.8), P = population, and D = water supply per capita (average value: 80 l/day).

Desarrollo Sostenible), in coordination with the Ministry of Housing and Basic Services, plays a role in the formulation and application of the environmental norms related to water supply and sanitation. It also oversees water quality.

- A Superintendent of Basic Sanitation (Superintendencia de Saneamiento Básico, SIASAB) is mandated to regulate water supply and sanitation services in the urban and rural sectors. In particular, SIASAB oversees the quality of service provision, approves tariffs according to sector regulations, grants concessions from customers, and applies fines.
- The Prefectura, with responsibility at the Department level for formulating investment projects, plans service expansion programmes and projects, supervises works, and provides technical assistance to the service companies. It actually works mainly in the rural areas.
- The Popular Participation Law and the Law of Municipalities transferred ownership and operational responsibility for provision of water supply and sanitation services to municipal governments, enlarging their roles and responsibilities. It is also the Municipal governments' task to develop plans and programmes for the expansion of water supply and sanitation services, in coordination with the Prefectura.

Presently, there are four types of institutional arrangement for the management of water supply and sanitation:

- **Cooperatives:** of which there are 120, mainly in Santa Cruz and Tarija
- **Autonomous municipal companies**: the main ones being in Cochabamba (SEMAPA), Sucre, and Potosí
- **Concessions with the private sector**: which only exist in La Paz and El Alto (Aguas del Illimani). This model provoked great social conflicts in the city of Cochabamba after its introduction in 1999 and the company (Aguas del Tunari) was forced to withdraw in April 2000, handing back the administration to SEMAPA.
- **Water committees:** formed with contribution and participation at the neighbourhood level.

Costs for wastewater treatment are included in the price of drinking water, which is already high in Cochabamba (US$0.23/m^3) compared to the prices charged by other (rural) drinking water suppliers (US$0.10–0.20/m^3), who only recover operational costs. The tariff for sewerage and wastewater treatment varies from 40–65% of the drinking water price. Although people seem to be aware and prepared to pay for wastewater treatment, a recent decision to further increase the drinking water price to allow more and better treatment had to be withdrawn, after violent protests by the

Cochabamba city population. This is a significant backwards step in improving the water quality for the irrigators, if indeed wastewater treatment were to be made effective.

The general lack of urban planning and management capacity in Cochabamba affects this situation. The municipal authorities have not been capable of steering the rapidly expanding city. Comparing the state of the Rocha river now to its situation in the 1990s reveals major differences in discharge and water quality (A.M. Romero, Cochabamba, 2002, personal communication). Cochabamba has also been confronted with uncontrolled housing construction that has certainly increased water pollution. There is a clear lack of land use planning that should cope with the growth in wastewater and its management. In Bolivia, water is available for those people who have established water rights that are closely linked to irrigation. This automatically means that people and institutions without such traditional rights have limited access to (good quality) water.

Agricultural Potential

A significant area in and around Cochabamba currently depends on untreated and treated wastewater for irrigation, especially in the dry years. In the coming 20 years, the volume of wastewater is expected to double (Table 12.6) and those farmers that have no or insufficient access to other water sources will certainly try to use wastewater. Although wastewater is of inferior quality because of its high salt contents and possibly even contains toxic elements, the farmers will first consider that it is the most reliable source of water. Contrary to supplies of surface water or water from a formal irrigation scheme, wastewater flow is increasing in volume and is available all year round.

Discussion and Conclusions

Treated domestic wastewater should be considered as a valuable source of water for irrigated agriculture. If well managed, such use is productive, cost-effective and environmentally safe. However, the way wastewater is actually used in Cochabamba is far from ideal and poses a number of health risk and environmental pollution problems. To avoid an environmental crisis, several things need immediate action.

The wastewater flow in Cochabamba partly originates from industries, including tanneries. This wastewater contains salts and such toxic elements as chromium (Cr^{6+}), that are harmful to crop production and/or are polluting the environment. As a first and immediate step, industries should be forced to reduce the contaminant load in their discharge by, for example, pre-treating their wastewater before discharging it. Special attention should be given to industries like the tanneries that discharge high quantities of soluble salts which degrade soils in the downstream irrigated area by rendering them saline.

Investments are required to improve the drainage of lower-lying areas. Observed salinity problems should also be studied in relation to the irrigation techniques used. A change in these techniques (possibly in combination with a change in the types of crops cultivated) might help to reduce this problem. However, such modern irrigation techniques as micro-irrigation, are expensive and do not completely reduce the risks of salinisation. It should be realised that irrigation with moderately saline water is possible so long as there is appropriate drainage for leaching. This would, however, transfer the salts to the drainage water that would undoubtedly be discharged again into the river.

An increase in the city's water treatment capacity is badly needed. In developing this capacity, care should be taken to invest in appropriate technology that can be managed within the limited available financial and managerial resources. In other countries, like Brazil, Colombia, and India, systems such as the upflow anaerobic sludge blanket (UASB) have been developed; these are not dependent on electricity and can provide adequate contaminant reduction with minimal maintenance (van Lier and Lettinga, 1999).

The present situation calls for a decentralised water treatment approach, given the fact that wastewater is produced and used for irrigation in different areas in and around the city. Decentralised systems can be initiated far more rapidly than large capital-intensive centralised treatment plants. In the Brazilian city of

Recife a decentralised approach has been officially included in the sanitation and sewerage master plan of the city (Florencio and Kato, 2001). The Water and Environmental Sanitation Centre, [Centro de Aguas y Saneamiento Ambiental (CASA)], of Cochabamba, could play an important role in technology choice, with specific attention to the requirement for low-maintenance systems If maintenance of the decentralised systems depends on local community initiative, then the community should also benefit from its investment. This means that farmers from the same community that treats the wastewater should be able to use the treated effluent.

An integrated water management (IWM) approach is surely needed to improve the present situation in Cochabamba. Farmers who now have direct access to wastewater flows and those just beyond are irrigating with water of extremely different qualities. An irrigation supply system that would allow mixing of water from different sources to manage the high salt content should be considered. At the same time, sanitation, wastewater treatment, and subsequent agricultural use should be based on a conceptual design framework in which the water flow from source to irrigation and drainage is subject to holistic management that also considers cost-effectiveness and environmental issues (Martijn and Huibers, 2001). An interdisciplinary and participative approach is needed. In common with most of Latin America, the Bolivian irrigators are organised in such a way that they represent themselves well in negotiations and could be partners in a design process.

Creating awareness among actors, building management capacity, extension, and communication are all seen as important ways to improve the present situation and to support future development.

Irrigated farming around Cochabamba presents an example of a degrading agricultural system caused by water pollution particularly that resulting from uncontrolled discharge of industrial liquid waste into surface water, and the use of irrigation techniques without drainage required to effectively manage the poor water quality.

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13 Treatment Plant Effects on Wastewater Irrigation Benefits: Revisiting a Case Study in the Guanajuato River Basin, Mexico

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Abstract

In 1999 field research was carried out to explore the advantages and risks of urban wastewater use for 140 ha of crop production in the Guanajuato River basin. It was found that wastewater which was freely available to the farmers represented an important additional source of irrigation water, with secondary benefits including nutrients and the foregone cost of wastewater treatment. In 2002, the urban water supply and sanitation utility, a financially autonomous public utility, began to operate an activated sludge wastewater treatment plant in response to the imposition of legally mandated fines for the release of untreated wastewater to open water bodies. As follow-up to the 1999 study, this chapter is based on field visits and interviews and sets out to qualitatively answer the following research question: Does the introduction of wastewater treatment influence the crop production benefits of wastewater irrigation? The study found that because wastewater treatment was oriented to comply with environmental regulations, little attention was paid to the links with the land irrigated by wastewater. The presence of the treatment plant provides the utility with the option of selling treated wastewater, thus increasing its own economic benefits. Industrial users appear to be the most suitable potential customers; the utility would stand to receive US\$0.43/m^3 in estimated sale price plus saving the US\$0.25/m^3 fine. This transfer of water would introduce competition among water-use sectors, a process that is already leading to wastewater farmers' uncertainty about their future share of irrigation water. However, to date no commercial transaction to transfer treated wastewater to non-agricultural users has taken place. For this reason the expected changes in impacts on wastewater farmers have been minimal. If this happens, however, the wastewater farmers stand to lose because only about 30% of the wastewater-irrigated land has a water concession title (linked to the land) issued by federal authorities.

Introduction

In 1999 field research was carried out by Scott *et al.* (2000) to explore the advantages and risks of urban wastewater use for crop production in the water-short Guanajuato River basin in west-central Mexico where at least 140 ha of land were irrigated with raw wastewater downstream of the city of Guanajuato[1] in two peri-urban communities: San José de Cervera

[1] Guanajuato is the name of the state as well as its capital city (and the river that runs through it). Unless otherwise indicated, Guanajuato here refers to the state not the city.

(eds C.A. Scott, N.I. Faruqui and L. Raschid-Sally)

and Santa Catarina. Findings showed that wastewater represented an important additional source of irrigation water, with secondary benefits including nutrients and the foregone cost of wastewater treatment. It was stated that 'wastewater irrigation is a critical component of intensive water recycling in the Guanajuato River basin, based primarily on the value of the water resource and the nutrients it transports. The land irrigated with raw wastewater downstream of the city serves as *de facto* water treatment with significant retention of contaminants' (Scott *et al.*, 2000). The study did not measure the environmental costs and risks associated with untreated wastewater irrigation, which if adequately quantified would reduce the overall benefits. The study did address health risks but was unable to draw firm conclusions based on: a. the difficulty in establishing clear causal links between wastewater quality and health, and b. insufficient data on diarrhoea incidence.

Wastewater irrigation and discharge to open water bodies – in Mexico all rivers, lakes, wetlands, and groundwater are considered public property under federal jurisdiction – are subject to the maximum allowable contaminant limits established in the environmental regulation NOM-001-1996.[2] This regulation also establishes a fine of US$0.25/m^3 of untreated wastewater discharge that exceeds the permitted limits. In accordance with this national policy, urban water supply and sanitation utilities across the country constructed wastewater treatment plants using a timeframe based on the population size of the city. In June 2000 the Guanajuato city utility called the Sistema de Agua Potable y Alcantarillado de Guanajuato (SIMAPAG) (in English, the Guanajuato Water Supply and Sanitation Board) undertook the construction of an activated sludge plant to treat all the wastewater discharge from the city centre. The treatment plant started operating in June 2002. This chapter addresses the changes in wastewater irrigation in the Guanajuato River basin that are occurring as a result of the treatment plant. It attempts to provide qualitative answers to the research question: 'Does the introduction of wastewater treatment influence the crop production benefits of wastewater irrigation?'

The need to assess the effects of the introduction of wastewater treatment on downstream irrigation is essential due to the rapid implementation of wastewater treatment in Mexico, a country where unregulated wastewater irrigation is prevalent. In addition, the experience of a middle-income country in converting from untreated to treated wastewater use provides important lessons for low-income countries that are considering wastewater treatment. Backed by the national environmental laws and state policies, treated wastewater volumes will increase in Mexico and as a consequence, the use and management of wastewater irrigation will change. For instance, in Guanajuato 87% of its wastewater should be treated by 2005 compared to the current 57% (CEAG, 1999). In this state alone, approximately 20,000 ha (5% of the 416,690 ha irrigated in the state) could be irrigated using the 207 million m^3 of wastewater currently generated annually in the state's 46 municipalities.

The first part of the chapter consists of a general overview of the Guanajuato River followed by a brief description of the salient characteristics of SIMAPAG and its wastewater treatment plant. In the second part the use of wastewater in agriculture and its consequences in the state of Guanajuato are reviewed, followed by a discussion of the treatment plant's impact on urban wastewater use for crop production. Finally, lessons learned and policy recommendations are presented.

The Guanajuato River Basin

The Guanajuato River constitutes a sub-basin to the Lerma–Chapala Basin. It encompasses the municipalities[3] of Guanajuato, Silao, Irapuato

[2] Having followed the procedures established in the Federal Law on Methodology and Regulations to formulate Mexican Official Regulations, the National Consultative Committee on Environmental Protection Regulations, on 30 October 1996, passed the Mexican Official Regulation (in Spanish, Norma Oficial Mexicana, NOM) NOM-001-ECOL-1996.

[3] In Mexico, the municipality is the next political and administrative level below the state and encompasses both the urban or town centre and the surrounding rural areas.

and Romita. The wastewater produced in these cities, estimated at 1 m^3/s, receives varying levels of treatment – from secondary treatment in Irapuato to none at all in smaller urban centres like Romita. As a result, the 12-km reach of the Guanajuato River from the city to La Purisima reservoir is highly contaminated with organic loads, bacteria and inorganic pollutants. In this reach, untreated wastewater is diverted for irrigation purposes. During the field work of 1999, the irrigation diversions for the two peri-urban communities, San José de Cervera and Santa Catarina, were studied in depth (Scott *et al.*, 2000). One important characteristic of this relatively small sub-basin is the presence of multiple water and nutrient recycling loops. Based on flow measurements of the total river discharge of 0.305 m^3/s flowing out of the study reach over half (0.162 m^3/s) was comprised of return flows. This means that the sub-basin's limited water resources could be managed to satisfy multiple demands.

National Water Commission (CNA) data show that from 1992 to 1999, water quality in the Guanajuato River further downstream of the larger city of Irapuato, but above its confluence with the Lerma River, deteriorated significantly (CNA, 2000). According to these data, the Guanajuato River is considered contaminated for agricultural uses.

SIMAPAG and the Wastewater Treatment Plant

In order to better understand options for wastewater management it is critical to review the basic features of the water supply and sanitation utility. One of a total of 31 water supply utilities in the state of Guanajuato, SIMAPAG supplies municipal water and manages sewerage in the city of Guanajuato (total population around 106,000). SIMAPAG is a financially autonomous public utility with an independent administration that is subject to regulatory oversight by a governing council of municipal representatives and citizens who are appointed by the elected municipal government. The SIMAPAG governing council appoints the utility's general manager and approves the budget including water and sanitation fees.

At the state level, water supply coverage is over 95% of the urban population and 75% of the rural population. In recent years, the growth in number of connections has consistently exceeded population growth (Fig. 13.1) indicating that urban water supply coverage will soon reach 100%. The relevance of these data is that wastewater volumes will continue to grow at rates faster than urban population growth. Many of the federal programmes to support municipal water utilities are not expressly oriented to increase water supply and sanitation coverage, but instead to rehabilitate infrastructure. This only permits increased coverage indirectly.

In 2001, Guanajuato city's potable water supply level was 95% and the sewerage coverage level was 82%. Domestic connections represented almost 94% of the total water connections. Meters (some 25,000 in total) are installed on all connections allowing the utility to estimate wastewater discharge by household. The average monthly consumption per connection was 27.7 m^3 at an average fee of US$0.59/$m^3$ (Scott *et al.*, 2000). Sewerage and other non-water supply fees represent 8.3% of the billed amount; this will increase to 10%. SIMAPAG pays the federal government approximately US$200,000 in water use fees; however, as an incentive federal authorities waived these fees during the period of wastewater treatment plant construction just as they do for other urban water utilities in the process of wastewater treatment implementation.

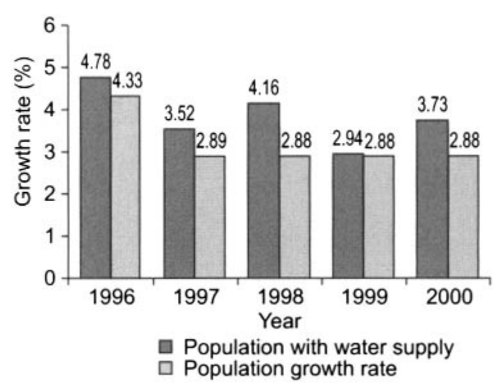

Fig. 13.1. Comparison between population growth rate and increase in water supply coverage in Guanajuato state, Mexico (CEAG, 2001).

In 2002, a financial surplus of US$158,000, or 25% of expenditure, was generated. Subject to the approval of the governing board, surpluses are used for infrastructure improvement and other capital investment. Despite significant outlays to cover SIMAPAG's share of the wastewater treatment plant construction in 2001 and 2002, the accumulated reserves totalled US$1,182,000 at the end of 2002 (Marco Antonio Ortíz, SIMAPAG general manager, personal communication, 2003). Additionally, the overall efficiency (including the physical, commercial and billing efficiency) has varied between 55.8% and 61.2% in the past 4 years. SIMAPAG aims to increase this to a consistent 60%, the benchmark set for receiving performance- based federal support programmes including wastewater treatment.

The total annual wastewater volume generated in Guanajuato's 46 municipalities is 207.13 million m^3. If this water could be used directly for agricultural purposes, around 20,000 ha of grain crops could be irrigated, equivalent to almost 5% of the actual irrigated land in the state (416,690 ha). At the end of 1998, only 25 million m^3/year were treated; however, in the first quarter of 1999, this increased to 34.46 million m^3/year. There are 16 urban wastewater treatment plants and another 26 plants in rural areas. Of the urban plants, at least four are officially recognised as having agricultural use (Irapuato, San Francisco del Rincón, Coroneo and Tierra Blanca). Eleven small rural plants, each with a design discharge of 2–10 l/s, generate treated wastewater used for irrigation. However, there is a declared lack of technical and administrative capacity on the part of many utilities to implement wastewater treatment and cost recovery.

SIMAPAG constructed an activated sludge[4] with chlorine disinfection treatment plant for a total investment cost of US$3.6 million (see Fig. 13.2 and Table 13.1). The federal government contributed 24%, the municipal government 40%, and SIMAPAG the remaining 36% derived from the operating budget surpluses carried forward from past years. According to the average consumption per connection the expected sewage

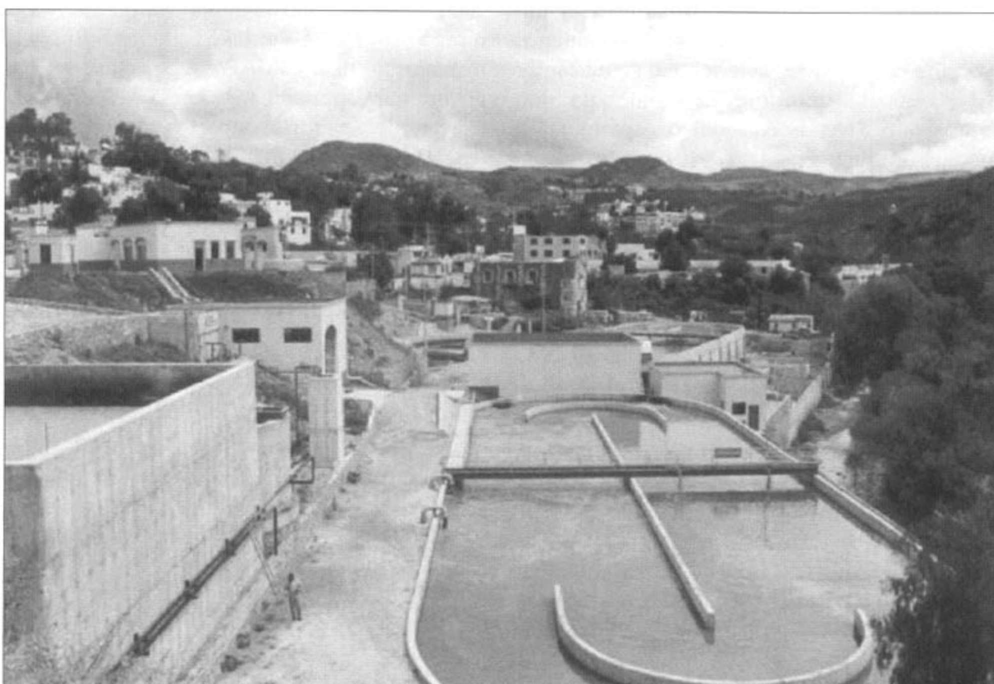

Fig. 13.2. The Guanajuato city wastewater treatment plant

[4]The 1,100 kg of sludge generated daily is landfilled.

Table 13.1. Plant treatment design parameters.

Parameter	Unit	Influent	Effluent
Design discharge	lps	140	140
Total suspended solids (TSS)	mg/l	217	< 60
Total biochemical oxygen demand (BOD_5)	mg/l	337	< 60
Total nitrogen (Kjeldahl)	mg/l	82	< 35
Faecal coliforms	MPN /100 ml	6.2×10^6	< 1000
Total phosphorus	mg/l	11	< 20

discharge[5] from Guanajuato city is 0.14 m^3/s or 12.1 million l/day. Before the wastewater treatment plant started operation, this effluent flowed directly down the Guanajuato River where it was diverted for irrigation. Currently 70% of the total wastewater discharge is treated – the wastewater collector pipe for the treatment plant inlet only covers the main part of the city and does not collect sewage from the neighbouring peri-urban community of Marfil that represents the remaining 30% of wastewater. The wastewater generated in this area continues to flow downstream untreated. SIMAPAG will have to pay some US$470,000 annually in discharge fines unless it makes satisfactory progress in treating this wastewater.

SIMAPAG had four principal motives behind the implementation of wastewater treatment, it aims to:

- Meet the maximum allowable contaminant limits according the National Water Law and comply with discharge regulations or face fines
- Assume responsibility for water quality preservation
- Improve the public health and ecology
- Benefit directly the 81,000 inhabitants who are provided with sewerage coverage.

Urban Wastewater Use for Crop Production and its Consequences

Irrigation with wastewater is a common practice in Guanajuato. According to official records, there are 3,200.4 ha irrigated with wastewater, with a water volume of 19.1 million m^3 (Sánchez, 1995), but there are numerous wastewater irrigation areas that have not been accounted for. One of the most important areas for this kind of irrigation is the area surrounding León, Guanajuato's largest city with a population of approximately 1 million. Starting at least 40 years ago, irrigation with wastewater began in a small area to the south-west of the city and spread southwards with the expansion of the urban area and the consequent greater availability of wastewater (Sánchez, 1995). A considerable volume of wastewater is used in agriculture, with or without federally approved water use rights.[6]

Health and environmental risks have been identified particularly because of the prevalence of chromium derived from Leon's important leather and tanning industries. The risks to exposed populations are dependent mainly on water management and the irrigation methods used (Blumenthal *et al.*, 2000). In León, wastewater is used in furrow irrigation of maize and alfalfa. Similarly, in the Guanajuato city study area only furrow irrigation is used for maize and alfalfa.

Treatment Plant Effects on Wastewater Irrigation Benefits

Benefits of untreated wastewater use

Before the construction of the wastewater treatment plant, a number of wastewater irrigation benefits in the study area were identified.

[5] This figure was estimated based on the 2000 SIMAPAG records of 27.7 m^3/month average consumption and 22,347 connections, and assuming that 70% of the total consumed water per outlet will return as sewage.

[6] All irrigation water users in Mexico are supposed to be listed in the Public Register of Water Rights (Registro Público de Derechos de Agua). Failure to register can entail that water use may be summarily curtailed.

According to Scott *et al.* (2000), the benefits from wastewater irrigation are as follows:

1. The water used for irrigation represents a recycling of urban wastewater in a basin context. Related studies found that irrigation output per hectare is approximately US$1,800, and per cubic metre of water is US$0.16 (1994 dollars) (Kloezen and Garcés-Restrepo, 1998). Therefore, the water value of wastewater used for irrigation represents a significant monetary benefit to both society and the water users.
2. The waste stream has a nutrient value that represents an input that reduces the agriculture production costs. For the case study, the annual gross values of the wastewater and wasteload to farmers in San José de Cervera were estimated at US$252,000 and US$18,900 in Santa Catarina.
3. The continued application of the wastewater to the land would be a more economical form of wastewater treatment than activated sludge treatment and subsequent discharge to the open river where treated water is mixed with untreated discharge further downstream.

These benefits were reassessed in light of the implementation and operation of the new wastewater treatment plant, based on field visits and discussions with the treatment plant manager and the SIMAPAG general manager as well as with farmers from San José de Cervera and Santa Catarina communities.

Impact on water value

The presence of a treatment plant provides SIMAPAG with the option of selling the treated water to whichever sector can afford it; however, no commercial transaction has taken place yet. Various plans to sell water for tourism development, a golf course, an expansion of the University of Guanajuato campus, etc. continue to be considered. This would definitely add value to the water but would also result in greater competition among water users, some of whom have existing rights over the wastewater flow. Findings showed that the operational cost of one m^3 of treated wastewater is US$0.11. By means of a sanitation service charge equivalent to 10% of the billed amount for water supplied, SIMAPAG recovers US$0.04/$m^3$ from domestic users and US$0.08/$m^3$ from industrial and commercial users. Therefore, in order to be profitable the sale price for treated water should be at least US$0.07/$m^3$. Industrial customers could afford to pay up to US$0.50/$m^3$ giving an estimated surplus of US$0.43/$m^3$. Small-scale agriculture could scarcely afford to pay for treatment or for the fine, confirming that the polluters should not expect existing users to pay for treatment. The productivity of small-scale irrigation systems in the area however (around US$0.15/$m^3$ according to Silva Ochoa *et al.*, 2000) is lower than the cost of the untreated wastewater discharge fine (US$0.25/$m^3$) and approximately in the same range as the operational cost of treatment (US$0.11/$m^3$). Higher productivity – up to US$0.50/$m^3$ – could be reached if more profitable crops like vegetables were cultivated, but vegetables and greens consumed raw are not permitted to be irrigated with wastewater in Mexico. From the above analysis it is clear that the treatment plant is not a benefit to the farmers.

Impact on nutrient value

The existing concentrations of total nitrogen (N) and total phosphorus (P) in the effluent are sufficient to meet the nutrient requirements for alfalfa. Considering a 1 m irrigation depth to satisfy the alfalfa nutrient demand, which is equivalent to 88 kg N/ha and 115 kg P/ha, the required concentrations are 9 mg/l for N and 12 mg/l for P, both significantly lower than the design quality of the effluent (Table 13.1). These results concur with what was observed during the field visits; farmers showed very little concern for the reduction of nutrients due to wastewater treatment upstream. Actually, farmers appeared to have little evidence of any treatment taking place because treated and untreated discharges mix in the river downstream of the plant. Improved water quality can only be visually appreciated 4 km downstream of the plant. Further down, a slaughterhouse dumps significant quantities of contaminants in the river. Moreover, in most cases the treated wastewater still has high nutrient concentrations ranging from 20–40 mg

N/l, 20–35 mg P_2O_5/l, and 40–50 mg K_2O/l. As a result, water users' primary concern is that volumes will reduce.

The sludge represents an important source of nutrients; the treatment plant produces 1.1 tonnes of waste solids daily. The storage and elimination of this material is one of the major operational problems faced by the plant. According to the recommended application rate of sludge for agricultural soils (15 t/ha per year), the total area that would benefit from the wastewater treatment is 30–50 ha, which is only around 20–30% of the total wastewater use area. Unfortunately, the solid waste is taken to a landfill. Because Guanajuato has no major industry, heavy metals are not a problem (the 1999 study found that heavy metals were within US and European norms).

Impact on foregone treatment costs

It appears obvious that wastewater irrigation was not considered as an alternative method for wastewater disposal. The definitive guideline for the selection of the wastewater treatment process was the environmental regulations described in NOM-001-1996. The possibility of using wastewater irrigation as a complementary process for wastewater treatment was not considered. However to make this a viable option the total land area required for this purpose should have water rights, which is not the case at present (most of the land currently irrigated with wastewater does not hold an officially recognised right). Annually, there are 300,000–500,000 m^3 of water that is legally granted, which represents just 30–50 ha of irrigated land.

From SIMAPAG's perspective, the wastewater treatment plant should be oriented to the use of treated wastewater in various types of landscape irrigation, i.e. golf courses and parks, where the maximum allowable limits are higher than those for agriculture. At present there is no concern to treat wastewater specifically for the requirements of the pre-existing use, which is irrigation. SIMAPAG seeks to treat water to the level required to avoid the fine and to sell treated water in order to recuperate the capital investment. The cost and difficulty in operating and maintaining a conventional treatment plant to produce effluent that meets the limits for irrigation are too high for agriculture to bear. This represents a clear case for the 'polluter pays' principle.

Conclusions and Recommendations

Wastewater treatment in Guanajuato city has been implemented despite the lack of an integrated framework for its use or for wastewater management in a larger basin context. The ideal outcome of wastewater treatment would be to increase the benefits of municipal water users and the utility as well as those of agricultural and other (potential) wastewater users. Nevertheless, Guanajuato's wastewater treatment project was oriented to meet environmental regulations and little attention was paid to the links with existing wastewater use for irrigation. As a result, the immediate benefit from the implementation of wastewater treatment is simply to avoid the pollution fine. Strictly from the financial perspective, this is cause enough to treat the city's wastewater.

The major impact of treatment for the users of wastewater is the possible reduction in the water discharge in the river if the treated water is sold to non-agricultural customers either inside or outside the Guanajuato River sub-basin. While there has been speculation that the General Motors automobile assembly plant in the adjoining Silao River sub-basin is looking for additional sources of water, at present the purchase and piping of water appear to be prohibitively expensive. Farmers are in a weak position to defend their access to the wastewater flows given that only 30–50 ha have a water entitlement.

There is little or no expected impact on the nutrient value resulting from treatment, given that the nutrient requirements of the principal crop, alfalfa, would continue to be met even after treatment. Additionally, other sources of untreated urban wastewater enter the river downstream of the treatment plant, entailing sufficiently high nutrient loads that little effect of treatment was perceptible to the farmers. The benefits from the waste solid sludge are being lost because these go directly to a landfill instead of being spread on agricultural land.

Further research is needed to identify conditions under which the substantial benefits of wastewater irrigation can be captured while financial sustainability of the water supply and sanitation utilities is maintained. The following issues need to be addressed in further detail:

- The conditions required for wastewater markets to function, specifically commercial feasibility for irrigation use of treated vs. untreated wastewater, pricing and supply mechanisms, etc.
- Water rights conflicts
- Hydrological impact of selling the treated water outside the sub-basin
- Water quality assessment of the final use, e.g. at the farm level for irrigation
- Accounting for the nutrients lost in the treatment process.

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14 From Wastewater Reuse to Water Reclamation: Progression of Water Reuse Standards in Jordan

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Abstract

Jordan has worked to manage irrigation with wastewater for several decades. Since the early 1980s the general approach has been to treat the wastewater and either discharge it to the environment where it mixes with freshwater flows and is indirectly reused downstream, or to use the resulting effluent to irrigate restricted, relatively low-value crops. Given the diminishing per capita freshwater supply, the increasing dominance of effluent in the water balance, the overloading of wastewater treatment plants, local riparian water rights, and the need to protect domestic and export produce markets, effectively managing water reuse, including enforcement of existing regulations, has become increasingly challenging. Jordan is in the process of rehabilitating and expanding its wastewater treatment plants, and exploring options for smaller communities. Reclaimed water, appropriately managed, is viewed as a major component of the water resources supply to meet the needs of a growing economy. Appropriate standards and guidelines for water reuse are an important requirement. The previous water reuse standards were reviewed, a working framework developed, stakeholder participation sought and input provided to the formal process for adopting the new standards. The revised standards allow for a wide range of water reuse activities including, where economic conditions allow, highly treated reclaimed water for landscapes and high-value crops, and for lower cost smaller-scale treatment and reuse activities with restricted cropping patterns.

Introduction

This chapter describes the updated water reuse standards in Jordan and the process that led to their adoption.

The terminology used in this chapter, **water reuse**, is intended to convey what may be understood variously as water reclamation, water recycling, wastewater reclamation, wastewater use, and wastewater reuse in different parts of the world. However, water reuse, as used here, specifically refers to a well-regulated and controlled use of properly treated and conveyed effluent after treatment of wastewater in well-designed and maintained treatment systems. Unplanned water reuse may be properly labelled wastewater reuse.

Wastewater has been used for irrigation in Jordan for several decades. Some treated effluent has been used directly on restricted crops of relatively low value, but the main practice has to been to discharge effluent to the environment where it mixes with freshwater flows before being used indirectly downstream. With dropping per capita freshwater availability, the increasing dominance of wastewater in the water balance, insufficient wastewater treatment capacity, and the need to protect domestic and export produce markets as well as local riparian water rights, managing water reuse and enforcing existing regulations have become increasingly challenging.

Previous Water Reuse Standards

The previous Jordanian Standards for Water Reuse (JS893/1995) were introduced in 1995, prior to which the World Health Organization (WHO, 1989) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* had been used (Nazzal *et al.*, 2000). Listing 47 specific constituents, JS893/1995 prescribed limits for each of the seven following uses of reclaimed water.

1. Irrigation of vegetables eaten cooked
2. Irrigation of fruit trees, forests, industrial crops, and grains
3. Discharge to streams and catchment areas
4. Artificial recharge of groundwater
5. Use in aquaculture (fish hatcheries)
6. Irrigation of public parks
7. Irrigation of fodder

JS893/1995 prohibited the following:

- Irrigation of crops eaten raw (tomato, cucumber, carrot, lettuce, radish, mint, parsley, pepper, cabbage, cauliflower, etc.)
- Irrigation during the last 2-week period before harvest
- Use of fruit fallen to the ground
- Deterioration of soil properties
- Use on crops sensitive to constituents of reclaimed water
- Sprinkler irrigation
- Transport of reclaimed water in unlined channels across recharge areas
- Dilution of reclaimed water with freshwater to meet the criteria
- Use of reclaimed water to recharge aquifers used for drinking water supplies.

JS893/1995 standards for reuse and discharge in different media are presented in Table 14.1 and for comparison with the updated Standard and Guidelines (Table 14.2).

Limitations of previous standards

The JS893/1995 Water Reuse Standard tried to regulate both water reuse and environmental discharges, so it was necessary to establish discharge requirements for treatment plants irrespective of, and in addition to, the standards for specific uses of reclaimed water.

JS893/1995 prohibited the recharge of groundwater used for drinking with reclaimed water, but the Jordan Water Strategy (MWI, 1997) specifically includes groundwater recharge as one of the desirable uses of reclaimed water. Updating the Standard attempted to resolve this discrepancy, but, it was clear that protecting the drinking water supply remained an over-riding concern of stakeholders.

JS893/1995 included a long list of constituents, some of which are relevant to environmental protection while others are relevant to water reuse. However, many of the listed parameters had little or no direct public health significance with regards to water reuse.

The export market for food crops grown in Jordan has suffered from restrictions imposed by some of the importing countries of the Arabian Peninsula and Persian Gulf because wastewater, or inadequately treated wastewater, is used to irrigate crops in some parts of Jordan. More recently, standards for exporting crops to Europe have become more rigorous, stressing the importance of addressing the role of wastewater in the water used for irrigation. To address this, the Government of Jordan (GoJ) is implementing an aggressive campaign to rehabilitate and improve the wastewater treatment plants in the country. Of primary importance is the need to establish reasonable standards to protect the health of farmers and the consuming public from infectious agents that can possibly be carried by inadequately treated wastewater.

Table 14.1. Existing (JS893/1995) numerical standards for use of treated wastewater in Jordan (Government of Jordan, 1995).

Quality parameter (mg/l except otherwise indicated)	Vegetables eaten cooked	Fruit trees, forestation, industrial crops and grains	Discharge to *wadis* and catchment areas	Artificial recharge	Fisheries[a]	Public parks	Fodder[b]
BOD5[c]	150	150	50	50	NA	50	250
COD	500	500	200	200	NA	200	700
DO	> 2	> 2	> 2	> 2	> 5	> 2	> 2
TDS	2,000	2,000	2,000	1,500	2,000	2,000	2,000
TSS	200	200	50	50	25	50	250
pH	6–9	6–9	6–9	6–9	6.5–9	6–9	6–9
Colour (PCU)[d]	NA	NA	75	75	NA	75	NA
FOG	8	8	8	Nil	8	8	12
Phenol	0.002	0.002	0.002	0.002	0.001	0.002	0.002
MBAS	50	50	25	15	0.2	15	50
NO_3-N	50	50	25	25	NA	25	50
NH_4-N	NA	NA	15	15	0.5	50	NA
T-N	100	100	50	50	NA	100	NA
PO_4-P	NA	NA	15	15	NA	15	NA
Cl	350	350	350	350	NA	350	350
SO_4	1,000	1,000	1,000	1,000	NA	1,000	1,000
CO_3	6	6	6	6	NA	6	6
HCO_3	520	520	520	520	NA	520	520
Na	230	230	230	230	NA	230	230
Mg	60	60	60	60	NA	60	60
Ca	400	400	400	400	NA	400	400
SAR	9	9	9	9	NA	12	9
RC[e]	0.5	NA	NA	NA	NA	0.5	NA
Al	5	5	5	1	NA	5	5
As	0.1	0.1	0.05	0.05	0.05	0.1	0.1
Be	0.1	0.1	0.1	0.1	1.1	0.1	0.1
Cu	0.2	0.2	0.2	0.2	0.04	0.2	0.2
F	1.0	1.0	1.0	1.0	1.5	1.0	1.0
Fe	5.0	5.0	2.0	1.0	0.5	5.0	5.0
Li	2.5	5.0	1.0	1.0	NA	3.0	5.0
Mn	0.2	0.2	0.2	0.2	1.0	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.4	0.2	0.2
Pb	5.0	5.0	0.1	0.1	0.15	0.1	5.0
Se	0.02	0.02	0.02	0.02	0.05	0.02	0.02
Cd	0.01	0.01	0.01	0.01	0.015	0.01	0.01
Zn	2.0	2.0	15	15	0.6	2.0	2.0
CN	0.1	0.1	0.1	0.1	0.005	0.1	0.1
Cr	0.1	0.1	0.05	0.05	0.1	0.1	0.1
Hg	0.001	0.001	0.001	0.001	0.00005	0.001	0.001
V	0.1	0.1	0.1	0.1	NA	0.1	0.1
Co	0.05	0.05	0.05	0.05	NA	0.05	0.05
B	1.0	1.0	2.0	1.0	NA	3.0	3.0
Mo	0.01	0.01	0.01	0.01	NA	0.01	0.01
FCC (MPN/100 ml)[f]	1,000	NA	1,000	1,000	1,000	200	NA
Pathogens	NA	NA	NA	NA	100,000[i]	nil	NA
Amoeba and *Giardia* (cyst/l)[g]	< 1	NA	NA	NA	NA	nil	NA
Nematodes (eggs/l)[h]	< 1	NA	< 1	NA	NA	< 1	< 1

[a] depends on fish type, pH, TDS, and temperature.

[b] *Trace elements and heavy metals values assume* annual irrigation of 10,000 m^3/ha

[c] BOD5 in waste stabilisation pond is filtered, but in mechanical treatment plant is nonfiltered

[d] Unit weight measured by unit of Platen Cobalt

[e] Contact time > 30 min

[f] Most probable number/100 ml

[g] One cyst/l

[h] Mean *Ascaris, Enclostoma,* and *Trycus*

[i] *Salmonella*/100 ml

BOD5 = Biochemical oxygen demand (Five Day)
COD = Chemical oxygen demand
DO = Dissolved oxygen
FCC = Faecal coliform count
FOG = Fat, oil and grease
MBAS = Methylene blue active substance
RC = Residual chlorine
SAR = Sodium adsorption ratio
TDS = Total dissolved solids
TSS = Total suspended solids
T-N = Total nitrogen
NA = Not applicable

Existing Water Reuse Practices

More than 70 million m^3 of reclaimed water, around 10% of the total national water supply, is used either directly or indirectly in Jordan each year (McCornick, 2001). The categories of use are: a. planned direct use within or adjacent to wastewater treatment plants (WWTPs), b. unplanned use in the *wadi* (a dry stream bed or the valley in which such a stream bed is located), and c. indirect use after mixing with natural surface water supplies and freshwater supplies downstream, primarily in parts of the Jordan Valley.

Direct water reuse

The use of reclaimed water at sites in the immediate vicinity or adjacent to the WWTPs is generally under the jurisdiction of the Water Authority of Jordan (WAJ), which plans, builds, owns, operates and maintains the WWTPs. A number of these sites are pilot projects with some research and limited commercial viability, but more recent projects funded by the United States Agency for International Development (USAID), are aimed at developing more productive use of the water resources while demonstrating public health and environmental protection. Other direct water reuse operations, such as the date palm plantations that receive reclaimed water from the Aqaba WWTP, are separate and viable enterprises. Farmers growing crops in these areas – under special contracts with WAJ – are generally satisfied with the water and continue to renew their contracts.

Unplanned water reuse in the *wadis*

With the diminishing contribution of natural springs to the base flow in some *wadis* due to over-pumping of groundwater in the highlands, and the increasing discharge of effluent into *Wadi* Zarqa from urban centres upstream, reclaimed water has become a significant portion of the dry-season flows. Farmers, who have traditional water rights to the base flow, have continued to irrigate from the flow in the *wadi*, that is mostly wastewater effluent. The Ministry of Health, in coordination with local authorities and the WAJ, recognising that the microbiological quality of such water presents a serious health risk and jeopardises wider export markets for crops, has enforced the existing standard (JS893/1995) where possible, but the irrigation of ground-grown vegetable crops persists in the less-accessible areas of *Wadi* Zarqa (McCornick *et al.*, 2001). The rights of the farmers to base flow in these *wadis* is recognised and respected, but only for use on restricted crops. In fact, with increasing populations in the Amman Zarqa area in recent years, flow in the *wadis* has increased and become more reliable, enabling the farmers to use larger volumes of water and irrigate larger tracts of land.

Indirect reuse of wastewater effluent

The majority of the reclaimed water generated in Jordan originates in the Amman Zarqa Basin (see Fig. 14.1). Treated effluent from the As-Samra WWTP is discharged to *Wadi* Zarqa. The *wadi* flows into the King Talal Reservoir (KTR), picking up whatever surface runoff occurs in the Amman Zarqa catchment. The water in the reservoir, blended with water from the King Abdullah Canal, when available, is used for irrigation in the southern portion of the Jordan Valley (McCornick *et al.*, 2002). From a Jordanian legal aspect this water, downstream of the KTR, is no longer considered to be reclaimed water. From a practical perspective, however, the microbiological and chemical qualities of the water are affected by the level of treatment at the WWTP and by non-point sources contaminating surface runoff from the Amman Zarqa catchment.

Motivation to Revise Water Reuse Standards

Policy and strategy context

Since 1998 Jordan has been revising the strategy and policies used to manage its scarce national water resources. The National Water Strategy (MWI, 1997) recognises that population pressure in Jordan has already caused a chronic deficit in available freshwater that has

Table 14.2. Revised standards of water reuse in Jordan (Government of Jordan, 2003).

Purposes of water use	Artificial groundwater replenish-ment	Cooked vege-tables	Recreation grounds, courses and roadsides inside the cities	Golf courses	Fruit trees	Road-sides outside the cities	Open green areas	Cereals and fodder crops	Industrial crops	Forest trees	Discharge into valleys and torrential streams: Mechanical system	Discharge into valleys and torrential streams: Natural system
	Operating specifications											
BOD (mg/l)	15		30			200			300		60	120
COD (mg/l)	100		100			500			500		150	300
DO (mg/l)	>2		>2			–			–		>1	>1
TSS (mg/l)	50		50			150			150		100[b]	–
pH (unit)	6–9		6–9			6–9			6-9		6–9	6–9
Cl_2 residual	0.5–1.0		0.5–1.0			–			–		0.5–1.0	–
Turbidity (NTU)[a]	2		10			–			–		–	–
NO_3 (mg/l)	45		45			70			70		45	45
NH_4 (mg/l)	5		10			–			–		–	–
T-N (mg/l)	30		45			45			45		45	45
	Environmental and health specifications											
E. coli MPN or CFU/100 ml	<2.2		100			1000			–		500	1000
Intestinal helminths eggs (egg/l)	≤1		≤1			≤1			≤1		≤1	≤1

[a] NTU: unit that measures turbidity of water using a typhilometer.
[b] Water treatment stations that use mechanical methods and have polishing (settlement) ponds are allowed to exceed twice the times TSS standard.

resulted in over-extraction of groundwater. Opportunities to develop new freshwater sources are limited, and those that exist are expensive, with high operating costs. Given this, treated wastewater is considered to be a resource that, with due care for public health and the environment, should be reclaimed and reused for agriculture and other non-domestic purposes, including groundwater recharge.

The National Wastewater Management Policy (MWI, 1998) states that water reuse for irrigation should be given a high priority, and that reclaimed water is to be sold at prices that, at a minimum, cover the operation and maintenance costs of delivery. The Policy also allows for the Jordanian Standards on Water Reuse to be periodically examined.

Furthermore, the Policy states that any use of reclaimed water must:

- Protect the public
- Conserve resources (water, soils/land, natural vegetation, etc.)
- Comply with international treaties
- Ensure environmentally sound practices.

Proposed uses of reclaimed water

In addition to the present water reuse practices in Jordan, there are a number of proposed developments where water reuse would be beneficial, yet would have been prohibited or difficult to manage under JS893/1995.

A case in point is the existing Aqaba WWTP, located on the coast of the Gulf of Aqaba at the northern extremity of the Red Sea. This WWTP is now operating at capacity, but the fast-developing Aqaba free trade zone will soon increase the treatment capacity requirements considerably. A major reconstruction project is scheduled to be completed in late 2004. The specifications for the new facility call for zero emissions of effluent into the Gulf of Aqaba. This requirement has further motivated decision-makers to maximise the use of reclaimed water. In addition to the relatively successful irrigation of date palms with reclaimed water that complies with the JS893/1995, the intent is to use the reclaimed water to irrigate more date palms, other crops, a golf course, and the urban

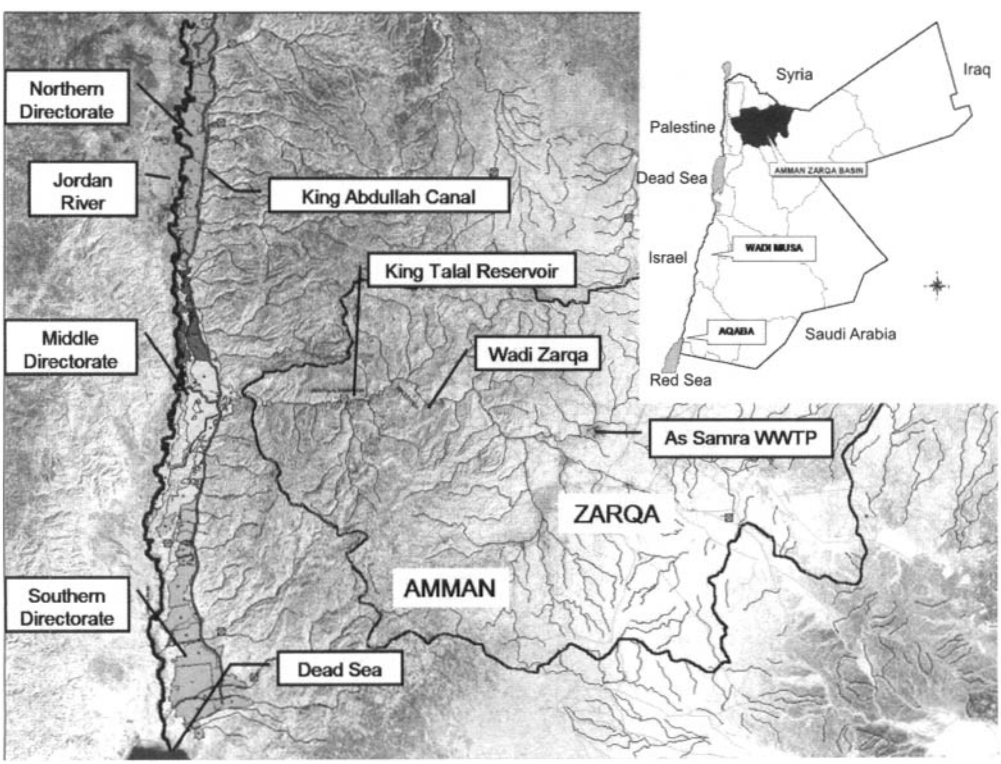

Fig. 14.1. Schematic map of Jordan, and the Amman-Zarqa Basin.

landscape within the Aqaba city area. Furthermore, industry presents a potential additional demand for the reclaimed water. JS893/1995 did not allow for the use of sprinkler systems that are required for the golf course and such use is still not allowed under the new standards.

A major consideration in the use of reclaimed water in Jordan is the potential impact of regulations on the export market of fresh fruit and vegetables, and the possibility of restrictions placed by importing countries based on the poor microbiological quality of the irrigation water.

Other reasons (Sheikh, 2001) for revisiting Jordanian Standard JS893/1995 are:

- Incorporating the latest knowledge about use of reclaimed water
- Incorporating water reuse into the overall integrated management of water resources in Jordan
- Protecting public health in use of reclaimed water – while leaving other important considerations (environmental protection, soil characteristics, agricultural productivity) to the discretion of customers and other governmental entities
- Simplifying compliance with uniform standards for all stakeholders
- Implementing a broad range of water reuse activities ranging from irrigation of crops eaten raw that would require disinfected tertiary effluent, to small community and satellite facilities where the WWTP produces secondary treated effluent
- Streamlining enforcement of the standards.

The Process of Revising the Standards

Technical experts were engaged to work with staff members of various national government agencies [MWI, WAJ, and the Jordan Valley Authority (JVA)] on revision of the Water Reuse Standards. Knowledge of the problems faced by farmers, industry, and GoJ helped to develop an appreciation of the constraints faced by all parties using treated effluent. A three-tiered standard was developed to ameliorate the shortcomings of JS893/1995.

From the expert review of the Jordanian Standards for Treated Wastewater Reuse insight was provided on ways and means of enhancing these Standards and of providing guidelines for water reuse and industrial discharges to sewers. Presentations highlighting experiences of other countries shed light on the benefits of using of reclaimed water. They also addressed and alleviated the concerns of the public, decision-makers and GoJ technical specialists. These informational sessions proved to be highly useful in reaching consensus on the content of the new Standard.

Review of Standards

The review of the Standards began early in 2000 when the history of relevant legislation and standards was reviewed (Nazzal *et al.*, 2000). A detailed review of JS893/1995 was conducted, present practices were examined, and a framework for revising them was developed (Sheikh, 2001). Over this period, input was sought from various stakeholders in the MWI, WAJ, JVA, Ministry of Health, Ministry of Agriculture, and tertiary education institutions.

Proposed framework

A proposed regulatory framework, with the primary goals of protecting public and farm-worker health, and developing a credible regulatory system for domestic and export markets, was presented to the stakeholders. The expectation was that, with stakeholder input, revised standards would evolve from the framework, and would eventually be adopted formally.

The proposed framework has three tiers. Tier 1 is legally enforceable water reclamation standards aimed at protecting public and farm-worker health (see Table 14.3). This will be accomplished through the regulation of parameters that: 1. ensure optimal performance of the WWTPs, 2. indicate the microbiological safety of reclaimed water, and 3. can be controlled at the WWTPs. Note that under the originally proposed regulatory regime, unrestricted irrigation (last column of Table 14.3) would, unlike JS893/1995, have allowed the irrigation of vegetables eaten raw.

The principles underlying Tier 1 allow for a wide range of uses of reclaimed water. For the

Table 14.3. Proposed Tier 1 standards for Jordanian water reuse regulation[a] (Sheikh, 2001).

Process control parameter	For use in restricted irrigation of: Orchards, forest, fodder, industrial crops, grains	For use in restricted irrigation of: Vegetables eaten cooked, processed	For use in unrestricted irrigation of vegetables eaten raw, public parks, other urban uses
Faecal coliform (MPN/100 ml)	1,000	200	23
Nematode eggs (no./l)	1	1	1
BOD5 (mg/l)	100	50	15
Turbidity (NTU)	12	10	2
Total nitrogen (mg/l)	45	45	30
Residual chlorine (mg/l)	NR[b]	NR	0.5

[a] Includes parameters that can be controlled by wastewater treatment operators.
[b] NR = not required.

irrigation of orchards, trees, fodder, industrial crops and grains, the WHO standards are still used as a guiding principle. For areas with a fragile environment, such as those around Aqaba, a higher level of treatment is necessary regardless of water reuse requirements. Tier 1 would have originally allowed for the use of highly treated effluent for irrigation of raw-eaten vegetables and parks with unrestricted public access as well as for other non-potable urban uses.

Tier 2 criteria is a set of guidelines aimed at protecting the soil and maintaining the highest possible level of crop productivity. Unlike the Tier 1 Standards, these guidelines are not legally enforceable. Rather, they are intended to assist the decision on a given use of an available source of reclaimed water. Guideline constituents are relevant to soil and agricultural productivity but are beyond the control of a typical WWTP. If they should not be present in an effluent stream, they are best removed at source. (An excellent example in Jordan was the case of boron in the Amman Zarqa basin, that was successfully reduced to safe levels through a source-control campaign in the 1980s and 1990s). Separating guideline parameters from standard parameters is a major departure from the JS893/1995, that attempted to regulate all parameters. The sampling and monitoring of guideline parameters would not be the responsibility of the independent agency proposed to oversee water reuse, but of other agencies. A list of guideline parameters and their limits is presented in Table 14.4.

Tier 3 is reserved for the so-called constituents of emerging concern, i.e. synthetic organic compounds, disinfection byproducts, pharmaceuticals, and endocrine disruptors. These constituents are not generally of major concern in water reuse, but they can cause problems if they end up in the domestic water supply. The revised standards call for continued research and vigilance in developing information on such constituents.

In addition to numerical standards and guidelines, the proposed regulatory framework includes the following eight narrative sections:

1. Definitions
2. Sources of reclaimed water
3. Uses of reclaimed water
4. Use area requirements
5. Monitoring requirements
6. Reporting and operational requirements
7. Design requirements
8. Reliability requirements.

Framework review

The draft framework was revised and distributed to the stakeholders and key experts in mid-2001. For new water reuse standards to be ratified in Jordan, they must first be agreed upon by the Select Committee of Wastewater Experts of the Water Authority of Jordan; next, they must be approved by the Standards Committee of the Jordan Institute of Standards and Metrology (JISM), and finally, they must receive the approval of the Director General of JISM. Both committees draw experts from government and non-government agencies, and the university community. Several members of these committees had served as key experts

Table 14.4. Upper limits of guideline values for properties of effluent used for irrigation and values of standard specifications in the event effluent water is discharged into valleys and streams or used for groundwater replenishment.

Tested elements (mg/l)[a]	Guideline values for irrigation	Standard specifications[b]
FOG	8	5.0
Phenol	< 0.002	< 0.002
MBAS	100	25
TDS	1,500	1,500
Total PO_4	30	15
Cl	400	350
SO_4	500	300
HCO_3	400	400
Na	230	200
Mg	100	60
Ca	230	200
SAR	6–9	6
Al	5	2
As	0.1	0.05
Be	0.1	0.1
Cu	0.2	0.2
F	1.5	1.5
Fe	5.0	5.0
Li	2.5 (0.075 for citrus crop)	2.5
Mn	0.2	0.2
Mo	0.01	0.01
Ni	0.2	0.2
Pb	5	0.2
Se	0.05	0.05
Cd	0.01	0.01
Zn	5	5
Cr	0.1	0.02
Hg	0.002	0.002
V	0.1	0.1
Co	0.05	0.05
B	1.0	1.0

[a] For explanation see Table 14.1

[b] Standard specifications should be adhered to when discharging effluent water into valleys or steams, or when using it for used for groundwater replenishment.

and stakeholders in the development of the framework.

In early 2002, a series of workshops was held at different locations in Jordan with the two committees and other stakeholders, including those interested in the proposed wastewater and water reuse facility at Aqaba. These workshops, using the draft framework as a guide, sought to develop a rational revision of the water reuse standards. Through a process of active negotiation amongst the various stakeholders, the workshops led to consensus on the following:

- Separation of the water reuse standards from the environmental discharge standards
- Division of the existing list of constituents into separate standards and guidelines for water reuse, and agreement on the appropriate numerical level for each
- Allowance for use of a highly treated reclaimed water for irrigation of crops eaten raw and other urban uses
- Allowance for groundwater recharge with reclaimed water, with the understanding that each proposed application is to be studied thoroughly, on a case-by-case basis
- Allowance for the use of sprinkler application systems using tertiary disinfected reclaimed water
- Creation of an independent and impartial enforcement body for oversight of water reuse activities and effective enforcement of adopted standards
- Publication of the operation and maintenance records, and monitoring of results from the treatment facilities.

Finalising the Standards and Guidelines

The workshops resulted in consensus, at least among the stakeholders present, on a revised listing of constituents, a distinction as to whether each constituent was a standards or guideline constituent, and suggested numerical values for each. Consensus was also reached on revising the existing standards to incorporate the major points of agreement presented above.

Subsequently, as the draft standards and guidelines progressed through the formal review process, further changes were made. The new standards are in two tiers (Standards and Guidelines). A major change from the proposed standard is that the irrigation of vegetables eaten raw with reclaimed water, no matter how well it is treated, is to remain prohibited. Recharge of groundwater is permitted, but not for aquifers that are to be used for drinking water supplies.

The application of reclaimed water by sprinkler irrigation remains prohibited. The new standard has been approved by the JISM, and was enacted in 2003 under the title JS893/2003.

Conclusions

Prior to implementation of direct water reuse, the GoJ, with the support of USAID, revisited and revised the existing Jordan Water Reuse Standard (JS893/1995). The review and revision process was informed by senior international expertise in the water reuse standards field, government agencies, and senior technical specialists from government and non-governmental organisations. Knowledge of the problems faced by farmers, and the industry, and the GoJ helped in the development of an appreciation of the constraints faced by all parties with regard to the reuse of treated effluent.

A detailed review of the existing Jordanian standards for water reuse provided insight into the ways and means of enhancing the standards and providing guidelines for water reuse and industrial discharges to sewers. A three-tiered framework of standards/guidelines was used to guide the process.

Presentations, workshops and study tours highlighting experiences of other countries shed light on the benefits of the use of properly treated wastewater and addressed and alleviated the concerns that the public, decision-makers and technical GoJ specialists had with regards to the water reuse issue.

The review and revision process proved to be highly beneficial in bringing differing opinions to close agreement on the content of the standard. The standards have now been approved by the JISM and officially enacted . It is expected that the new standards will provide Jordanian farmers with opportunities to comply without losing any vested rights to riparian water, and with much improved health and safety conditions for themselves, their children, and their customers.

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15 Treated Wastewater Use in Tunisia: Lessons Learned and the Road Ahead

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The World Bank, Jakarta, Indonesia

Abstract

With per capita freshwater availability of around 450 m^3, Tunisia is one of the most drought-stressed countries in the Middle East and North Africa (MENA) region. In the MENA region, and indeed worldwide, Tunisia along with Israel, has been recognised as a leader in the area of wastewater reclamation and use. This chapter presents the case of a middle-income country that has pursued a conscious strategy of treated wastewater reuse in agriculture with a fair measure of success. The current status of wastewater treatment and the use of treated wastewater in agricultural irrigation are reviewed. The impacts of water quality are discussed in this context, and the institutional, legal, and economic aspects analysed. The final section presents the lessons learned from the Tunisian experience and the options and hurdles for expanding the scope of treated wastewater use in agriculture. The key findings are that despite strong government support, treated wastewater use in irrigation has faced several constraints, chief among them being problems of social acceptance, agronomic considerations and sanitation, and restrictive regulations that have tended to limit its full potential for development. Further, the multiplicity of agencies and overlapping institutional responsibilities have also tended to limit the potential for expansion. Through its carefully phased approach to treated wastewater use and the concomitant development of a regulatory framework that prohibits untreated wastewater use, Tunisia has significantly mitigated the environmental and public health risks associated with untreated wastewater use elsewhere in the world.

Background

Tunisia is a middle-income country located on the southern rim of the Mediterranean Sea with a population of approximately 10 million that is growing at about 1.8% per annum. Annual per capita income is around US$4,250 (World Development Report, 2002). Tunisia has a semi-arid climate and few renewable natural resources. It occupies 165,000 km^2 with the Atlas mountain range in the north accounting for 25% of the area. The Central Steppe and Sahel regions make up another 25% and the Southern Sahara region 50%. The annual rainfall varies from 600 mm in the north (400 mm in Tunis) to 100 mm in the southern region. The population is relatively urbanised, with 58% living in urban areas on the northern and eastern coast. Administratively, Tunisia is divided into 23 governorates, 136 counties, and 250 communes.

Water Resources and Quality

The annual total volume of exploitable water resources in Tunisia is about 4670 million cubic metres (MCM) of which about 57% (2,700 MCM) is surface water and the remaining 43% (1970 MCM) groundwater. Tunisia is a drought-stressed country with per capita renewable water availability of 486 m^3 – well below the average of 1,200 m^3/capita for the Middle East and North Africa (MENA) region. Of the available surface water resources of 2,100 MCM, only about 1,220 MCM are expected to be captured for actual use. Eighteen existing dams, 21 projected dams, and 235 hillside dams are expected to augment the available supply but rapid sedimentation of reservoirs will progressively reduce storage capacity and shorten life. Deep groundwater extraction rates are currently at 73% of annual recharge, and shallow groundwater is at 97% in the coastal and central regions. Excessive groundwater extraction in the coastal regions of Cap Bon, Soukra, and Ariana has resulted in saline intrusion in many areas leading to groundwater being rendered unsuitable for further irrigation. Water quality, especially salinity, is a serious constraint. Only 50% of all water resources have salinity levels lower than 1,500 mg/l and can be used without restrictions. While the surface water has a generally low salinity (with the exception of the tributaries entering the Medjerda river from the south), groundwater resources are badly affected with 84% of all groundwater resources having salinity levels of more than 1,500 mg/l and 30% of the shallow aquifers more than 4,000 mg/l. World Health Organization (WHO) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* (1989) specifies considerably lower limits for potable water. This saline irrigation water reduces crop yields and requires the installation of costly drainage systems to maintain soil fertility. The effect of salinity on the water balances is an important consideration for Tunisia's water resource planning (World Bank, 1994). As in most other countries, agriculture accounts for the bulk of water consumption (89%) with domestic use accounting for 8% and industrial use 3%.

Tunisia has also experienced three serious droughts in the last decade that have affected agricultural growth and domestic consumption. With an increasing population, rapid urbanisation, and rise in living standards developing additional water resources is imperative. The last three Five-Year Plans (Government of Tunisia, 1987, 1992, 2002) have emphasised water harvesting and treated wastewater use. Since the severe drought in 1989, the use of treated wastewater in irrigation has been a part of the Government's overall water resource management strategy. As seen in Table 15.1, treated wastewater use and desalination are both expected to virtually double in the coming years.

Current Status of Wastewater Treatment

About 70% of the urban population is connected to a sewerage network but among the rural population only 20% are connected. The number of wastewater treatment plants (WWTPs) has gradually risen in the last decade and is expected to reach 83 by 2006 (Table 15.2). Currently, 61 WWTPs are in operation with

Table 15.1. Projected water resources in Tunisia – accessible (A) and available (B) (MCM/annum) for different time horizons (1998).

	1996		2010		2020		2030	
	A	B	A	B	A	B	A	B
Large dams	1,340	871	1,800	1,170	1,750	1,138	1,750	1,138
Hillside dams and lakes	65	59	100	50	70	35	50	45
Tubewells and springs	997	997	1,250	1,150	1,250	1,000	1,250	1,000
Open wells	720	720	720	720	720	620	720	550
Treated wastewater	120	120	200	200	290	290	340	340
Desalinated water	7	7	10	10	24	24	49	49
Total	3,249	2,774	4,080	3,300	4,104	3,107	4,159	3,122

Source: Bahri, 2000.

9,650 km of wastewater network collecting 178 MCM wastewater, 148 MCM of which are treated and used in agriculture, to water golf courses and for other purposes. Almost 83% is treated in 44 WWTPs by activated sludge, 0.5% is treated in 3 WWTPs by biological filters, 7.6% in 7 plants in natural lagoons, and 8.6% in 7 plants in aerated lagoons (Koundi, 2001). Effluent is treated to the primary and secondary levels.

Table 15.2. Evolution in number of wastewater treatment plants in Tunisia, 1995–2006.

Year	WWTPs (number)	Capacity (MCM/ annum)	Treated (MCM/ annum)
1995	48	135	111
1996	49	137	116
1997	51	145	131
2001	66	175	155
2006	83	185	165

Source: Ministry of Agriculture, 1998.

Treated Wastewater Use in Agriculture

Tunisia has had a cautious and gradual approach to applying treated wastewater in irrigation. Since 1965, wastewater from the Charguia WWTP has been used to irrigate citrus orchards in the Soukra irrigation scheme covering 1,200 ha (now reduced to 600 ha due to urbanisation) north of Tunis in order to safeguard them from saline intrusion caused by the overexploited aquifer. However, it was not until 28 July 1989 with the passage of the Decree 89-1047 setting conditions for the use of treated wastewater for agricultural purposes, that the use of treated wastewater in irrigation really expanded in a controlled manner (Ministry of Agriculture, 1998). This Decree set the conditions for the use of treated wastewater in agriculture. In addition to the institutional aspects, the Decree also specified the modalities for control of quality including the necessary physico-chemical parameters, microbiological parameters and the frequency of monitoring (Ministry of Agriculture, 1998). The main legal framework is also contained in the Code des Eaux (Water Code) dating back to 1975. As Table 15.3 shows, use in irrigation and golf courses is predominant. However, only about 35 MCM of treated wastewater is currently used on about 6,500 ha mainly (55%) in the area surrounding Tunis which represents about 20–30% of the volume produced. It is estimated that by 2020 about 20,000–30,000 ha, or about 7–10% of total irrigated area, will be irrigable using treated wastewater (World Bank, 1997; Ministry of Agriculture, 1998).

Table 15.3. Categories of treated wastewater use in Tunisia.

Use	Area irrigated		Volume used	
	ha	%	MCM	%
Irrigated perimeters	6,272	90	3.72	43
Golf courses	570	8	4.07	46
Others	155	2	0.95	11
Total	6,997	100	8.74	100

Source: Ministry of Agriculture, 1998.

Effluent Water Quality and Impacts of Treated Wastewater Use

In Tunisia the quality of treated wastewater varies spatially with the lowest salinity found in the northwest (min. 1,000; max. 1,500; average 1,300 mg/l) owing to the good quality of surface water resources and the low level of industrial activity in that region. By contrast, the WWTPs in the south exhibit alarmingly high concentrations of salt due to the salinity of the distribution waters and the presence of important industries that dispose of their wastes in certain stations (min. 2,700; max. 8,900; avg. 4,100 mg/l) (see Table 15.4). This is a major problem for the farmers who express concerns about the long-term impacts on their soils and crops. Around Moknine, the high salinity of the treated wastewater supplied by the National Sanitation Agency [Office National d' Assainissement] (ONAS) resulted in serious soil degradation. In order to drain the salts from the soil and to provide compensation, the farmers in that area now receive free conventional water from the neighbouring

Table 15.4. Average quality of treated wastewater in different regions of Tunisia, 1996.

Region	WWTPs	Mean annual conductivity EC (µS/cm)	Mean annual salinity (mg/l)	Average volume treated (MCM/annum)
Tunis	4	4,877	3,700	5.00
Northwest	4	1,698	1,300	4.77
Northeast	10	2,855	2,200	2.30
Centre	17	4,230	3,300	1.95
South	14	5,253	4,100	1.87

Source: Calculated from Ministry of Agriculture, 1998.

Nebhana dam. A high rate of suspended solids exceeding the norm of 30 mg/l in many cases has also been reported, with associated discoloration of the water. This has also led to complaints about clogging local irrigation systems, and poses a constraint to farmers adopting drip irrigation.

Evidence of microbial contamination exists and poses a health and sanitary risk to both farmers and consumers. A 1985 study jointly carried out by the Ministries of Agriculture and Public Health evaluated the impact of treated wastewater on crops and human health in the Soukra, Borj Touil, and Djebel Ammar areas. The study revealed 141 cases of gastrointestinal (GI) disease (21% of the surveyed Soukra population). Some of the diseases could be related to treated wastewater use, but the study was not exhaustive enough to clearly identify the sources. In 1990, a study carried out by the regional health and agricultural authorities of Ariana in Borj Touil recommended strict control of wastewater use in the Soukra and Borj Touil regions (UNDP *et al.*, 1992). An ONAS survey carried out in 1992 pointed to a lack of information amongst farmers about wastewater quality, health risks related to wastewater use and impacts on crops and soils. Farmers do not systematically receive health education concerning the risks they incur, nor do they adopt the preventive measures that are advocated by the public health service. The Ministry of Public Health does not have the necessary means or organisation to effectively supervise the use of treated wastewater in irrigation. Implementation of effective disinfection for reclaimed wastewater effluents using maturation ponds or high-rate ponds could reduce the public health risks. This would also eliminate the need for extensive and complex epidemiological studies to assess the health status of populations using treated wastewater for irrigation or living within the irrigated areas (Asano and Mujeriego, 1992).

Water Quality Standards and the Legal Framework

Treated wastewater use in agriculture is regulated by the 1975 Water Code and associated Decree No. 89-1047 (Ministry of Justice and Human Rights, Republic of Tunisia, 1989). The Water Code prohibits use of untreated wastewater in agriculture and restricts the use of reclaimed water for irrigation of any vegetable to be eaten raw. The use of secondary treated effluents for growing all types of crops except vegetables, whether eaten raw or cooked is allowed. Water quality criteria for treated wastewater use in agriculture have been developed using the 1989 WHO Guidelines as the basis and a list of crops that can be irrigated has also been established. According to the 1989 Decree No. 89–1047, treated effluent can only be used to irrigate crops that are not directly consumable. No vegetables can be irrigated with treated wastewater. The main crops irrigated with treated wastewater are: fruit trees including citrus, grapes, olives, peaches, pears, apples, pomegranates, etc. (28.5% by area); fodder including alfalfa, sorghum, clover, etc. (45.3%); industrial crops such as sugarbeet (3.8%); and cereals (22.4%). 57% of the area equipped with irrigation facilities is sprinkler-irrigated and 48% surface irrigated. Water quality standards have also been established for wastewater disposal in receiving waters (seas, lakes and rivers). According to Bahri (2000), monitoring the quality of treated water for a set of physical-chemical parameters once a month, for trace elements once every 6 months, and for helminth eggs every 2 weeks was originally envisaged. However, due to organisational and capacity constraints in the Ministry of Public Health, such monitoring is not systematic. Nonetheless, unlike other countries of the Middle East (e.g. Syria and Egypt), there is no evidence of the widespread use of untreated wastewater in agriculture. Compliance with existing restrictions on cropping patterns is relatively good. This is facilitated by the fact that the bulk of the wastewater (over 50%) originates in the capital Tunis, which is relatively small (population approximately 1 million) allowing the effective enforcement of existing guidelines. In small and medium-sized towns, ONAS is currently developing an indigenous low-cost technology for treatment but coordination with the new Ministry of Agriculture, Environment, and Water Resources, that was formed in 2002 when the Ministries of Agriculture and Environment merged, to determine market demand from farmers is still limited.

Economic and financial aspects of wastewater treatment

ONAS, which is responsible for the collection, treatment, and the disposal of wastewater, faces varying costs of treatment depending on the age and type of the plant, its location, and capacity with a high of US$0.51/m^3 (Menzel Bouzelfa WWTP in the northeast; 1995; capacity 2065 m^3/day) to a low of US$0.02/m^3 (Dar Jerba WWTP in the south; 1972; capacity 1100 m^3/day). These costs include the investment,[1] and operations and maintenance (O&M) costs. The average cost of secondary treatment is estimated at US$0.14/m^3 but a study commissioned by ONAS in 1996 estimates that this will more than double to US$0.29/m^3 in the next 5 years or so, owing to the high costs of new investments (Ministry of Agriculture, 1998).

In Tunisia, the price charged by the Commissariat Régional du Développement Agricole (CRDA), the Regional Commissioner for Agricultural Development, for the water supplied for irrigation (conventional and treated wastewater) varies by governorate. Usually the price of water includes the costs of conveyance, O&M, but not of investment. In the northern CRDA of Ariana, generalised irrigation costs are determined by the overall price of O&M, irrespective of whether the specific source is treated wastewater. In 1996, this was estimated at 103 millièmes (mmes)/m^3 ~US$0.06/m^3 (1 Tunisian Dinar (DT) = 1,000 millièmes; 1 DT = US$0.66).

In the Ben Arous CRDA, the O&M costs of treated wastewater were estimated at 122 mmes/m^3 including labour costs (18%), costs of electricity for pumping (68%), and other costs (14%). The estimation of the O&M costs is sensitive to the volume of water pumped and billed. For example, in the Ariana CRDA, the quantity of water pumped in the irrigation perimeter was more than 2.9 MCM. If this volume was in reality properly accounted for, the O&M costs would have been 44 mmes/m^3, lower than those actually charged by the CRDA, i.e. 55 mmes/m^3. Table 15.5 presents the variation in treated wastewater prices among CRDAs and the differences between the prices charged for treated wastewater and conventional water (Ministry of Agriculture, 1998).

In 1997, a Presidential Decree set the price of treated wastewater at a uniform 20 mmes/m^3 or US$0.01/m^3 in order to encourage farmers to expand its use. This is a significant subsidy considering the average cost of treated wastewater is estimated at US$0.14/m^3, and is expected to rise to US$0.29/m^3 in the coming years as new WWTPs come on line. However, the impact of this subsidy in expanding demand has been far lower than expected due to such reasons as poor quality, social acceptance, agronomic considerations, and sanitation. Further, despite the tariff reforms undertaken by the Government, which require the CRDAs to annually raise the price of water by 15% on average, the price of conventional water still remains very low. Where the farmers have a choice between treated wastewater and

[1] Capital costs amortised over 45 years with an interest rate of 7%; equipment amortised over 15 years at 7%.

Table 15.5. Comparison of prices [DT/m³ (US$/m³)] for treated wastewater and conventional water in Tunisia prior to the 1997 Government Decree.

WWTP (name)	Irrigation scheme	Price of wastewater charged by CRDA	Price of conventional water	Price of wastewater as a percentage of conventional water (%)
Cherguia	Borj Touil	0.031 (0.020)	0.091 (0.060)	34.1
Choutrana	Soukra	0.069 (0.046)	0.091 (0.060)	75.8
Sud Méliane	Mornag	0.059 (0.039)	0.090 (0.059)	65.6
SE3 Nabeul	Bir Faiedh, Oued Souhil	0.059 (0.039)	0.062 (0.041)	95.2
SE4 Nabeul	Borj Khiar-Mess. Borj Romana	0.059 (0.039)	0.062 (0.041)	95.2
Sousse south	Zaouiet Sousse	0.050 (0.033)	0.104 (0.069)	48.1
Kairouan	Draa Tammar	0.032 (0.021)	0.061 (0.040)	52.5
Sfax	Hajeb	0.020 (0.013)	0.030 (0.020)	66.7

Source: Calculated from Ministry of Agriculture, 1998
Note: 1 DT = US$0.66

conventional water, they prefer conventional water because of the crop restrictions on treated wastewater and problems with its quality. For farmers who would not otherwise have had access to irrigation, treated wastewater is the preferred option because it has helped raise their incomes. For example, farmers living on the perimeter of Borj Touil on the northern coast had no access to surface water resources, and groundwater resources there are far too saline for their use

Institutional and Organisational Structure

Water resources are managed at the national level by the newly-consolidated Ministry of Agriculture, Environment and Water Resources (MAEW) formed by the merger of the Ministry of Environment with the Ministry of Agriculture in September 2002. Its hydraulic works section, the Direction Générale des Grands Barrages et des Grands Travaux Hydrauliques (DGBGTH), is responsible for the construction of major water resources projects. Responsibility for the water supply systems in urban areas and large rural centres is assigned to the Société Nationale d'Exploitation et de Distribution des Eaux (SONEDE), a national water supply authority that is an autonomous public entity under the MAEW. Planning, design, and supervision of small and medium water supplies and irrigation works are the responsibility of the Direction Générale du Génie Rurale (DGGR), a department of the MAEW. Responsibilities for managing investment planning and implementation of projects and agriculture activities are with the Commissariats Régionaux au Développement Agricole (CRDAs). These were created as semi-autonomous agencies in each of the country's governorates to represent the Ministry of Agriculture, now the MAEW. They now manage over 50% of public investment in the agriculture sector. A few water users groups (Associations d'Intérêt Collectifs, AICs) have also been created to handle water distribution e.g. the AIC in Monastir. In 1975, with the assistance of the World Bank, the Government created the ONAS, which is responsible for the sewerage subsector management including the collection, treatment, and disposal of wastewater in urban, industrial, and tourism zones. In 1993, ONAS's mandate was consolidated under the (then) created Ministry of Environment and Land Use Planning with increased responsibility for sewerage operations. Now ONAS has expanded into an institution responsible for the protection of the aquatic environment, working in close cooperation with the National Environmental Protection Agency (Agence Nationale de Protection de l'Environnement, ANPE, established in 1989), which is charged with developing and enforcing regulations concerning wastewater discharge. The other key ministry involved is the Ministry of Public Health (MPH), which regulates the quality of wastewater used for irrigation and of marketed crops, as well as monitoring water pollution and enforcing control. This Ministry has an important say in pollution control and wastewater use regulations.

Lessons Learned and the Road Ahead

The results and experience gained in Tunisia on treated wastewater use place Tunisia among the leading countries in the Mediterranean area in the field of treated wastewater use in irrigation. It is one of the few countries where treated wastewater use has been made an integral part of environmental pollution control and water management strategies. The knowledge and experience gained by researchers in the Institut National de Recherche Génie Rural, Eaux, et Forêts (INRGREF) should provide excellent guidance to other countries in arid and semi-arid regions in defining the different irrigation uses for reclaimed wastewater, quality requirements for specific uses, the treatment levels best suited to each use, and the most adequate management options available for implementing current and proposed projects. Through its planned and cautious approach together with a well-developed regulatory framework, Tunisia has significantly mitigated the environmental and public health risks associated with untreated wastewater use elsewhere in the world. As a middle-income country, Tunisia also has the benefit of an affluent, well-educated population that has helped to practically eliminate untreated wastewater use. This has not meant that wastewater use in Tunisia is without its constraints. The following important lessons have been learned from Tunisia's implementation of a conscious strategy of treated wastewater use over the decades.

Institutional

There is a multiplicity of agencies that are currently involved in treated wastewater use with often conflicting objectives and overlapping responsibilities. The lack of co-ordination has resulted in a mismatch in the supply and demand. ONAS generates treated wastewater according to its prerogatives and the established quality standards, but not necessarily to match the quality and quantity demands of the primary users – the farmers. On the other hand, the CRDAs representing farmers' interests would like to obtain treated wastewater as needed during the cropping season at certain times, in certain volumes, and of a quality appropriate for crops

Currently there is no single agency with responsibility for treated wastewater reuse (regulation and enforcement of standards and procedures, management, etc.). A possibility for increased coordination among different stakeholders would be the creation of an executive commission with representatives from the key ministries and agencies. This commission would be tasked with implementing the national strategy for treated wastewater use including supervision, coordination, control and establishment of new use initiatives, education programmes etc. Due to Government concerns about rising public expenditures in the civil services, implementation of this recommendation in the near future is unlikely, unless the wastewater commission were to be created by drawing from the staff of existing agencies.

Technical

Firstly, in order to be able to better match demand and supply, the development of associated infrastructure especially inter-seasonal storage facilities needs to be emphasised. Farmers are willing to pay more if they can be assured of a timely and reliable quantity and quality of water supply. With the growth in the number of WWTPs, ONAS has to work with MAEW, CRDAs, and farmer representatives to determine technical and management solutions that are mutually satisfactory. Secondly, with the Government's push towards water-saving technologies on a national scale, effective filtration systems need to be devised to enable the use of treated wastewater in micro-irrigation systems such as drip irrigation without clogging.

Social/agronomic

Farmers are still reluctant to use treated wastewater and do not possess the necessary training to use it for agricultural irrigation in a safe and hygienic manner. For the farmers who do use treated wastewater, there is little evidence to suggest that chemical fertiliser use has decreased, a process that is likely to result in over-fertilisation and aquifer contamination in the long term. This points to the need to strengthen agriculture and irrigation extension services so that farmers are appropriately trained. Extension agents themselves need to be better equipped to respond to farmers' needs and concerns.

Public outreach and education programmes are also essential if greater social acceptance of treated wastewater is to be generated. The use of treated wastewater effluents is legitimate from the Islamic religious viewpoint, and has therefore to be examined in each case from the aspects of health, cost, and public acceptance (Farooq and Ansari, 1983; Faruqui *et al.*, 2001). Building community participation through water users groups (AICs) during the planning stages of projects can help build socio-cultural acceptance.

Economic

The current standards and restrictions on cropping patterns will need to be revisited. Current restrictions on the use of treated wastewater for higher-value crops discourage farmers from using this resource despite its highly subsidised price. This will necessitate a revision in the 1975 Water Code and the associated regulatory decrees. The Government is already thinking along these lines and will develop a revision of the Water Code that will result in a more practical pricing structure and a revision of the cropping restrictions based on the quality of treated wastewater. The Government's emphasis on treated wastewater use in irrigation has not been based on a rigorous market assessment of real demand. Too often, the rates of return on wastewater treatment and reuse projects are artificially high because they assume a rate of use that is unrealistic. There is untapped demand for industrial and recreational use of treated wastewater. Implementation of a market-based strategy of treated wastewater use will necessitate greater coordination between the different stakeholders. The absence of a single coordinating agency will be a major hurdle.

Endnote: At the time of writing, the author was a Visiting Scientist at the South Asia Regional Office of the International Water Management Institute (IWMI) in Patancheru, India and Senior Economist in the Rural Development, Water and Environment Department, Middle East and North Africa Region of the World Bank.

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16 Confronting the Realities of Wastewater Use in Irrigated Agriculture: Lessons Learned and Recommendations

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Abstract

This concluding chapter synthesises results and lessons learned throughout this volume, which deals with the reality of wastewater use in agriculture in developing countries. It then extrapolates from these lessons, to make pragmatic recommendations aimed at protecting both the public health and farmers' livelihoods. Addressing these lessons in a significant fashion is becoming ever more necessary, as it is likely that wastewater use will increase in many less-developed countries, due to growing urban and peri-urban populations and their matching demands for produce. The practice also deserves recognition for its potential socio-economic benefits, since some farmers would be unable to earn a living without using wastewater, and for others, its use increases the income they would normally make, lifting them out of poverty. However, unregulated wastewater use also raises serious concerns about the health of both consumers and farmers, creating the competing need to balance health impacts against livelihood needs. This chapter elucidates lessons learned, and makes four recommendations to policy-makers and practitioners: 1. to develop and apply appropriate guidelines for wastewater use, 2. to treat wastewater and control pollution at source, 3. to apply a range of non-treatment management options, and 4. to conduct research to both improve understanding of the practice, and to identify opportunities and constraints to the adoption of these recommendations.

Introduction

This book set out to describe the reality of wastewater use in agriculture in developing countries, and to make pragmatic recommendations aimed at protecting both the public health and farmers' incomes. The thematic chapters explored a number of issues that are necessary to understand the different dimensions of the problem, including a suggested classification of the different types of wastewater use, the need to take a livelihood-based approach focused on farmers, the need for public health guidelines, and an analysis of the cost-effectiveness of treatment required to meet guidelines. The case studies demonstrated the wide range of wastewater use practices around the world, and illustrated the futility of prescribing a single, rigid management approach. They also revealed

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common obstacles to improving the practice, and from these it has been possible to identify key issues that must be addressed in order to maximise the potential benefits, while minimising the potential costs that wastewater use offers.

This concluding chapter now summarises these lessons learned, makes recommendations, and points to future research needs, that could contribute to safe and sustainable wastewater use under the diverse conditions that we have seen.

Extent

The first lesson forms the fundamental basis from which we must proceed, and it is that the general lack of knowledge of the importance of wastewater use impedes its inclusion as a priority issue to be considered in policy-making. Case studies from this volume illustrate this aspect and it is estimated that up to one-tenth of the world's population eats food produced using wastewater (Lunven, 1992). As popula-

Lessons Learned

The complex challenges of managing wastewater require a pragmatic, proactive and forward-looking perspective. The lessons learned from past experience with wastewater use and management suggest that:

- Comprehensive realisation of the importance of wastewater use in agriculture is still on the peripheral edges of public awareness, and is not always clear to many policy-makers and donors;
- There is insufficient understanding of the social and economic factors that drive farmers to use wastewater, and thus inadequate consideration of these in policy formulation;
- The protection of public health and the alleviation of poverty are not mutually exclusive outcomes when it comes to wastewater use, however, one may have to be given greater emphasis than the other in different contexts;
- Effective measures do exist to protect health and environmental quality, particularly when these are included in integrated, multi-barrier approaches to wastewater management;
- Rigid wastewater use guidelines tend to become targets rather than norms;
- Effective, lower-cost, decentralised treatment systems exist; conventional, northern treatment technologies tend to be unsustainable, in part because of high capital and recurring costs;
- Many forms of wastewater use are practised in various contexts for different reasons, and individual socioeconomic contexts contribute to varying levels of acceptability of wastewater use;
- Increasing year-round demand for fresh fruits and vegetables in developed countries, and increasing tourism in a globalised world, make wastewater use an issue for more than just developing countries;
- Sound legal and regulatory frameworks require sustained application and enforcement;
- Insecure land tenure mitigates against farmer investment in safer and more efficient wastewater irrigation technologies;
- The informal nature of wastewater irrigation tends to leave it in institutional no-man's land; and
- A lack of coordination among institutions within and outside of government, and the tendency towards isolated, uni-disciplinary research on wastewater, has inhibited the testing and design of integrated, workable solutions.

A successful approach to wastewater management that incorporates these lessons may be incremental if necessary, i.e. building and sustaining individual components, but above all it must be sustained institutionally over the long term. The following sections provide more details on the lessons learned.

tions continue to grow and more freshwater is diverted to cities for domestic use – 70% of which later returns as wastewater – the use of wastewater is certain to increase, both in terms of the areas irrigated, and in the volumes applied. For instance, as outlined by Huibers *et al.* (Chapter 12, this volume), the amount of wastewater used in and around Cochabamba, Bolivia, is expected to double over the next twenty years.

However, the quality of the wastewater used and the nature of its use can vary enormously, both between and within countries. In many low-income countries in Africa, Asia, and Latin America, the wastewater tends to be used untreated, while in middle-income countries such as Tunisia and Jordan, treated wastewater is used. These disparities render direct case comparisons difficult, and even estimating the extent of the practice within countries is problematic – global figures even more so. Here, van der Hoek's suggested classifications, in Chapter 2 of this volume, of the different types of wastewater use – direct, indirect, treated, untreated, planned, and unplanned – will be very useful in comparing different cases, and in developing more meaningful and accurate estimates.

Scenarios of Use

Local socioeconomic conditions and culture are also factors that influence the choice of crops that farmers irrigate, and this has further divergent health impacts. For instance, most vegetables irrigated with wastewater in Pakistan are eaten cooked, whereas in Dakar (Faruqui *et al.*, Chapter 10, this volume), most are normally eaten raw. Additionally, the rationale for using wastewater varies enormously in different contexts. In Tunisia or Jordan, many farmers would be unable to earn a livelihood without using wastewater – they have no other choice. In other cases, for example, in Vietnam (Raschid-Sally *et al.*, Chapter 7, this volume), two different scenarios can occur – in some cases, farmers may inadvertently use wastewater even when they do have an adequate supply of water, because of unplanned discharges into natural water courses and canals, while in others, wastewater may be deliberately pumped into irrigation canals by authorities, when there is inadequate water at the tail-end of irrigation schemes.

Livelihoods and Profitability

In contrast, in situations such as Dakar and Pakistan, farmers prefer wastewater even when freshwater is available, because they earn higher profits using wastewater. As both cases demonstrate, wastewater can be a more reliable source, both in terms of availability and volume, than either rain or freshwater supply from irrigation systems. In these cases, it also allows them to crop more than once a year, sometimes up to 3 crops per year, depending on the crop. In Pakistan (Ensink *et al.*, Chapter 8, this volume), farmers using wastewater earned approximately US$300 per year more than those using freshwater. Furthermore, in addition to generating income for farmers, wastewater use in urban and peri-urban agriculture also provides jobs and income for merchants who sell the produce. In Ghana, it is estimated that using only 10% of the wastewater in urban and peri-urban agriculture (UPA) could generate employment for up to 25,000 farmers, worth US$18 million per year (Sam Agodzo, personal communication).

Given that farmers can earn higher profits by using wastewater, it is becoming increasingly evident that they are also willing to pay for it. In Pakistan, the rent for land with access to wastewater can be two to six times more expensive than for land without such access. For example, in Quetta, which depends on a fossil aquifer projected to run out within 20 years (OCHA IRIN, 2002), the average rent for land with access to wastewater is US$940/ha, compared to US$170/ha for land irrigated with freshwater (Ensink *et al.*, Chapter 8, this volume). In Jordan, the Aqaba wastewater plant is a viable enterprise. Reclaimed water is sold at prices that cover the operation and maintenance costs of delivery, and farmers growing date palms using effluent from the plant continue to renew their contracts (McCornick *et al.*, Chapter 14, this volume).

Environmental Impacts and Health Risks

However, the current practice of wastewater use threatens public health and the environment, and possibly limits its long-term sustainability. The major threat to farmers and their families is from intestinal parasites – most often worms. In Pakistan, farmers using raw wastewater are five times more likely than those using canal water to be infected by hookworms. Living in the small intestine, hookworms cause heavy blood losses, and anaemia and retardation in children (Ensink *et al.*, Chapter 8, this volume). In Dakar, 60% of the farmers using raw wastewater were infected with either amoebae, which cause amoebic dysentery, roundworms, which cause ascariasis, whipworm, or threadworms. The farmers who used a combination of wastewater and groundwater had a lower infection rate of 40%. (Faruqui *et al.*, Chapter 10, this volume). Another health threat is bacterial and viral infections, both minor and serious, which can occur after the consumption of raw vegetables contaminated with faecal matter – the cause of the 1970 cholera epidemic in Jerusalem (Fattal *et al.*, Chapter 5, this volume) and typhoid epidemics in Santiago (1983) (Fattal *et al.*, Chapter 5, this volume), and Dakar (1987) (Faruqui *et al.*, Chapter 10, this volume), were all isolated to urban and peri-urban agriculture (UPA). As Buechler points out in Chapter 3, this volume, health risks also vary according to gender, class, and ethnicity. For instance, women often perform the tasks requiring the most extensive contact with wastewater, such as transplanting and weeding in flooded areas like paddy fields, in both Latin America and South Asia. Furthermore, the children of farmers or farm workers, who have not yet built up immunity, tend to be most at risk to gastrointestinal problems.

In terms of environmental impact, wastewater use over a long period of time can result in heavy metal accumulation, especially with industrial wastewater sources. Irrigation with industrial wastewater has been associated with a 36% increase in enlarged livers and 100% increases in both cancer and congenital malformation rates in China, compared to control areas where industrial water was not used for irrigation (Yuan, 1993, cited in Carr *et al.*, Chapter 4, this volume). In Japan, chronic cadmium poisoning as a result of wastewater use has caused Itai-itai disease, a bone and kidney disorder (WHO, 1992). Ironically, in some of the cases, including Haroonabad, Pakistan, and Dakar, Senegal, groundwater contamination from microbial pathogens or nitrates is not a concern, because the groundwater is already too polluted or saline to serve as a drinking water supply.

Finally, the long-term use of wastewater can become self-limiting due to soil damage. Although the organic matter in wastewater can help improve soil texture and water-holding capacity, wastewater also has harmful effects, particularly in arid environments, by causing soil salinisation, blocking soil interstices with oil and grease, and accumulating heavy metals. So far, in most of the cases presented, the environmental impacts have been minor or undetectable. However, in Pakistan, over-applied wastewater with insufficient drainage (also the case with freshwater irrigation) has resulted in signs of degrading soil structure, visible soil salinity, and the delayed emergence of wheat and sorghum due to an excess of applied nutrients. Although such concrete impacts on soil are generally not yet measurable, these effects are likely to occur, given continued application and greater wasteloads. In some places such as Dakar, where groundwater is highly saline, if it were used for irrigation instead of wastewater, the impacts on soil could arguably be worse.

Change in Attitudes and Its Implications

Notwithstanding these impacts, attitudes towards wastewater use are changing among researchers and policy makers. First, there is a growing recognition that its use can also generate some positive health impacts. Food security is enhanced for both producers and consumers, as the increased agricultural output generates higher incomes for farmers, and provides more affordable fresh fruits and vegetables to the poor. In both cases, this increased food security can combat malnutrition, a leading factor in half of the deaths of children in developing countries (WHO, 2000), and also a cause of stunted physical and cognitive growth (Berkman *et al.*, 2002, cited in Carr *et al.*, Chapter 4, this volume). Increased incomes are associated with better health, even when wastewater irrigation leads to more disease risks. Carr *et al.* reference a study in which a village with a rice irrigation scheme had more malaria vectors than a nearby village in Tanzania, but a lower level of malaria transmission – because the first village had more resources to buy food, children were better nourished, and the villagers could afford mosquito nets (Ijumba, 1997, cited in Carr *et al.*, Chapter 4, this volume).

Second, even those updating the World Health Organization (WHO) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture* (WHO, 1989) acknowledge that at times the current guidelines may be too strict. In the analysis presented by this volume's theme papers, Fattal *et al.*, conclude in Chapter 5 that the current WHO wastewater effluent guidelines provide a safety factor one to two orders of magnitude greater than that called for by the United States-Environmental Protection Agency (USEPA) for microbial standards for drinking water. The paper by Richard Carr of the WHO (Carr *et al.*, Chapter 4, this volume) makes clear that managing health risks should be a holistic exercise, accounting for risks from all water-related microbial exposures. Future WHO guidelines will be based on the Stockholm Framework (Carr *et al.*) which suggests that countries adapt the guidelines to their own social, economic, and environmental circumstances. This framework requires that the risk of gastrointestinal illness be considered *within the context of all possible exposures*, including water supply, sanitation and contaminated food, which facilitates decision-making that addresses the greatest risks first. As an example, Fattal *et al.*, provide estimates that show for a city of one million using untreated wastewater, that treating the wastewater to the current WHO unrestricted guidelines would cost US$125 per incidence of disease prevented. From a health perspective, the question here is whether some other measure applied to improving water supplies, or towards health education, could be equally or more effective at preventing disease, at a lower cost.

An example in this volume given by Carr *et al.* (Chapter 4) helps demonstrate the point that full wastewater treatment is not necessarily the most cost-effective way of protecting public health: consider a river basin in which the background level of acute gastrointestinal illness is 0.8 episodes per person per year – the typical rate amongst adults worldwide. In this case, using wastewater treated to the current WHO guidelines (10^3 faecal coliforms (FC)/100 ml) in urban farming would, at maximum, increase the incidence rate to 0.8001 episodes per person annual. Such a small difference is undetectable, and contributes virtually nothing to the background level of diarrhoea. In other words, there is no additional increase in risk associated with using wastewater treated to the current WHO standard. In contrast, the use of untreated wastewater, which contains about 10^8 FC/100 ml, could increase the incidence of diarrhoea by up to 76%, i.e. to about 1.4 episodes/person/year. Almost doubling the risk level by using untreated wastewater may be inappropriate, but with limited funds, it may simply be too expensive to pursue a policy of zero incremental risk by treating to the current WHO guidelines. In such cases, it may be pragmatic to accept a level of risk that is lower than one from using untreated wastewater, but that is slightly higher than the typical background level of illness. For example, one could follow instead the suggested future WHO restricted irrigation guideline of treating the wastewater to the level of 10^5 FC/100 ml, which necessitates a lower level of treatment than the current ones. The money saved by not adopting full treatment could then be more effectively spent on other measures to reduce gastrointestinal illness, such as improving drinking water quality. An extreme example from the southern Punjab in Pakistan illustrates this point: in this basin, where the only source of drinking water is from irrigation canals with *Escherichia coli*/100 ml, levels that far exceed the WHO drinking water standard (Carr *et al.* Chapter 4, this volume), it would be inappropriate to expect that the wastewater be treated to a higher quality than the water that people are drinking.

In an ideal world, policy decisions would be made based on scientific analysis showing the actual risk levels, as described above. However, public perception of risk must also be considered. While serious chronic gastrointestinal illnesses such as amoebic dysentery, roundworm, and hookworm, are endemic throughout the developing world, large-scale epidemics and serious illnesses such as cholera and typhoid have been less common. Past cholera epidemics isolated to raw wastewater use, such as the ones that occurred in 1970 in Jerusalem, 1984 in Dakar, and 1983 in Santiago, have faded from public memory. Yet, global public awareness of health impacts will have a greater reach today than in 1984, due to the advances in information and communication technologies made in the last 20 years. In effect, an epidemic would quickly generate worldwide publicity through the Internet, and magnify local knowledge of the issue. The public reaction to the 2003 SARS epidemic greatly exceeded the actual risk level, and generated devastating impacts on the economies of affected cities, including Hong Kong, Hanoi, and Toronto. For this reason, although Saudi Arabia's ban on vegetable imports from Jordan (see McCornick *et al.*, Chapter 14, this volume) may be dubious from the viewpoint of scientific risk assessment, it is understandable from a political viewpoint, in terms of the impact that negative public perception could have. Furthermore, awareness of the risks associated with consuming contaminated produce is growing within industrialised countries. For instance, 23% of the fresh fruits and vegetables consumed by Americans are imported, and this figure is growing. A recent *New York Times* article (Burros, 2003) stated that contaminated green onions imported from Mexico were linked to recent outbreaks of hepatitis A, which killed three people and sickened hundreds. The same article made reference to recent outbreaks of food-borne illness traced to Guatemalan raspberries, and to salmonella that was traced to Mexican cantaloupes (Burros, 2003). Even if actual risk levels are low, media attention and public reaction could spell trouble for developing countries, whose food exports may be irrigated with wastewater.

Even farmers in countries that do not export vegetables could suffer devastating impacts, if another crisis generated enough publicity so that the public, including tourists, refused to consume vegetables that may or may not have been irrigated with wastewater. Several agencies including the Ghana Tourist Board, have expressed concerns about the hygienic cultivation of vegetables in Ghana, and launched a campaign for safer vegetable production (Sonou, 2001). Thus, another tradeoff that must be addressed is the public perception of risk versus the actual risk.

It becomes clear that in seeking realistic solutions, policy-makers must account for both untreated and treated wastewater use, and make policy choices that protect farmers' livelihoods and the public health. Bharmoriya's Chapter 11, this volume neatly illustrates the conundrum: About 100 villages downstream of Vadodara practise untreated wastewater use, as they have few other options to support their livelihoods. This generates about US$5.5 million annually, but the practice threatens their own health, and that of the roughly 1.5

Table 16.1. Timeframe for meaningfully implementing recommendations in the least developed countries (LDCs).

Recommendation	Timeframe for meaningful implementation
Develop and apply guidelines	Medium to long term
Treat wastewater and control at source	Medium to long term
Apply other management options	
• Increase farmer and public awareness	Short to medium term
• Minimise human exposure	Short to medium term
• Treat infections	Short to medium term
• Use safer irrigation methods	Short to medium term
• Restrict crops	Short to medium term
• Improve institutional coordination	Medium to long term
• Increase security of land tenure	Medium to long term
• Increase funding	Short, medium and long term
Conduct research	Short, medium and long term

million residents in and around the city. The following section suggests recommendations to tackle such difficult cases as this one.

Recommendations

The following recommendations, summarised in Table 16.1, are organised into four categories: develop and apply guidelines, treat wastewater and control at source, apply other management options, and conduct research. Note that Table 16.1 also outlines when each recommendation can be meaningfully implemented in the least-developed countries.

Depending upon the context and stakeholder views, it is suggested that policy-makers take a holistic and integrated approach, and act immediately on those recommendations requiring little or no further study. For instance, in Tunisia, where risk of exposure from drinking water sources and contaminated food is low, appropriate guidelines are already in place, and Shetty *et al.* (Chapter 15, this volume) outline that the focus there ought to be on continuing improvement of institutional coordination, increasing farmer education, and safer, more sustainable irrigation methods. Similarly, in Jordan, a major focus should be on improving institutional coordination, and on collecting and treating wastewater with improved source control – part of which is occurring through the expansion of the As-Samra wastewater treatment plant. In contrast, poorer countries in Latin America, Asia and Africa, such as Bolivia, Pakistan, and Senegal, will need more time to develop the guidelines for collecting and treating wastewater, with appropriate source controls. Therefore, to minimise the risks to public and farmer health, it is essential to increase awareness amongst affected groups, and with this added knowledge, to begin minimising human exposure, to treat infections, and to use safer irrigation methods.

In other words, countries can and should begin work on all recommendations concurrently, but it is acknowledged that in the least-developed countries, it will take time to develop and implement both guidelines and affordable treatment. However, many of the management options can be acted on immediately, with visible benefits to the most marginalised groups. In the poorer countries in particular, it is essential to practice what is in effect a multi-barrier approach, because it is unlikely that one measure alone will protect both farmer and public health. More details on each recommendation are discussed below.

Develop and apply holistic and appropriate health guidelines

It is essential for countries to develop guidelines that are adapted to their individual social, economic and environmental context. This means following the Stockholm Framework and the impending revised WHO guidelines, which recommend assessing the risks associated with wastewater use in agriculture within the context of the actual disease rates of the population from all sources, including water supply, sanitation, and contaminated food. Mexico is a case in point, where the WHO guidelines were adapted to reflect local conditions. As risk factors may vary from river basin to river basin within a country, so may the guidelines. Taking a holistic and flexible approach also means that the guidelines will change over time. As the relative risk factors change – for instance, when water supply and sanitation improve – the guidelines for wastewater should become accordingly more stringent. For greatest impact, the guidelines should be implemented with other health measures, such as health education, hygiene promotion, and the provision of adequate drinking water and sanitation. Positive health impacts arising from wastewater use, such as the resulting improved nutrition due to greater household income and food security, should also be duly considered.

Treat wastewater and control at source

Focusing as much as it is economically feasible at the start of the wastewater use chain will reduce downstream problems. This entails domestic treatment, but whether this requires higher levels of treatment for unrestricted use, or lower levels for restricted use, depends principally on whether vegetables are eaten raw or not. In most cases, treatment will necessitate collecting and treating wastewater in decentralised plants that focus less on environmental pollutants, such as suspended solids and biochemical oxygen demand (BOD), and more on pathogens. The paper by Silva-Ochoa and Scott, Chapter 13, this volume, demonstrated that treatment plants are still being built without consideration of the benefits of use in UPA. Waste stabilisation ponds and chemically enhanced primary treatment with sand filters are two examples of methods that have proven efficient in protecting public health, while being less costly than traditional mechanical, secondary treatment plants. The oft-repeated refrain that treatment is too expensive is questionable – if the Stockholm Framework is properly applied, then in many countries the required standards will actually result in falling costs for the necessary treatment. Furthermore, as shown, farmers are increasingly prepared to pay for wastewater, so financing can be some mix of polluters and users pay principles. It is estimated that levying pollution taxes for only 10% of generated wastewater in Ghana, could bring in up to US$38 million annually (Agodzo, personal communication).

While treatment to meet appropriate guidelines may not yet be feasible in all cases, it should still be one of the desired end results. This however, does not preclude phasing in better treatment over time and progressively providing increased risk reduction, with the goal of eventually arriving at the ultimate target of full treatment. In Pakistan, where most irrigated vegetables are eaten cooked and the main health impact is hookworm in farmers, encouraging the use of footwear by farmers and gloves by crop handlers is more important at this stage than full treatment. Partial treatment would likely bring risk levels down to acceptable levels, and could be as simple as irrigation storage reservoirs, as outlined by Carr *et al.*, which have been proven to reduce risks to farmers and their families in Mexico to minimal levels. In this case, following a hypothetical strategy suggested by Carr *et al.*, Chapter 4, this volume, initial standards could be set at 10^5 FC/100 ml and 50 nematode eggs/l. This standard could be attained using irrigation storage reservoirs with sufficient retention time to allow the pathogens to die off. As resources become available to build additional treatment facilities, and as risks of disease from the water supply or contaminated foods fall, the standards could be tightened to 10^4 FC/100 ml and 10 nematode eggs/l, which could be met with natural primary treatment and storage reservoirs. Eventually, the standard could reach the current recommendation of 10^3 FC/100 ml and 1 nematode egg/l, which can be met by a waste stabilisation pond that provides secondary treatment, with sufficient retention time, disinfector, or polishing slow-sand filters. Inherent in this recommendation is the need to work with industries, institutions, and municipalities, in order to control industrial and toxic contaminants, such as heavy metals, at source. As Silva-Ochoa and Scott note in Chapter 13, it is also important to ensure that treatment does not shift sole access to the resource from poorer farmers, who currently depend on untreated wastewater, to more powerful farmers, or private organisations such as golf courses.

Apply other management options

Increase farmer and public knowledge and awareness

Education programmes for all stakeholders, including farmers, the public, and policy-makers, are essential complements to other risk-reduction tools. The findings in this volume can help stakeholders confront realities, and can form the basis for awareness-raising strategies, including discerning the extent of wastewater use, the extent to which farmers' livelihoods depend upon the practice, and both the positive and negative health impacts within the overall health context of the population. This should be followed by the application of mitigation strategies in line with the WHO guidelines, especially those under the control of the individual stakeholders, such as the wearing of shoes by farmers, and the adequate cooking of produce by consumers. In order to ensure that awareness strategies are relevant and sustainable, both secular tools such as schools and media campaigns, along with culturally appropriate non-secular tools, need to be used for such strategies to be comprehensive and broad-based. A comprehensive public awareness programme would likely also bring actual and perceived risk levels closer in line, lessening the chance that unnecessarily strict guidelines would be adopted, which could drain a country's limited financial resources without resulting in greatly improved public health.

Minimise human exposure

The WHO has outlined preventive measures for groups potentially at risk from the use of wastewater in agriculture, including farmers and their families, crop handlers, consumers, and those living near the fields. The first two groups are especially susceptible to helminthic infections, so for protection, health authorities can encourage the use of shoes and gloves. Field workers need to be provided with potable water for drinking and hygiene. Similarly, produce vendors should use safe water for washing and rinsing produce – it is ineffectual to protect the crops in the fields if they are contaminated in the market. Finally, consumers should wash and cook vegetables and meats thoroughly, and maintain good hygiene practices. Consumers aware or suspecting that produce is contaminated should soak it in a disinfectant such as sodium hypochlorite or potassium permanganate. Of course these measures in themselves carry risks if the concentration of the disinfectant is excessive, so as always, it is essential for public health departments to underpin all of these measures with comprehensive health and hygiene education campaigns aimed at all stakeholders.

Treat infections

Infection with helminths is the most important health risk associated with wastewater use. In cases where even partial treatment is not possible, and where time is needed to implement other management options, effective health protection may be provided by regular mass treatment of exposed people with anthelmintic drugs. This is especially so if the communities of wastewater farmers are localised, and rather homogeneous. Of course the repeated treatment with safe, single-dose, affordable anthelmintic drugs is a short-term approach, but one that can provide immediate health benefits

Use safer irrigation methods

Irrigation methods can affect both the degree of plant contamination, and the types of precautions farmers can take. In Dakar, the principal method of irrigating with watering cans intensifies the risk of contamination, because droplets touch the plant leaves, while in Pakistan, over-irrigation in furrows without adequate drainage creates an ideal environment for hookworm infection. Localised irrigation techniques such as drip or trickle irrigation are the safest, because the wastewater is applied directly to the root zone of the plants. As an added benefit, this also reduces water consumption. Such techniques require treatment to reduce suspended solids that clog the openings, or the use of drip irrigators with fairly large holes. The treatment can be simple and inexpensive – storage reservoirs that allow suspended solids to settle out may be sufficient. Although drip irrigation is generally the most expensive to implement, some farmers in middle-income countries like Jordan (Faruqui and Al Jayyousi, 2002) are already using this method, and even some in lower-income countries such as Cape Verde and India (FAO, 2001) are doing so as well. Furthermore, low-cost drip irrigation systems such as the 'drum and bucket' that International Development Enterprises (IDE) has tested in Kenya and Zimbabwe have proven successful. Such schemes can be affordable if donors step forward with micro-credit projects to fund this small-scale infrastructure.

The timing of wastewater use can also reduce health impacts. Tunisian standards follow the WHO guideline recommendation that wastewater irrigation be stopped two weeks before harvest. However, this may not always be feasible for farmers without an alternate source of irrigation, as crops will literally wither in the field, particularly during hot and dry times of the year. In such cases, the waiting time period would have to be shortened.

Restrict crops

Crop restrictions can be used where water of sufficient quality is not available for unrestricted irrigation. While crop restrictions can protect consumers, they do not protect farmers and their families, so this measure cannot be applied on its own. Crops restrictions have proven most feasible (for example in Mexico, Peru, and Chile) (Blumenthal *et al.*, 2000), in situations when an irrigation project is centrally managed, strong law enforcement exists, and most importantly, when the crops allowed under the restrictions are profitable. For instance in Haroonabad and Faisalabad, Pakistan, farmers are happy to produce vegetables that are usually eaten cooked, because high demand makes these crops most profitable. In this case, crop restrictions are unnecessary, because there is no strong incentive to produce vegetables eaten raw. In cases when restrictions alone are impractical, such measures must be combined with a methodical public awareness and farmer education programme. In this way, if regulation fails, increased public awareness and market forces may succeed, as there may be reduced consumer demand to purchase vegetables eaten raw that are irrigated with wastewater.

Integrate guidelines and improve institutional coordination

The cases illustrate that health, agricultural, and environmental guidelines often overlap, and sometimes even conflict. Furthermore, there is a lack of collaboration between non-governmental organisations, for example, farmer groups, and those at different levels of government, from municipalities to national departments, including such entities as the Ministries of Agriculture, Health, and Urban Planning. It is essential that all stakeholders be brought together to find mutually satisfactory solutions – based on public input and the Stockholm Framework – policy-makers can then develop integrated health, agricultural and environmental quality guidelines, and implement them in partnership with communities. Although there are still some problems with Tunisia's organisational setup, as outlined by Shetty *et al.* (Chapter 15, this volume) the country has merged the Ministries of Agriculture, Environment, and Water Resources in a new super ministry that now manages water (including wastewater) in a more integrated manner.

Increase security of land tenure

To seriously confront the reality of wastewater use, and to have any lasting positive impact on the health of farmers, the issue of land reform needs to be included as an essential component of any integrated policy. At present, both farmers using wastewater and those using freshwater are already practicing UPA on thousands of hectares of undeveloped public land in and around cities. Often the issue is not the availability of the land, but rather the lack of an authoritative guarantee for its use for a specific period of time, without the threat of sudden expulsion. In exchange for this added security, farmers may even be willing to pay to lease the land, if they are not already doing so. It is unlikely that insecurity of tenure is preventing farmers from taking steps to minimise their exposure, such as buying shoes, gloves or medicine. However, secure tenure is more likely to increase the propensity of farmers to invest in land and irrigation improvements, and some such as localised irrigation systems – whether simple drum and bucket systems, or hoses, pumps, and drip irrigators – have additional protective health benefits. Land reform would also facilitate the building of storage reservoirs, a simple method of treatment that carries the additional benefit of helping balance irrigation water supply with demand. In many cases, these would have to be built on farmers' land, and neither the state nor farmers are likely to build decentralised treatment or storage facilities on land of uncertain status.

Increase donor/state funding

Ideally, polluters (both industry and households), governments, farmers, and consumers, would all pay a share of the costs needed for safe and sustainable UPA that protects the environment and public health, and that enhances food security and nutrition. Polluters and governments alike should pay for the cost of treatment. Farmers should pay for access to the irrigation water, and for drip irrigators that protect their own and consumer health, recouping some of these costs from the consumers who pay for their produce. Farmers can also be reasonably expected to contribute to a portion of the cost for decentralised treatment, if it is close to or on their land.

Cost sharing may be a realistic medium-term scenario, but only if all stakeholders are convinced of the benefits stemming from policy measures such as wastewater treatment, or the implementation of safer irrigation systems. Farmers may be more willing to contribute if the benefits of such measures are first demonstrated to them. Governments may also be more willing to contribute to the cost of implementing the above recommendations after realising the economic and employment impacts arising from food markets, and the improved nutrition associated with UPA that uses wastewater. However, this requires investment before the fact, to bring services up to a standard to which all stakeholders are willing to contribute. During this transition period, it is crucial for foreign aid donors to step in to provide the initial funds, in order to prove to both farmers and policy-makers that the benefits of UPA can be realised without excessive health risks. Without additional funding, many of the recommended options cannot be meaningfully implemented.

Conduct research

Due to the informal and quasi-illegal nature of wastewater irrigation, and the cost and time required to do methodical research, many findings to date only probe the surface. More profound and methodical research will be necessary if the issues related to the realities of wastewater use are to be brought onto the global agenda. Chapter 8 by Ensink *et al.*, is a good model of comprehensive scientific, research on wastewater use in a particular case, while Buechler's Chapter 3 outlines useful suggestions to ensure that research is centred on the livelihoods of farmers, the principal actors in this play, while also capturing all social, economic, and political aspects. In fact, research needs to be participatory, and account for farmers' concerns, perceptions, and practices, if the research results are to be implemented in a sustainable fashion. Some key research gaps that must be addressed before the above recommendations can be meaningfully implemented include:

- testing the feasibility and cost-effectiveness of non-treatment management options;
- designing efficient, cost-effective, and sustainable natural wastewater treatment systems that conserve nutrients while effectively removing pathogens;
- identifying incentives for industrial effluent separation and treatment;
- developing appropriate standards and guidelines to protect public health in different contexts;
- finding the best institutional policies, frameworks, and implementation mechanisms to help municipal and national institutions work together to support urban farmers and protect public health; and
- investigating the political economy of wastewater use in UPA, including analysis of inequitable access to irrigation sources and land.

In addition, in order to attract increased donor and state funding, information on the following topic is required.

Value-addition of wastewater use

Better economic estimates of the value of UPA that uses wastewater will emphasise its importance for poverty alleviation to donors and policy-makers. Researchers have only been able to present vague economic estimates on the benefits and costs of UPA, and most donors and policy-makers are completely unaware of the degree of urban farming and its importance to the national economy. For instance, in Pakistan, 26% of the vegetables produced are grown using wastewater (Ensink *et al.*, Chapter 8, this volume). Decision-makers need hard estimates of the total area cropped, the annual production of different types of crops produced, and their monetary values. This could then be compared to the total amount produced in rural agriculture. Once its economic significance is realised, both donors and policy-makers are likely to pay more attention.

One important missing area of research is a comprehensive guide to the economic impact of wastewater use that goes beyond the employment and nutritional benefits discussed above. Some attempts have been made to develop frameworks for such an analysis (Hussain *et al.*, 2001) but there is little information on the economic externalities associated with discharging wastewater into water bodies and wetland systems that have downstream beneficial uses. Little work has been made on savings in treatment costs associated with land application of wastewater, or income-generating opportunities derived from agricultural use. The results of such analysis could potentially impact the way in which wastewater agriculture is viewed. Research on household greywater reuse in Jordan has demonstrated that the benefit-cost ratio of reuse for agriculture is as high as 5 (Faruqui and Al Jayyousi, 2002). Also needed is a similar examination of semi-collective treatment systems, on which policy recommendations can be based. Ensink *et al.* (2004) provided an innovative way of estimating the value of land accessible to farmers, by identifying the higher rents for land having access to wastewater for irrigation, as compared to land that is irrigated with freshwater. However, more work is needed on this aspect of wastewater use.

Conclusions

The deepening integration of today's food markets makes the use of wastewater in agriculture a vital issue for all countries to address, and this recognition must start with the acknowledgement that the practice is already widespread, and contributes much more to farmers' livelihoods and to food security than is commonly understood. In some cases, farmers would be unable to earn a living without using wastewater, and for others, its use increases the income they would normally make, lifting them out of poverty. However the practice often threatens the health of the farmers, their families, the broader public, and the environment. Policy-makers must find a way to protect both farmers' incomes as well as public health, in a way that is economically sustainable. This volume was inspired by a workshop in Hyderabad, India, in November 2002, at which researchers, and policy-makers brainstormed potential options, and offered some suggestions, encapsulated in the *Hyderabad Declaration on Wastewater Use in Agriculture* (Appendix 1, this volume).

These realisations have changed the views of policy-makers, even among those involved in setting the initial 1989 WHO guidelines. The newly emerging ones recommend that guideline setting be a holistic risk-analysing exercise, adapted to each country's social, economic, and environmental circumstances. This would entail taking into account background levels of gastrointestinal illness, and allocating scarce health protection dollars to the highest priority. An integrated set of measures, that collectively form a multi-barrier approach to protect health is also suggested, including progressively phased-in treatment, and other management options. These encompass raising public awareness, using safer irrigation methods, minimising human exposure, restricting crops, disinfecting of produce by consumers, institutional coordination, increasing land tenure, and increasing funding. Finally, in order to achieve meaningful implementation, and to secure the necessary funding from donors, further research must be done to evaluate the feasibility and cost-effectiveness of the above suggestions, and to establish better estimates of the economic value of wastewater use in urban and peri-urban agriculture.

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Appendix 1

The *Hyderabad Declaration on Wastewater Use in Agriculture*

14 November 2002

1. Rapid urbanisation places immense pressure on the world's fragile and dwindling fresh water resources and over-burdened sanitation systems, leading to environmental degradation. We as water, health, environment, agriculture, and aquaculture researchers and practitioners from 27 institutions and representing experiences in wastewater management from 18 countries recognise that:
   1.1 Wastewater (raw, diluted or treated) is a resource of increasing global importance, particularly in urban and peri-urban agriculture
   1.2 With proper management, wastewater use contributes significantly to sustaining livelihoods, food security and the quality of the environment
   1.3 Without proper management, wastewater use poses serious risks to human health and the environment.

2. We declare that in order to enhance the positive outcomes while minimising the risks of wastewater use, there exist feasible and sound measures that need to be applied. These measures include:
   2.1 Cost-effective and appropriate treatment suitable for wastewater, supported by guidelines and their application
   2.2 Where wastewater is insufficiently treated, until treatment becomes feasible:
      - Development and application of guidelines for untreated wastewater use to safeguard livelihoods, public health and the environment
      - Application of appropriate irrigation, agricultural, post-harvest, education and public health practices that limit risks to farming communities, vendors, and consumers.
   2.3 Health, agriculture and environmental quality guidelines that are linked and implemented in a step-wise approach
   2.4 Reduction at source of toxic contaminants in wastewater.

3. We also declare that:
   3.1 Knowledge needs should be addressed through research to support the measures outlined above
   3.2 Institutional coordination and integration together with increased financial allocations are required.
4. Therefore, we strongly urge policy-makers and authorities in the fields of water, agriculture, aquaculture, health, environment and urban planning, as well as donors and the private sector to:

   Safeguard and strengthen livelihoods and food security, mitigate health and environmental risks and conserve water resources by confronting the realities of wastewater use in agriculture through the adoption of appropriate policies and the commitment of financial resources for policy implementation.

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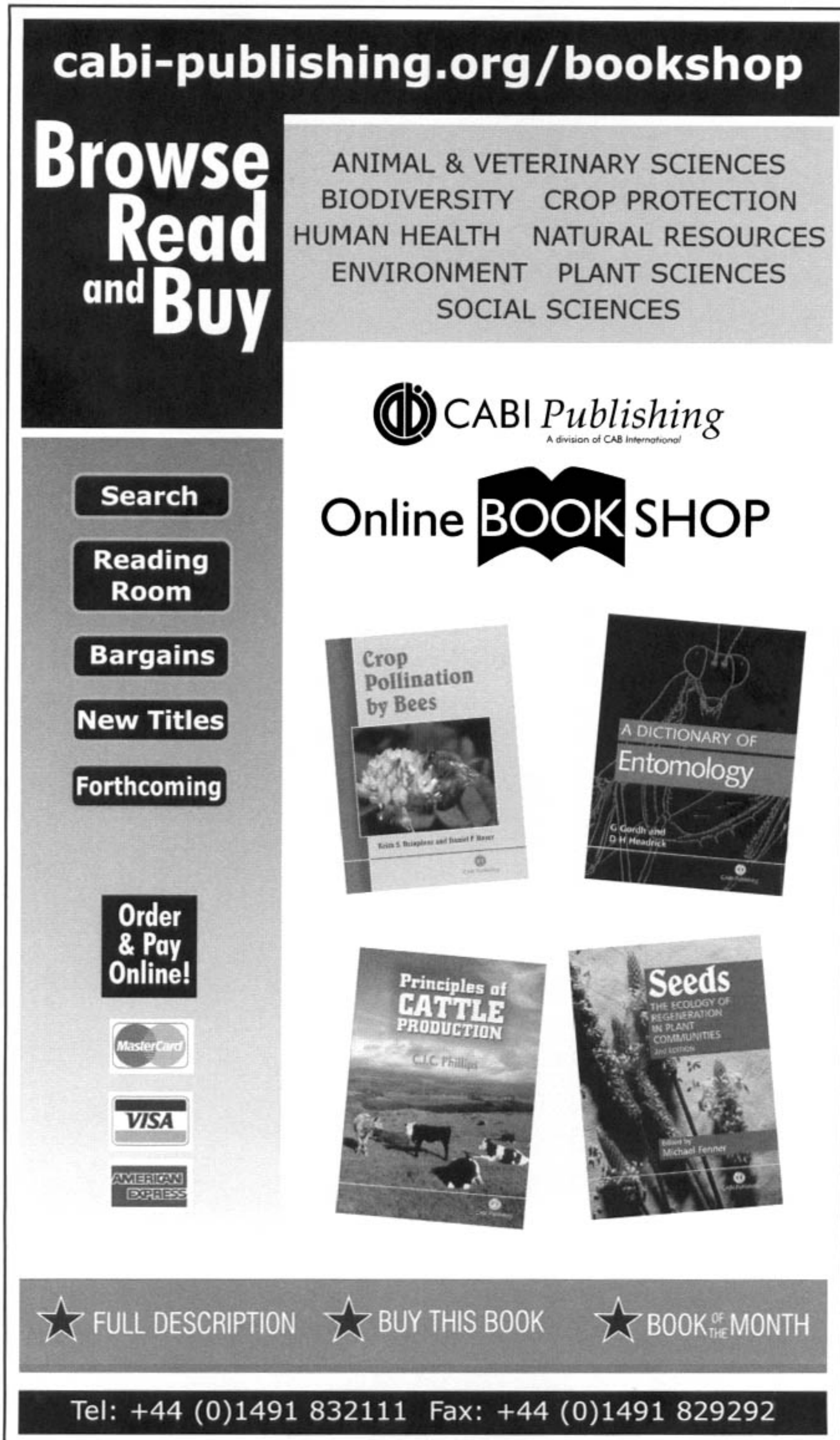
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WHO GUIDELINES FOR THE

SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

VOLUME I

POLICY AND REGULATORY ASPECTS

World Health Organization

UNEP

United Nations Environment Programme

GUIDELINES FOR THE SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

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CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

AIDS	acquired immunodeficiency syndrome
BOD_5	five-day biochemical oxygen demand
2,4-D	2,4-dichlorophenoxyacetic acid
DALY	disability adjusted life year
DDT	dichlorodiphenyltrichloroethane
HIV	human immunodeficiency virus
IWRM	integrated water resources management
MDG	Millennium Development Goal
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
P_{inf}	probability of infection
QMRA	quantitative microbial risk assessment
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
UN	United Nations
UNICEF	United Nations Children's Fund
UV	ultraviolet
WHO	World Health Organization
WTO	World Trade Organization

PREFACE

The United Nations General Assembly (2000) adopted the Millennium Development Goals (MDGs) on 8 September 2000. The MDGs that are most directly related to the safe use of wastewater, excreta and greywater in agriculture and aquaculture are “Goal 1: Eliminate extreme poverty and hunger” and “Goal 7: Ensure environmental sustainability.” The use of wastewater, excreta and greywater in agriculture and aquaculture can help communities to grow more food and make use of precious water and nutrient resources. However, it should be done safely to maximize public health gains and environmental benefits.

In 1973, the World Health Organization (WHO) produced the publication *Reuse of effluents: Methods of wastewater treatment and public health safeguards*. This normative document provided guidance on how to protect public health and how to facilitate the rational use of wastewater and excreta in agriculture and aquaculture. Technically oriented, the publication did not address policy issues per se.

A thorough review of epidemiological studies and other new information led to the publication of a second edition of this normative document in 1989: *Health guidelines for the use of wastewater in agriculture and aquaculture*. The guidelines have been very influential with respect to technical standard setting and also at the policy level, and many countries have adopted or adapted them for their wastewater and excreta use practices.

The present third edition of the Guidelines has been updated based on new health evidence, expanded to better reach key target audiences and reoriented to reflect contemporary thinking on risk management.

The use of wastewater, excreta and greywater in agriculture and aquaculture is increasingly considered a method combining water and nutrient recycling, increased household food security and improved nutrition for poor households. Recent interest in wastewater, excreta and greywater use in agriculture and aquaculture has been driven by water scarcity, lack of availability of nutrients and concerns about health and environmental effects. It was necessary to update the Guidelines to take into account scientific evidence concerning pathogens, chemicals and other factors, including changes in population characteristics, changes in sanitation practices, better methods for evaluating risk, social/equity issues and sociocultural practices. There was a particular need to conduct a review of both risk assessment and epidemiological data.

In order to better package the Guidelines for appropriate audiences, the third edition of the *Guidelines for the safe use of wastewater, excreta and greywater* is presented in four separate volumes: *Volume 1: Policy and regulatory aspects*; *Volume 2: Wastewater use in agriculture*; *Volume 3: Wastewater and excreta use in aquaculture*; and *Volume 4: Excreta and greywater use in agriculture.*

WHO water-related guidelines are based on scientific consensus and best available evidence; they are developed through broad participation. The *Guidelines for the safe use of wastewater, excreta and greywater* are designed to protect the health of farmers (and their families), local communities and product consumers. They are meant to be adapted to take into consideration national sociocultural, economic and environmental factors. Where the Guidelines relate to technical issues — for example, excreta and greywater treatment — technologies that are readily available and achievable (both from a technical viewpoint and in terms of affordability) are explicitly noted, but others are not excluded. Overly strict standards may not be sustainable and, paradoxically, may lead to reduced health protection, because they may be viewed as unachievable under local circumstances and, thus, ignored. By proposing procedures that are adaptable to specific circumstances, the Guidelines strive to maximize overall public health benefits and the beneficial use of scarce resources.

This edition of the Guidelines supersedes previous editions (1973 and 1989). The Guidelines are recognized as representing the position of the United Nations system on issues of wastewater, excreta and greywater use and health by UN-Water, the coordinating body of the 24 United Nations agencies and programmes concerned with water issues. This edition of the Guidelines further develops concepts, approaches and information in previous editions and includes additional information on:

- the context of the overall waterborne disease burden in a population and how the use of wastewater, excreta and greywater in agriculture and aquaculture may contribute to that burden;
- the Stockholm Framework for the development of water-related guidelines and the setting of health-based targets;
- risk analysis;
- risk management strategies, including quantification of different health protection measures;
- guideline implementation strategies.

The revised Guidelines will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health and water and waste management, including environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The use of wastewater, excreta and greywater in agriculture and aquaculture has policy relevance in relation to poverty reduction, the protection of public health and the environment, food security and energy reliance. In countries where the scale of current reuse practices is substantial or where a considerable reuse potential exists, there is a need to create a distinct policy framework for wastewater, excreta and greywater use. In other countries, the issue interfaces with a number of key policy areas, and its governance therefore calls for the harmonization of relevant policies on this subject and for its mainstreaming within the most crucial ones.

This volume of the Guidelines focuses on policy, regulation and institutional arrangements. Accordingly, its intended readership is made up of policy-makers and those with regulatory responsibilities. It provides guidance on policy formulation, harmonization and mainstreaming, on regulatory mechanisms and on establishing institutional links between the various interested sectors and parties. It also presents a synthesis of the key issues from Volumes 2, 3 and 4 in the executive summaries in the second part of this volume. It contains the index for all four volumes of the Guidelines, and a glossary of terms used in all four volumes is presented in Annex 1.

The information in this volume is meant to give policy-makers and regulators an overview of the risks and benefits associated with the use of wastewater, excreta and greywater in agriculture and aquaculture without going into technical detail. It also presents an overview of the nature and scope of options for protecting public health. This information should be useful in the development of national policies for the safe use of wastewater, excreta and greywater. Detailed technical information on health risk assessment, health protection measures and monitoring and evaluation is presented in Volumes 2, 3 and 4.

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1
POLICY ASPECTS

The ultimate aim of these Guidelines is to protect and promote public health. Adequate capacity is required at the national level to maximize the benefits of the use of wastewater, excreta and greywater in agriculture and aquaculture, to minimize the health risks involved and to promote proper environmental management, ensuring long-term sustainability. An essential element of this national capacity consists of an enabling policy environment. This chapter summarizes the information needed to formulate decision-making criteria, establish decision-making procedures and create effective institutional arrangements for their implementation.

1.1 Policies as a basis for governance

Good governance requires consistency in decision-making towards agreed objectives. Policies make up the framework to set national development priorities and provide decision-making criteria to guide the development process towards achieving them. Policies may lead to the creation of legislation. Legislation establishes the responsibilities and rights of different stakeholders — and, supported by the institutional arrangements created between agencies, this determines which agency has the lead responsibility for creating regulations and who has the authority to implement and enforce the regulations. Translating policy into strategy requires the allocation of human and financial resources in accordance with the policy objectives and the capacities of the stakeholders.

In developing a national policy framework to facilitate the safe use of wastewater, excreta and greywater in agriculture and aquaculture, it is important to define the objectives of the policies, assess the current policy environment, formulate new policies or adjust existing ones, and develop a national strategy.

The use of wastewater, excreta and greywater can have one or more of several objectives. Defining these objectives is the first step in developing a national policy framework. Assessing the existing or potential magnitude of wastewater, excreta and greywater use, in both absolute and relative terms for the different types of use, provides a key to the type of policy formulation or adjustment that may be needed.

Environmental protection is a policy goal in most countries, from the viewpoints of both conservation of natural resources and ecosystem services and public health protection. A sectoral view of wastewater, excreta and greywater in this context would consider them to be costly by-products of the process of urbanization, requiring substantial investments in treatment plants and disposal mechanisms. Yet such a view overlooks their value as a source of water and/or nutrients for plant production and fish cultivation.

For the governments of many developing countries, attaining and maintaining food security for the entire population are the key policy goals. To achieve these goals, some countries provide incentives for the increased use of available natural resources (including water resources) towards local food production; others may provide subsidies to farmers to maintain a critical human resource base for local agricultural production. Where national resources for food production are under pressure and essential foods have to be imported from abroad, governments often provide subsidies to ensure that the poor can meet their basic needs in terms of nutrition. In this context, the use of wastewater, excreta and greywater is of particular relevance. In situations of water stress, wastewater must be considered a valuable water resource and an important positive trade-off in the process of rapid urbanization. Where essential food items have to be imported, waste use to enhance local agricultural production will result in important import substitutes.

In light of the above, it is crucially important to map out the existing policy landscape and upgrade the map periodically, as a basis for judging whether the options and opportunities of wastewater, excreta and greywater use are being considered in their full potential and whether safe use practices are being promoted to maximum cost-effectiveness.

Policy appraisal should take place from two perspectives: that of the policy-maker, who will want to ensure that the national policies and associated legislation, institutional framework and regulations meet the wastewater, excreta and greywater use objectives (e.g. maximize economic returns without endangering public health or the environment); and that of the project manager, who will want to ensure that current and future waste use activities can comply, realistically, with all relevant national and local laws and regulations.

Depending on local conditions, policies for the use of wastewater, excreta and greywater may be emphasized within the food security or within the environmental protection policy framework. Whatever the case may be, for their *safe* use, effective links will have to be established with the national public health policy framework.

The main policy issues to investigate are:

- *Public health*: To what extent is waste management addressed in national public health policies? What are the specific health hazards and risks associated with the use of wastewater, excreta and/or greywater in agriculture and aquaculture? Is there a national health impact assessment policy? Is there a policy basis for non-treatment interventions in line with the concepts and procedures contained in the Stockholm Framework?
- *Environmental protection*: To what extent and how is the management of wastewater, excreta and greywater addressed in the existing environmental protection policy framework? What are the current status, trends and expected outlook with respect to the production of wastewater, excreta and greywater? What is the capacity to management wastewater, excreta and greywater? What are the current and potential environmental impacts? What are the options for reuse in agriculture or aquaculture?
- *Food security*: What are the objectives and criteria laid down in the national policies for food security? Is water a limiting factor in ensuring national food security in the short/medium/long term? Are there real opportunities for the use of wastewater, excreta and greywater in agriculture and aquaculture to (partially) address this problem? Is reuse currently practiced in the agricultural production system? Has an analysis of the benefits and risks of such waste use been carried out?

Policy-makers should use the updated evidence concerning health impacts associated with the use of wastewater, excreta and greywater in agriculture and aquaculture presented in these Guidelines to develop rational and cost-effective policies for protecting public health and maximizing the beneficial use of natural resources.

1.2 The international policy framework

With the adoption of the Millennium Declaration, signed by 147 heads of state, the 189 nations in attendance at the special session of the United Nations (UN) General Assembly in September 2000 established a comprehensive global framework to support concerted efforts towards poverty reduction and sustainable development. The Declaration led to the formulation of eight Millennium Development Goals (MDGs) to be achieved by 2015 that respond to the world's main development challenges.

The eight MDGs break down into 18 quantifiable targets that are measured by 48 indicators:

- Goal 1: Eradicate extreme poverty and hunger
- Goal 2: Achieve universal primary education
- Goal 3: Promote gender equality and empower women
- Goal 4: Reduce child mortality
- Goal 5: Improve maternal health
- Goal 6: Combat HIV/AIDS, malaria and other diseases
- Goal 7: Ensure environmental sustainability
- Goal 8: Develop a global partnership for development

The Millennium Declaration has been signed by heads of state, and it is the commitment at this level that determines its significance. For the first time, all public sectors are committed to contributing towards achieving the same goals. This is particularly important for the sectors responsible for the development, management and use of water resources. Fragmentation at the policy and operational levels has become a major bottleneck in dealing with water resources, as good-quality fresh water is becoming increasingly scarce. At the Johannesburg World Summit on Sustainable Development in 2003, integrated water resources management (IWRM) was included in the international policy framework, and a first goal was set for countries to establish national IWRM policy goals by 2005. For regions in the world where water scarcity levels are highest, the use of wastewater, excreta and greywater is an important component of IWRM. In developing national IWRM policies, it will have to be given serious consideration.

In brief, the MDGs:

- synthesize, in a single package, many of the most important commitments made separately at the international conferences and summits of the 1990s, including those for the safe use of wastewater, excreta and greywater in agriculture and aquaculture dating back to the 1992 UN Conference on Environment and Development in Rio de Janeiro;
- recognize explicitly the interdependence between growth, poverty reduction and sustainable development;
- acknowledge that development rests on the foundations of democratic governance, the rule of law, respect for human rights and peace and security;
- are based on time-bound and measurable targets accompanied by indicators for monitoring progress;
- bring together, in the eighth Goal, the responsibilities of developing countries with those of developed countries, founded on a global partnership endorsed at the International Conference on Financing for Development in Monterrey, Mexico, in 2002, and again at the Johannesburg World Summit on Sustainable Development in August 2003.

The links between the MDGs and the safe use of wastewater, excreta and greywater in agriculture and aquaculture are explored in Table 1.1.

1.3 Policy issues

In the policy formulation and adjustment process, several issues associated with the use of wastewater, excreta and greywater in agriculture and aquaculture deserve a closer look. They are listed below and will be discussed in the following subsections:

Table 1.1 The relationship between MDGs and wastewater, excreta and greywater use in agriculture and aquaculture

Millennium Development Goals and their targets	Relationship to wastewater, excreta and greywater use
Goal 1. Eradicate extreme poverty and hunger Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than US$ 1 a day Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger	• Wastewater, excreta and greywater make up an important resource for intensive agricultural production by the urban and rural poor and thereby strengthen their livelihood opportunities. • Agricultural produce cultivated through the use of wastwater, excreta and greywater adds importantly to the food security of poor rural and urban communities. • Reduced downstream ecosystem degradation resulting from the use of wastewater, excreta and greywater makes livelihood systems of the poor more secure.
Goal 2. Achieve universal primary education Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling	• No direct link to universal school attendance, but experiences in India demonstrate the value of the safe use of greywater to maintain a more hygienic school setting, an important factor in parents' collaboration to ensure that their children attend school. Reduction in diarrhoeal and parasitic diseases will result in increased school attendance.
Goal 3. Promote gender equality and empower women Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005, and to all levels of education no later than 2015	• The productivity of market gardens and other small-scale peridomestic agriculture is boosted by the use of wastewater, excreta and greywater, and in many parts of the world this particularly favours the economic position of women.
Goal 4. Reduce child mortality Target 5: Reduce by two thirds, between 1990 and 2015, the under-five mortality rate	• The combination of improved sanitation and the safe use of wastewater, excreta and greywater helps reduce the burden of sanitation and hygiene-associated ill-health. • Improved nutrition and food security reduce susceptibility to diseases in children.
Goal 5. Improve maternal health Target 6: Reduce by three fourths, between 1990 and 2015, the maternal mortality rate	• Improved health and nutrition associated with waste-fed agriculture and aquaculture reduce susceptibility to anaemia and other conditions that affect maternal mortality. • Improved nutrition and food security reduce susceptibility to diseases that can complicate pregnancy.
Goal 6. Combat HIV/AIDS, malaria and other diseases Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases	• Safe use of wastewater, excreta and greywater and basic sanitation help prevent water-related diseases, including diarrhoeal diseases, schistosomiasis, filariasis, trachoma,[a] intestinal worm infections and foodborne trematode infections. • Improved health and nutrition reduce susceptibility to/severity of HIV/AIDS and other major diseases. • Increased awareness and knowledge of better water management practices will support community-based environmental management approaches towards malaria transmission risk reduction.

Table 1.1 (continued)

Millennium Development Goals and their targets	Relationship to wastewater, excreta and greywater use
Goal 7. Ensure environmental sustainability Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources Target 10: Halve, by 2015, the proportion of people without sustainable access to safe drinking-water and basic sanitation Target 11: Achieve significant improvement in lives of at least 100 million slum dwellers by 2020	• The safe use of wastewater, excreta and greywater contributes to less pressure on freshwater resources and reduces health risks for downstream communities. • Improved sanitation in support of safe excreta use reduces flows of human waste into waterways, helping to protect human and environmental health. • Improved water management, including pollution control and water conservation, is a key factor in maintaining ecosystem integrity. • Waste-fed periurban agriculture can contribute importantly to improving the livelihood of slum settlers.
Goal 8. Develop a global partnership for development Target 12: Developing open trading and financial systems Targets 13 and 14: Addressing special needs of less developed countries, landlocked and small island developing countries Target 15: Managing debt relief and increasing official development assistance Target 16: Creating productive youth employment Target 17: Providing affordable medicine Target 18: Spreading benefits of new technologies, especially information and communications	• Development agendas and partnerships should recognize the fundamental role that safe use of wastewater, excreta and greywater in agriculture and aquaculture and basic sanitation play in economic and social development. • Options for self-employment are enhanced if the opportunities for the safe use of waste in agricultural production are stimulated. • Compliance with the methods and procedures in the WHO Guidelines facilitates international trade in waste-fed agricultural produce.

[a] Schistosomiasis is a chronic, usually tropical, disease characterized by disorders of the liver, lungs, urinary system or central nervous system. Filariasis is a disease caused by thread-like worms, which are transmitted by mosquitoes and invade the lymphatic vessels, causing chronic swelling of the lower extremities. Trachoma is a contagious infection of the cornea and conjunctiva caused by a bacterium and causing granulation and scar formation.

- Implementation of the WHO Guidelines will help to maximize the health and environmental benefits of using wastewater, excreta and greywater in agriculture and aquaculture.
- The use of wastewater, excreta and greywater in agriculture and aquaculture, both formally and informally, is widespread.
- Reuse can contribute to nutrient and water recycling and improved household nutrition and food security.
- There are international policy implications of waste-fed agriculture, in the context of international trade of safe food products.
- The practice can be associated with negative health impacts.
- Cost-effective interventions for different situations are available to control negative health impacts.
- National consumer protection legislation will have an international impact on the policies for the safe use of wastewater, excreta and greywater.

1.3.1 Implementation of WHO Guidelines to protect public health

The objective of these Guidelines is to maximize the health and environmental benefits associated with the use of wastewater, excreta and greywater in agriculture and aquaculture. This can be accomplished by preventing the transmission of disease and the exposure to hazardous chemicals. Health protection measures target large population groups, and, in local settings, they may be particularly focused on specific vulnerable groups. The Guidelines should be considered in the context of national environmental, social, economic and cultural conditions.

The approach followed in these Guidelines (see Box 1.1) is intended to support the establishment of national standards and regulations that can be readily implemented and enforced and are protective of public health. Each country should review its needs and capacities in developing a regulatory framework. Successful implementation of the Guidelines will benefit from a broad-based policy framework of incentives and sanctions to alter behaviour and monitor and improve situations. Intersectoral coordination and cooperation at national and local levels and the development of suitable skills and expertise will facilitate the Guidelines' implementation. Ultimately, the regulatory framework should adopt the format of a safe reuse of wastewater plan, in line with the concept of water safety plans in other areas of water quality management and health protection and promotion.

In many situations, it will not be possible to fully implement the Guidelines at one time or in the first stage. The Guidelines set target values designed in such a way as to allow progressive implementation and, therefore, to be achieved over time in a systematic, orderly and incremental way, depending on current realities and the existing resources of each individual country or region. The greatest threats to health should be prioritized and addressed first. Measures that are most cost-effective at an early stage may be substituted by others that become more cost-effective as the process of risk assessment and management proceeds. Over time, it should be possible to adjust the risk management framework to strive for the progressive improvement of public health conditions. In most countries, standards for regulating wastewater, excreta and greywater use have evolved over time into an infrastructure of management strategies. Simultaneously, new technologies have been developed. This is an important consideration when developing national policies for the safe use of wastewater, excreta and greywater in agriculture and aquaculture. They need to be flexible and responsive to new situations and developments.

1.3.2 Wastewater, excreta and greywater use

More than 10% of the world's population consumes foods produced by irrigation with wastewater. The percentage will be considerably higher among populations in low-income countries with arid and semi-arid climates. Both treated and untreated wastewater are used directly and indirectly (i.e. as faecally contaminated surface water) for irrigation in developed and less developed countries. In places where untreated wastewater or highly contaminated surface water is used for irrigation, health and environmental problems of the same nature and magnitude as those associated with direct wastewater use in agriculture may arise. Overall, population growth will be the main driving force for a further demand on water resources. There is a growing recognition that the production of wastewater will increase as an outcome of continued urbanization and that wastewater needs to be better incorporated into the overall management of water resources.

The traditional use of excreta in agriculture and aquaculture has occurred for centuries and continues in many countries. In urban and periurban agriculture in less industrialized countries, the use of untreated faecal sludges (i.e. from the contents of on-site sanitation

> **Box 1.1. What are the Guidelines?**
>
> The WHO Guidelines are an integrated preventive management framework for maximizing the public health benefits of wastewater, excreta and greywater use in agriculture and aquaculture. The Guidelines are built around a health component and an implementation component. Health protection is dependent on both elements.
>
> **Health component:**
> - establishes a risk level associated with each identified health hazard;
> - defines a level of health protection that is expressed as a health-based target for each risk;
> - identifies health protection measures that, used collectively, can achieve the specified health-based target.
>
> **Implementation component:**
> - establishes monitoring and system assessment procedures;
> - defines institutional and oversight responsibilities;
> - requires system documentation;
> - requires confirmation by independent surveillance.

systems such as unsewered family and public toilets and septic tanks) is widespread. The vast majority of urban dwellers in these countries is served today and will be served in the future by such installations; hence, adequately treating these sludges by appropriate methods to attain safe biosolids or compost constitutes a crucial goal for improving public health. On-site sanitation systems not requiring off-site haulage and treatment, such as double-pit latrines with or without urine diversion (which are being promoted in rural and periurban settings in recent years), may also contribute to safeguarding public health. Systems that divert wastes into streams (e.g. urine and faeces) often require less water to operate and are increasingly being seen as alternatives to waterborne sewerage — especially in arid/semi-arid regions. These systems should be managed in such a way as to reduce the potential for disease transmission and maximize the beneficial use of resources.

Waste-fed aquaculture occurs mostly in parts of Asia. The intentional use of wastewater and excreta in aquaculture is declining due to urbanization, which reduces the amount of land available for ponds, and the switch to high-input aquaculture, which is not compatible with traditional waste-fed practices. The unintentional use of wastewater, excreta and greywater in aquaculture is probably increasing, because surface waters used for aquaculture are increasingly polluted with human waste, and overall aquacultural production is growing.

These trends may vary locally. Policy formulation, harmonization and adjustment call for a sound analysis of relevant trends in the local context and of the locally viable options for risk management solutions. This information should be the basis to develop decision-making criteria and procedures around the use of wastewater, excreta and greywater in agriculture and aquaculture. Adequate investment in trend analysis is a critical starting point to obtain optimal harmonization and avoid perverse policies.

1.3.3 Benefits of wastewater, excreta and greywater use

Wastewater, excreta and greywater are increasingly used for agriculture and aquaculture in both developing and industrialized countries. The principal forces driving this increased use are:

- increasing water scarcity and stress;
- expanding populations, with increasing environmental pollution from improper wastewater disposal;
- recognition of the resource value of wastewater, excreta and greywater.

It is estimated that within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity (Hinrichsen, Robey & Upadhyay, 1998). Growing competition between agriculture and urban areas for high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this resource. More fresh water is abstracted and used in agriculture in arid and semi-arid countries than for any other purpose (i.e. for domestic uses and industrial uses combined). In many cases, it is better to use wastewater, excreta and greywater in agriculture than to use higher-quality fresh water, because crops benefit from the nutrients they contain. Thus, wastewater, excreta and greywater can help to meet water demand and allow the preservation of high-quality water resources for drinking-water supplies.

Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources. The use of wastewater, excreta and greywater in agriculture and aquaculture can act as a low-cost treatment method that increases food production to supply growing urban and periurban populations. More use of wastewater, excreta and greywater will occur in urban and periurban agriculture, because this is where the wastewater is generated and available and where the demand for food is highest.

Wastewater, excreta and greywater are often reliable year-round sources of water, and they contain the nutrients necessary for plant and fish growth. Irrigation with wastewater can, in most situations, supply all the nutrients required for crop growth. The value of these substances has long been recognized by farmers worldwide. Their direct use in agriculture and aquaculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on water resources and soil, as well as potential health impacts on downstream communities. The water and nutrient resources help people to grow more food without the costs of using more fertilizers. The reliability of the water supply means that crops can be grown year-round in warm climates. It also represents an important asset in situations where climate change will lead to significant changes in patterns of precipitation. The use of wastewater, excreta and greywater will be an important component of a package of coping strategies in areas affected by such change.

Policies to promote the beneficial application of wastewater, excreta and greywater should first of all operate at the national level. The policy framework should link environmental and health protection policies with food security and consumer protection policies to attain maximum health benefits in terms of improved nutrition while reducing health risks related to infectious diseases. Bilateral and multilateral development agencies, too, should formulate and implement policies aimed at promoting the safe use of wastewater, excreta and greywater in agriculture and aquaculture, as an integral part of their goals in the conservation and management of natural resources and the reduction of poverty.

1.3.4 International policy implications: international trade

The rules that govern international trade in food were agreed during the Uruguay Round of Multilateral Trade Negotiations and apply to all members of the World Trade Organization (WTO). With regard to food safety, rules are set out in the Agreement on the Application of Sanitary and Phytosanitary Measures. According to this agreement, WTO members have the right to take legitimate measures to protect the life and health of their populations from hazards in food, provided that the measures are not unjustifiably restrictive of trade (WHO, 1999). There have been documented cases where the import of contaminated vegetables has led to disease outbreaks in recipient countries. Pathogens can be (re)introduced into communities that have no natural immunity to them, resulting in important disease outbreaks (Frost et al., 1995; Kapperud et al., 1995). Guidelines for the international trade of wastewater-irrigated food products should be based on scientifically sound risk assessment and management principles.

The WHO Guidelines for the safe use of wastewater, excreta and greywater in agriculture and aquaculture are based on a risk analysis approach, which is recognized internationally as the fundamental methodology underlying the development of food safety standards that both provide adequate health protection and facilitate trade in food. Adherence to the WHO Guidelines in the application of wastewater, excreta and greywater for the production of food products destined for export will help to ensure an unencumbered international trade of safe food products. Clearly, this requires a sound monitoring process to ensure compliance with the risk management measures and appropriate quality control along the way from wastewater generation to produce consumption. The procedures for this monitoring process should be embedded into national policies and regulations for water quality that also apply to drinking-water quality, safe recreational waters and the concept of water safety plans in general.

1.3.5 Health implications of wastewater, excreta and greywater use

The health risks most studied in the context of the use of wastewater, excreta and greywater are those associated with excreta-related infectious diseases. The evidence base is less extensive for the transmission of vector-borne diseases and schistosomiasis through reuse activities. The health risks for each category (i.e. agriculture, aquaculture and general excreta and greywater use) are described in the subsections below.

The planning and development of projects for the use of wastewater, excreta and greywater in agriculture and aquaculture should include a health impact assessment or an environmental impact assessment with a sound health component. National environmental/health impact assessment policies should explicitly refer to this type of project and the associated risks in the screening criteria they list. Scoping of such projects for impact assessment should include the identification of vulnerable groups. Three different community groups are at risk from wastewater, excreta and greywater use activities in agriculture and aquaculture:

- farm or pond workers (and their families, if they all participate in the activities or live at the site where the activities take place);
- local communities in close proximity to activities, and people who otherwise may have contact with fields, ponds, wastewater, excreta, greywater or products contaminated by them;
- product consumers.

Agriculture

In countries or regions where poor sanitation and hygiene conditions prevail and untreated wastewater and excreta are widely used in agriculture, intestinal worms pose the most frequently encountered health risks. Other excreta-related pathogens may also pose health risks, as indicated by high rates of diarrhoea, other infectious diseases, such as typhoid and cholera, and incidence rates of infections with parasitic protozoa and viruses.

In countries where higher sanitation and hygiene standards prevail, infrastructure for waste treatment is available and treatment processes are well managed, viral illnesses pose greater health risks than other pathogens. This is partly because viruses are often difficult to remove through wastewater treatment processes due to their small size, but also because of the resistance of some viruses in the environment and their infectivity at low concentrations. Additionally, people living in conditions where higher sanitation and hygiene standards prevail often have no prior exposure to viral pathogens and therefore have no acquired immunity and are more vulnerable to viral infection and illness.

Aquaculture

Studies of health risks associated with waste-fed aquaculture have rarely been conducted. There is limited evidence that links exposure to waste-fed aquaculture or its produce to illness in product consumers and local communities in intense contact with contaminated pond waters. Skin diseases such as contact dermatitis (eczema) may also occur in farmers with high contact with faecally contaminated ponds while harvesting aquatic plants.

In general, fish and plants raised in contaminated waters may passively transmit pathogens on their surfaces to product handlers or consumers. The fact that fish concentrate bacteria and other microbes (including viruses and protozoa) in their intestines is, however, of greater public health importance. The greatest risk to consumers is likely to result from cross-contamination from the gut contents to the edible fish flesh during unhygienic fish processing. Unhygienic fish processing can increase the levels of microbial contamination by 100-fold or more in edible portions of the fish.

In certain regions of the world, foodborne trematodes may pose a significant health risk in relation to waste-fed aquaculture. In areas where such infections as clonorchiasis, opisthorchiasis, fascioliasis and fasciolopsiasis are common and where fish or plants are frequently eaten raw, incidence rates can be attributed to this practice. In vulnerable groups such as children, foodborne trematodes can cause severe illness and, occasionally, death. A number of animals may serve as reservoirs, and their presence will help to sustain their presence and transmission in affected areas. A recent systematic literature review indicates that foodborne trematode infections are on the rise in areas where freshwater aquaculture is also increasing (Keiser & Utzinger, 2005).

Excreta and greywater use

The risks associated with the use of excreta (including source-separated urine and faeces) stem mostly from excreta-related pathogens. Urine usually does not contain high concentrations of pathogens but may have some as a result of faecal cross-contamination during collection. Eggs of the parasitic blood fluke *Schistosoma haematobium* are an exception to this rule.

The use of faecal matter from on-site sanitation installations such as septic tanks and the pits of unsewered family and public toilets can pose significant health risks if it has not been adequately treated. The primary health hazard arises from the presence of worm eggs in areas where intestinal worms are common. The eggs of these parasites can survive for months or even years in the faecal matter and in the soil.

The health risks associated with the use of greywater in agriculture are considered to be lower than those for wastewater or faeces. Greywater generally has lower concentrations of pathogens in it than wastewater, but it may still contain some pathogens, which are introduced into the greywater from washing babies' diapers, laundry, personal hygiene or other sources.

1.3.6 Cost-effective strategies for controlling negative health impacts

The management of risk is facilitated by conducting an analysis of the entire production cycle from waste generation to consumption of the product. Knowledge of the system is then used to identify health protection measures that can reduce health risks at different points, in order to arrive at the agreed health-based targets.

Public health policies for interventions should ensure that the most cost-effective measures are applied in specific contexts. Measures from a range of categories may be applied at different points during the cycle, and they are normally used in combination to reach the desired goals:

- Treatment of wastewater, excreta and greywater is used to prevent the contaminants from entering the environment.
- Crop/produce restriction (i.e. only crops that are not eaten directly by people or that are always processed or cooked before they are eaten) is used to minimize health risks to product consumers.
- Waste application techniques (e.g. drip irrigation) and withholding periods aim to reduce contamination of the products or allow sufficient time for pathogen die-off in the environment prior to harvest.
- Exposure control methods (e.g. protective equipment, good hygiene) will prevent environmental contamination from reaching exposed groups.
- Produce washing/rinsing/disinfection and cooking reduce exposures for product consumers.
- Vector control reduces exposures for workers and local communities.
- Chemotherapy and immunization can either prevent illness for those who are exposed or treat those who are ill and thus reduce future pathogen inputs into the wastewater, excreta or greywater.

Determining the cost-effectiveness of different measures under local conditions requires an economic analysis, for which it is recommended to engage a health economist.

1.4 Policy formulation and adjustment: the step-by-step process

The development and maintenance of a national policy framework for the safe use of wastewater, excreta and greywater are part of a step-by-step, iterative process that should address the formulation and mainstreaming of new policies and the adjustment and harmonization of existing ones. At the heart of this process lies a productive policy dialogue among all interested parties. The steps of this process include:

- establishment of a mechanism for ongoing policy dialogue;
- defining objectives;
- situation analysis, policy appraisal and needs assessment;
- political endorsement, dialogue engagement and product legitimazation;
- research.

1.4.1 Establishment of a policy dialogue mechanism

Identification of stakeholders and interested parties will help define the best mechanism to initiate and maintain a productive and comprehensive policy dialogue. In some countries, this group will consist mainly of policy-makers of relevant ministries, and the establishment of an interministerial task force to engage in the dialogue will be sufficient action to ensure a rapid evolution of the policy framework required. In countries with a high degree of decentralization, mechanisms will have to be established for an effective feedback loop as part of the dialogue that ensures a meaningful involvement of policy- and decision-makers at the provincial and local administrative levels. There may be countries where decentralization has evolved to a level where policy-making is initiated at the district level, for example through district development councils, and this will require that the policy dialogue on the safe use of wastewater, excreta and greywater for agriculture and aquaculture is similarly initiated at that level, in districts where such use is a reality or has future potential. The engagement of civil society in policy debate helps create a strong platform of support for new policies. It requires additional mechanisms, such as special forums, focus group discussions and community consultation, to ensure that these broader views are reflected in the policy framework.

1.4.2 Defining objectives

Defining clear objectives is essential in developing a national policy framework (Mills & Asano, 1998). Generic policy goals are presented in section 1.1. More specifically, objectives of the use of wastewater, excreta and greywater for agriculture or aquaculture may be:

- increasing national or local economic development;
- increasing crop production;
- augmenting supplies of fresh water and otherwise take full advantage of the resource value of wastewater;
- disposing of wastewater in a cost-effective and environmentally friendly manner;
- improving household income, food security and/or nutrition.

Where wastewater is already used, subsidiary objectives may be the incorporation of health and environmental safeguards into management strategies or the improvement of product yields through better practice.

1.4.3 Situation analysis, policy appraisal and needs assessment

In most countries, a variety of policies will already exist, in a number of different sectors, that will influence decision-making over wastewater, excreta and greywater use in agriculture and aquaculture. As described in section 1.1, the appraisal of existing policies should be carried out with both a policy-maker's and the project coordinator's viewpoint in mind. A first mapping out of all relevant policies without qualifying attributions will provide a landscape of criteria and procedures that influence the subject under scrutiny. Next, an assessment of the potential of these policies to have positive or negative health effects sets the format for a needs assessment, whose outcome will provide recommendations for policy harmonization, policy adjustment and the formulation of additional, new policies that can fill gaps that have been identified.

The outcome of the situation analysis, policy appraisal and needs assessment provides the basis for designing the process along which to proceed. In some cases, the gaps identified may be of dimensions that direct the main focus of the ensuing process to be on the formulation of new policies; in other cases, there already may be a substantial body of policies that influence decision-making on the issue, but the individual policies in the different sectors may be poorly harmonized. Finally, a policy imbalance may be detected, with some sectors addressing health issues adequately in their policy framework, while the policies of others may show small, but significant, gaps.

1.4.4 Political endorsement, dialogue engagement and product legitimization

New policies and adjustment of existing policies will sooner or later have to be adopted by the political system. Political endorsement of the policy process at the earliest stage will contribute to ensuring a smooth acceptance and integration of policy proposals later on. The most obvious way to obtain this endorsement is the organization of a national seminar, where all stakeholders are invited to develop a policy process and anchor it in an action plan. At the end of the seminar the political leadership of all sectors involved is invited to review this plan, comment on it and endorse it. This endorsement will legitimize the participation of all involved in the process and ensure that the end product is in line with political expectations and sentiments.

Establishing a mechanism for policy dialogue is usually less of a challenge than keeping the process going. Review, formulation and negotiation may proceed slowly, particularly if the dialogue takes place in a multisectoral context. A task force should be established with clear terms of reference, and it should be adequately resourced so that periodic meetings can be organized and sub-tasks commissioned. Strong leadership will help expedite progress, but it will need to be sufficiently neutral to ensure the continued engagement of all parties.

The outcome of the policy process is a set of recommendations concerning new policies and the adjustment of existing ones. The report of the task force should be submitted to the authority that established it, with copies to all political leaders of different relevant sectors. After some final review and negotiations, the proposals are likely to be accepted, and the process of formalizing the additions and changes will begin. This process may be different in different countries. In some countries, a simple decree from the Prime Minister's Office will be enough to establish the new policies. Elsewhere, the policy framework may have to pass through parliament successfully before it can become effective. It is sensible to keep the task force members actively involved at this stage, since the need for backup support or further work may suddenly arise. Once the policy has become effective, it is important to disseminate the relevant information to stakeholders at all levels.

1.4.5 Research

All policy development must be evidence based. Research on minimizing health impacts associated with the use of wastewater and excreta in agriculture should, therefore, be conducted at national institutions, universities or other research centres. It is important to conduct this research at the national or subnational level, because contextual data sets on risk assessment and management and on effective health protection measures will be valuable inputs into the policy-making process. Most of this information is very country specific. In countries where the use of wastewater and excreta for agriculture is newly introduced or has not been practised on a large scale, pilot schemes may be set up to collect the essential data sets. In situations where wastewater irrigation is practised in small-scale diffuse facilities, often at the household level, national research may be used to validate health protection measures. A systematic planning of pilot projects should ensure that the full range of non-treatment options is studied, so that policies can focus on the most critical interventions under local circumstances.

Another dimension is that of research policies. The safe use of wastewater, excreta and greywater in agriculture and aquaculture has in common with many other public health issues the multidisciplinary nature of the research that should strengthen the relevant knowledge base. It is therefore essential that national research policies focus on the promotion of multidisciplinary research and on the translation of the outcomes of such research into harmonized sectoral policies. Issues of research policy are usually dealt with by national science and technology councils.

1.5 Institutional arrangements

There are many actors influencing the decision-making process with respect to the use of wastewater, excreta and greywater in agriculture and aquaculture. At the national level, ministries and other public sector agencies with responsibilities for water management, waste management, agriculture and fisheries, public health, the environment, trade and industry and local government all have the potential to influence the planning, design and operations of wastewater, excreta and greywater use activities and to address the adverse consequences they may have. Some of the decision-making may be delegated to lower administrative levels: provincial, municipal or district authorities. Small-scale wastewater, excreta and greywater use projects may be completely informal, initiated by local communities with or without the help of local nongovernmental organizations.

The sectoral structure of governments works well to deal effectively with core societal issues, but the fragmentation is less conducive to the management of cross-cutting issues, of which the safe use of wastewater, excreta and greywater in agriculture and aquaculture is an example. The sectoral barriers are determined by the competition between different ministries for limited financial resources, and they come to expression in the missed conversations between professionals who speak different "languages."

This chapter provides a brief introduction to the concept of intersectoral collaboration, possible mechanisms to promote such collaboration at the national level, integration at the local level and steps towards achieving effective institutional arrangements between sectors.

1.5.1 The concept of intersectoral collaboration

In the health sector, the concept of intersectoral collaboration obtained a high profile as a result of the 1978 Alma Ata Declaration. This joint WHO/UNICEF declaration (http://www.who.int/hpr/NPH/docs/declaration_almaata.pdf) provided the foundation for the Health for All goals, the strategy of primary health care (PHC) to achieve the goals and the eight pillars supporting this strategy, one of which is intersectoral collaboration. It recognizes the reality that the health status of communities results not just from health sector planning and action, but also, more importantly, from decision-making in other sectors. Such decisions have an impact on the environmental and social determinants of health, and, as a result, they have the potential to change the community health status, inadvertently, in a positive or negative way.

Clearly, the use of wastewater, excreta and greywater for agriculture and aquaculture is relevant in this context. Decisions about the use of these resources are made outside of the health sector, and if the intersectoral barriers are not overcome, the negative health impacts will increase the workload for the health services. In other words, the health sector will have to deal with an increased disease burden. Thus, the planning of wastewater projects without due attention to health risks and related health safeguards implies the transfer of hidden costs to the health sector and a costly burden to society at large.

Lessons learned from experiences in intersectoral action for health include the need

- to anchor the overall coordinating role with one ministry;
- to allocate adequate resources to the coordination itself;
- to carry out economic evaluations of intersectoral actions to document their relative cost–benefit;
- to specify allocation of responsibilities and obligations in a formal document of agreement;
- to keep the constituencies of the individual sectors well informed about the benefits gained from working intersectorally;
- to incorporate intersectoral negotiation and decision-making in curricula of tertiary learning institutes.

1.5.2 Mechanisms to promote intersectoral collaboration

A first step towards the creation of intersectoral collaboration is the preparation of an inventory of intersectoral mechanisms that already exist at the national level. In most countries, coordination between the various public sectors is centred on the implementation of national macroeconomic policies. Most developing countries have an economic and social council, with the remit to coordinate development planning in the light of poverty reduction (MDGs, poverty reduction strategy papers) and economic progress; this is a meeting point for all sectors. In countries with a strongly centralized economy, ministries of planning may continue to play a role in orchestrating the national planning process, again involving all other sectors.

The conservation of natural resources is another area of common interest in most countries. While ministries of environment may perform a standard-setting role and have responsibilities to look after the obligations that come from national and international legally binding instruments (legislation, international environmental conventions), most countries have an environmental protection agency that functions, in a more or less autonomous way, as the implementation extension of the environment ministry. Such agencies are, for example, responsible for environmental impact assessment and the ensuing environmental management plans. Similar responsibilities could be developed for the health aspects of the use of wastewater, excreta and greywater.

As already mentioned, the third type of structure where different sectors interact consists of national councils for science and technology. With their focus on research, they provide excellent forums to promote the strengthening of knowledge and evidence bases that support policy and regulation for effective safe use practices. They also offer existing links between the various public sectors and academia, with the opportunity to bring valid research questions to the attention of universities and to translate research outcomes into relevant policy and regulatory frameworks.

Some of the intersectoral coordination required for the safe use of wastewater, excreta and greywater may find a "home" in one or more of the above generic structures. Yet there will remain a need to create specific institutional arrangements between the relevant public sectors — in principle, agriculture, health and environment. A number of options exist:

- *Establishment of an intersectoral committee*: In many countries, this has time and again been the standard approach to tackling problems of an intersectoral nature. Yet it has also been, more often than not, an approach that has produced no or inadequate solutions. Intersectoral committees are generally not well resourced, are not mandated to make binding recommendations, often lack members in a leadership role and may be perceived by most members as one sector's way of special pleading for its own interests. So while the establishment of such a committee may give temporary relief from political pressures, it seldom provides an effective solution to an intersectoral problem.

- *Establishment of a memorandum of understanding*: This is a project-oriented rather than a strategic solution, but in the project context it has proved to be a valuable and effective way to achieve intersectoral action. By spelling out the nature of tasks at hand, defining responsibilities and determining resource flows, a memorandum of understanding provides a clear framework for intersectoral collaboration that can be easily monitored for compliance. It is a mechanism regularly instigated by bilateral or multilateral donors. Because of its time-limited nature, it is a context within which partners from different sectors have an opportunity to get to know each other, develop mutual trust and respect, and lay the foundations for more durable institutional arrangements.
- *Creation of special legislation*: Where the need for long-term interactions between sectors is foreseen, creating special legislation may be well worth the effort, because it entails an unmatched level of control over compliance through the judicial system. Legislation may also include a budget appropriation to cover the incremental costs of intersectoral action, which will ensure an incentive to sustain intersectoral links that overcome fragmentation. The creation of legislation can be time-consuming, and this approach is therefore most suitable to establish generic rather than project-specific institutional arrangements.
- *Targeted capacity building and informal networking*: A more informal approach to achieving intersectoral action is to implement a capacity-building programme for intersectoral negotiation and decision-making. Problem-based learning set in a realistic context (e.g. how to achieve the safe use of wastewater, excreta and greywater in agriculture and aquaculture) will bring professionals from different relevant sectors together to go through a systematic programme of critical decision-making. The bonding process that occurs during the courses may result in informal networking between people working at mid-level management in the different sectors. The creation of an enabling policy environment for intersectoral action is an essential element for the success of this approach.

Descending from the national level to subsidiary levels of administration, competition between sectors diminishes and opportunities for effective collaboration increase. Yet even in a decentralized governance structure, there may be constraints on different sectors collaborating at the community level if resource decisions continue to be anchored at higher levels. Sharing of resources may then be blocked and integrated approaches to development issues hampered.

In the case of safe use of wastewater for agriculture, for example, there is scope for relevant messages on health risk assessment and management to be transmitted to farmer communities through existing agricultural channels: the conventional agricultural extension programmes or the more participatory farmer field schools. This requires, as a start, good communications between health and agricultural authorities to review what messages could be effectively delivered and the way of delivery. Information packages will then need to be composed or, in the case of the farmer field schools, curricula prepared. The rationale of this intersectoral approach is that farmers are more likely to accept messages that will affect their farming practices from trustworthy extension workers than from health workers with little or no credibility in the domain of agriculture. From the extension workers' perspective, this implies that the messages delivered must be reliable and evidence-based, as a major concern would be that their credibility might be undermined by inaccurate or wrong information.

2
REGULATION

This section provides an overview of the technical issues that regulators should consider when developing new or modifying existing regulations for the safe use of wastewater, excreta and greywater in agriculture and aquaculture. The previous chapter provides guidance on how to put in place a policy framework conducive to the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Once such a framework is in place, practical regulatory functions can be defined, and the mechanisms for their implementation designed. All functions have to be designed with broad policy objectives in mind, and they must be realistic in terms of capacity (or available capacity to be developed), capabilities and jurisdiction. This is the scope of the present chapter.

Essential functions in regulation include:

- identification of hazards;
- generating evidence for health risks and the effectiveness of possible health protection measures to manage them;
- establishing health-based targets to manage health risks;
- implementing health protection measures to achieve the health-based targets;
- system assessment and monitoring.

2.1 Identification of hazards

The primary health hazards associated with the use of wastewater, excreta and greywater in agriculture and aquaculture are excreta-related pathogens, some vector-borne diseases and certain chemicals. Health risks describe the probability, under specific circumstances, that these health hazards will indeed be able to influence human health adversely.

Pathogens can survive long enough in the environment (wastewater, water, soil, crops) to be transmitted viably to people. Some pathogens can multiply in the environment. Certain environmental factors contribute, to a greater or lesser measure, to the die-off of pathogens. These factors include time, temperature, moisture, exposure to light and ultraviolet (UV) radiation, presence of appropriate intermediate hosts, type of plant and others. Treatment of wastewater, excreta and greywater can significantly reduce the concentrations of some contaminants (e.g. excreta-derived indicator organisms, pathogens and some chemicals) and thus the risk of disease transmission. In many developing countries, wastewater treatment is not a feasible option, and non-treatment approaches need to be considered to prevent transmission of pathogens or exposure to hazardous chemicals. This is more demanding on regulators, as the measures entailed vary in time and space.

Hazards associated with the use of wastewater, excreta and greywater in agriculture and aquaculture are presented in Table 2.1. The regulatory framework needs to translate the broad policy guidance on hazard identification into system-specific actions that focus on concrete hazards and the effective contextual health protection measures that may be deployed to eliminate or reduce their negative effects.

2.2 Evidence for health risks

Depending on local circumstances, health hazards associated with wastewater, excreta and greywater use may turn into health risks. The probability of this occurring (i.e. the level of risk) has a number of environmental and social determinants and is based on available evidence. Key evidence for health risks associated with this practice in agriculture and aquaculture is summarized below.

Table 2.1 Examples of hazards and exposure routes associated with the use of wastewater, excreta and greywater in agriculture and aquaculture

Hazard	Exposure route	Comments
Excreta-related pathogens		
Bacteria (*Escherichia coli*, *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp.)	Contact Consumption	Bacteria die off more rapidly on crops than some other pathogens (e.g. helminths) but may still present a health risk. Disease outbreaks of cholera, typhoid and dysentery have been associated with the use of wastewater, excreta or greywater for irrigation of vegetables. As these pathogens can survive in the environment sufficiently long to pose health risks, produce disinfection/washing and cooking are important health protection measures.
Helminths		
- Soil-transmitted helminths (*Ascaris*, *Ancylostoma*, *Necator*, *Hymenolepis*, *Strongyloides*, *Toxocara*, *Trichuris*, *Taenia* spp.)	Contact Consumption	Major risk in agriculture, especially where untreated wastewater and excreta are used and sanitation standards are low. Eggs can survive in the environment for a long time. Hookworm infections (*Ancylostoma duodenale*, *Necator americanus*) are common in some areas where farmers do not wear adequate shoes or boots.
- Trematodes (*Clonorchis*, *Opisthorchis*, *Fasciola*, *Schistosoma* spp.)	Contact Consumption	Major risk in aquaculture where trematode parasites are present. Distribution is limited to certain geographic areas. Foodborne trematodes are transmitted through food consumption (especially the consumption of raw, unprocessed fish); schistosomiasis is spread through skin contact with contaminated fresh water.
Protozoa (*Giardia*, *Cyclospora*, *Cryptosporidium*, *Entamoeba* spp.)	Contact Consumption	Have been found on wastewater-irrigated vegetables at the point of harvest and in the market. Protozoa can survive in the environment long enough to pose health risks.

Table 2.1 (continued)

Hazard	Exposure route	Comments
Viruses (hepatitis A and E viruses, adenovirus, rotavirus, norovirus)	Contact Consumption	Viruses are present in high numbers in wastewater and excreta, and some types can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks.
Vector-borne pathogens (*Plasmodium* spp., dengue virus, *Wuchereria bancrofti*, Japanese encephalitis virus)	Vector contact	Risk for any water resource development activities in relevant geographic areas where vector-borne diseases are present. Most insect vectors breed in clean water, with the exception of vectors of lymphatic filariasis, which breed in organically polluted water.
Skin irritants	Contact	The causes of skin irritation such as contact dermatitis (eczema) are likely due to a mixture of microbial and chemical hazards.
Chemicals		
Antibiotics (chloramphenicol)	Consumption	Potential risk to consumers of aquacultural products where these substances are used in fish production.
Cyanobacterial toxins (microcystin-LR)	Contact Consumption	Potential risk to consumers of aquacultural products — especially blue-green algae nutritional supplements (*Spirulina*).
Heavy metals (arsenic, cadmium, lead, mercury)	Consumption	May accumulate in plants — both aquatic and terrestrial.
Phthalates and phenols	Consumption of water coming from aquifers recharged through wastewater irrigation	These compounds have been found in aquifers used for human drinking-water supplies that have been inadvertently recharged through wastewater irrigation. Some of these chemicals may have endocrine disrupting properties.
Halogenated hydrocarbons (dioxins, furans, PCBs)	Consumption	Not absorbed by plants, but may contaminate surfaces if plants are not peeled or washed before consumption. Potential for bioaccumulation in larger carnivorous fish raised in waste-fed aquacultural facilities.
Pesticides and their residues (e.g. aldrin, DDT)	Contact Consumption	Risk mostly related to pesticide application practices.

Sources: WHO (1995, 1999); BGS-CNA (1998); Chorus & Bartram (1999); Blumenthal et al. (2000a, 2000b); Gilroy et al. (2000); van der Hoek et al. (2005).

2.2.1 Agriculture

Epidemiological studies and quantitative microbial risk assessment (QMRA) have been used to estimate microbial risks and risks from hazardous chemicals for groups with different levels of exposure associated with the use of wastewater, excreta and greywater. The evidence is summarized in Tables 2.2 and 2.3.

Table 2.3 presents a summary of the QMRA evidence for the transmission of rotavirus infection due to different exposures. The risks of rotavirus transmission were always estimated to be higher than the risks associated with *Campylobacter* or *Cryptosporidium* infections.

Less evidence is available for health risks associated with chemicals. What we know is based on quantitative risk assessment and indicates that chemical uptake by plants is highly dependent on the types of chemicals and the physical and chemical properties of the soil. Chemical concentration limits based on health considerations are presented in Table 2.6 below.

2.2.2 Aquaculture

The health impacts of waste-fed aquaculture have rarely been studied. There is evidence that fish and plants grown under waste-fed conditions can become contaminated with human excreta-related pathogens on their surfaces and (in the case of fish only) in their intestines. The relationships reported between microbial water quality indicators and contamination of edible fish tissues are contradictory and controversial. The balance of evidence suggests that when fish are grown under stressful conditions (e.g. low dissolved oxygen, high ammonia concentrations or in overcrowded situations), there may be microbial penetration of edible fish tissues. However, the level of contamination is always very small and will generally be insignificant compared with the contamination of edible fish flesh that can occur during unhygienic fish cleaning or processing.

For trematodes, the evidence is clearer. If the trematode is present in the faeces of infected humans or animals, if there is a suitable intermediate host (certain species of aquatic snails) and if the fish or plant is consumed raw or inadequately cooked, transmission to humans can occur. Therefore, in areas where these conditions occur, a suitable microbial water quality indicator for fish ponds is the presence/absence of viable trematode eggs.

A study on health status and trends in communities practising waste-fed aquaculture indicated that heavy contact with waste-fed ponds and consumption of fish raised in these ponds could lead to measurable impacts on people's health. Another study showed that farmers of aquatic plants in ponds contaminated with wastewater and industrial effluents often developed skin diseases such as contact dermatitis. These studies have been used to develop the health-based targets that have been included in Volume 3 of these Guidelines.

2.2.3 Excreta and greywater

Exposure to untreated faeces always has to be considered unsafe, due to the potential presence of high levels of disease-causing organisms; concentrations depend on their prevalence within a given population. The organisms include bacteria, viruses, parasitic protozoa and helminths. They can cause a range of infectious diseases, the vast majority of which affect the gastrointestinal system. Enteric viruses are now considered to be the cause of the majority of gastrointestinal infections in the industrialized countries (Svensson, 2000). In the rural zones of many developing countries, open defecation and the use of untreated faeces are often associated with the transmission of intestinal worms

Table 2.2 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health threats		
	Helminths	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risks of helminth infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms per 100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risks of helminth infection for both adults and children in contact with untreated wastewater; increased risk of hookworm infection to workers who do not wear shoes; risks for helminth infection remain, especially for children, even when wastewater is treated to <1 helminth egg per litre; adults are not at increased risk at this helminth concentration	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms per 100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection reported to be insignificant for contact with both untreated and treated wastewater; another study in Pakistan estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with irrigation with fresh water; increased risk of amoebiasis observed from contact with untreated wastewater
Nearby communities	Transmission of helminth infections not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data for transmission of protozoan infections during sprinkler irrigation with wastewater

Sources: Shuval, Yekutiel & Fattal (1984); Fattal et al. (1986); Shuval et al. (1989); Blumenthal et al. (2000a); Armon et al. (2002); Blumenthal & Peasey (2002); J.H.J. Ensink, W. van der Hoek & F.P. Amerasinghe (unpublished data, 2005).

to both farmers and product consumers. This is especially true for children under 15 years of age engaged in agricultural activities, who may have intense contact with fields fertilized with untreated excreta. In endemic areas where land is fertilized with untreated human faeces, workers without proper protection (e.g. gloves, shoes) are at a high risk of contracting hookworm infections. Risks of infectious diseases are significantly reduced when excreta are treated to the level suggested in Section 2.3, when farmers

Table 2.3 Summary of quantitative microbial risk assessment results for rotavirus[a] infection risks for different exposures

Exposure scenario	Water quality[b] (*E. coli*/100 ml of wastewater or 100 g of soil)	Median infection risks per person per year	Notes
Unrestricted irrigation (crop consumers)			
Lettuce	10^3–10^4	10^{-3}	100 g eaten raw per person every 2 days 10–15 ml wastewater remaining on crop
Onions	10^3–10^4	5×10^{-2}	100 g eaten raw per person per week for 5 months 1–5 ml wastewater remaining on crop
Restricted irrigation (farmers or other heavily exposed populations)			
Highly mechanized	10^5	10^{-3}	100 days' exposure per year 1–10 mg soil consumed per exposure
Labour intensive	10^3–10^4	10^{-3}	150–300 days' exposure per year 10–100 mg soil consumed per exposure

[a] Risks estimated for *Campylobacter* and *Cryptosporidium* are lower.
[b] Non-disinfected effluents. Use of disinfectant-sensitive index organisms would lead to underestimation of risk in disinfected systems.

use protection and practise good hygiene and when consumers wash and rinse their food products with clean water prior to consumption.

The use of source-separated urine in agriculture usually entails low health risks, as predicted by QMRA. Some pathogens, including *Leptospira interrogans*, *Salmonella typhi*, *Salmonella paratyphi*, *Schistosoma haematobium* and some viruses, are excreted with urine. The pathogenic bacteria and *Schistosoma* eggs die off quickly if the urine is stored under recommended conditions. Most health risks associated with the use of urine have their roots in cross-contamination with faecal material. The risks can be reduced to a very low level by storing the urine in a sealed tank or container. Depending on the crops to be fertilized, the ambient temperature and the storage temperature, urine needs to be stored for between one and six months prior to use for community systems but not for individual ones. The risks are in general much lower than those from the use of wastewater. Use of personal protective equipment is recommended when the urine is applied to the fields.

Similarly, the use of greywater in agriculture and aquaculture poses less health risk than the use of wastewater and faecal material. There may still be some health risks, generally related to faecal cross-contamination. Yet these can be reduced by health protection measures or adequate treatment. Greywater may contain considerable concentrations of easily degradable organic compounds, favouring the growth of faecal indicators. Testing for these indicators may, therefore, yield false-positive outcomes (Manville et al., 2001).

2.3 Health-based targets

Estimating the level of disease associated with the use of wastewater, excreta and greywater can be difficult. Some diseases or ill-health conditions can be measured to indicate the level of health risks. In most cases, measuring the outcome will not index risk, however, as many outcomes are multifactorial: they result from multiple transmission pathways (pathogens) or multiple exposures (hazardous chemicals). Diarrhoea and intestinal helminth infections are often measured as general indicators of excreta-related diseases. Trematode infections may be considered where they are present in the population. Diseases related to chemical exposures are harder to detect because the health outcomes may take longer to develop and are often caused by many different chemicals through a variety of exposure routes. Skin diseases can be measured among people who have heavy contact with wastewater — especially where the wastewater is inadequately treated and has high toxic chemical inputs from industry.

Health-based targets are used by regulators to develop appropriate health protective legislation; they establish a defined level of health protection for a given exposure. This can be based on a measure of disease (e.g. 10^{-6} DALY, or disability adjusted life year, per person per year) or the absence of a specific disease related to that exposure (e.g. no transmission of foodborne trematodes resulting from the consumption of waste-fed aquacultural products). After the health target is defined, a combination of health protection measures that could achieve the target is specified. These may include, for example, crop/produce restriction; waste application techniques; measures to control exposures to hazards; wastewater, excreta or greywater treatment processes or technologies; and other interventions to reduce risk (e.g. normal washing and rinsing of irrigated vegetables, cooking food thoroughly prior to consumption, etc.). Health-based targets should be set at the national level, feasible to implement in the local circumstances and part of the overall regulatory framework.

The health-based targets for agriculture, aquaculture and the general use of excreta and greywater are presented in the subsections below.

2.3.1 Wastewater use in agriculture

The health-based targets for wastewater use in agriculture are presented in Table 2.4. The combinations of health protection measures that can be used to achieve the health-based targets are presented in Figure 2.1. Table 2.5 describes different health protection measure combinations to achieve the health-based targets. For specific settings, both the health-based targets and the combination of health protection measures need to be adapted.

Figure 2.1 shows pathogen reductions achieved by several options for combining wastewater treatment and other health protection control measures to achieve the health-based target of a DALY loss of $\leq 10^{-6}$ per person per year. The options in Figure 2.1 represent typical combinations of health protection control measures, but they are illustrative only. Planners and designers of wastewater use schemes may wish to explore and use other combinations of health protection control measures, and new treatment technologies will offer the opportunity of developing new options.

Option A in Figure 2.1 shows that the required pathogen reduction is achieved by the combination of (a) wastewater treatment, which provides a 4 log unit pathogen reduction (approximately equivalent to an *E. coli* level of 10^3/100 ml in unchlorinated effluents), (b) a 2 log unit reduction due to pathogen die-off between the last irrigation and consumption, and (c) a 1 log unit reduction due to normal household washing of the salad crops or vegetables with water prior to consumption. This option, which provides a 7 log unit pathogen reduction, is suitable when root crops that may be eaten uncooked are irrigated with treated wastewater.

Option B has a lower degree of wastewater treatment than Option A (3 log units, rather than 4) combined with two post-treatment health protection control measures: a

Table 2.4 Health-based targets and helminth reduction targets for treated wastewater use in agriculture

Type of irrigation	Health-based target for viral, bacterial and protozoan pathogens	Microbial reduction target for helminth eggs
Unrestricted	≤10^{-6} DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Restricted	≤10^{-6} DALY per person per year[a]	≤1 per litre (arithmetic mean)[b,c]
Localized (e.g. drip irrigation)	≤10^{-6} DALY per person per year[a]	(a) Low-growing crops:[d] ≤1 per litre (arithmetic mean) (b) High-growing crops:[d,e] No recommendation

[a] The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.
[b] When children under 15 years of age are exposed, additional health protection measures should be used.
[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.
[d] High-growing crops include fruit trees, olives, etc.
[e] No crops to be picked up from the soil.

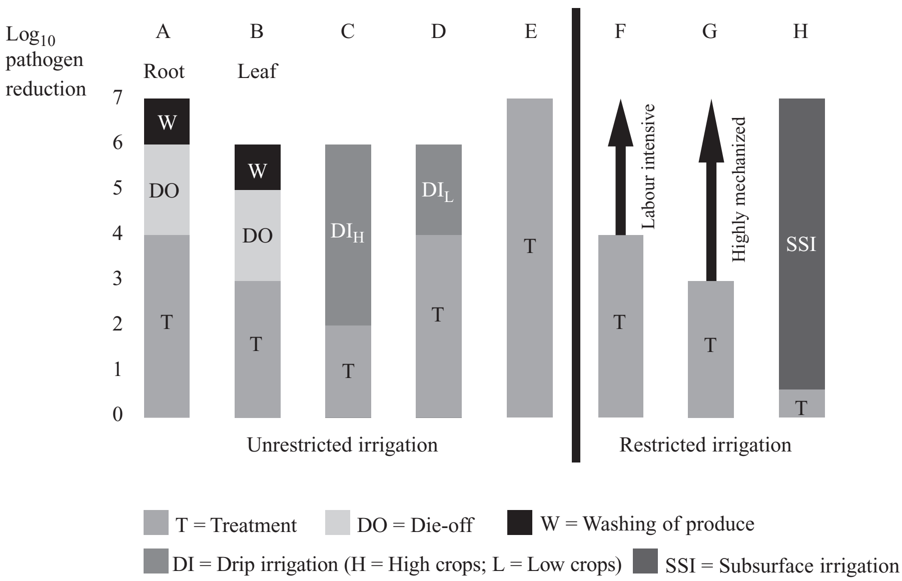

Figure 2.1

Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALY per person per year

Table 2.5 Verification monitoring[a] (*E. coli* numbers per 100 ml of treated wastewater) for the various levels of wastewater treatment in Options A–G presented in Figure 2.1

Type of irrigation	Option (Figure 2.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	A	4	$\leq 10^3$	Root crops
	B	3	$\leq 10^4$	Leaf crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[b]
Restricted	F	3	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15 years of age)
	G	2	$\leq 10^5$	Highly mechanized agriculture
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

[a] "Verification monitoring" refers to what has previously been referred to as "effluent standards" or "effluent guideline" levels.

[b] For example, for secondary treatment, filtration and disinfection: five-day biochemical oxygen demand (BOD_5), <10 mg/l; turbidity, <2 nephelometric turbidity units (NTU); chlorine residual, 1 mg/l; pH, 6–9; and faecal coliforms, not detectable in 100 ml (State of California, 2001).

2 log unit reduction due to die-off and a 1 log unit reduction due to washing the salad crops or vegetables with water prior to consumption. This option, which provides a 6 log unit pathogen reduction, is suitable for the irrigation of non-root salad crops (e.g. lettuce, cabbage) and vegetables eaten uncooked.

Option C combines an even lower degree of treatment (2 log units) with drip irrigation of high-growing crops (such as fruit trees, olives), which achieves the required remaining 4 log unit pathogen reduction.

Option D incorporates the drip irrigation of low-growing non-root crops (a 2 log unit reduction), so a greater degree of treatment (4 log units) is provided (a valid alternative would be, for example, a 2 log unit reduction by treatment followed by a 1 log unit reduction due to die-off and a 1-log unit reduction due to produce washing).

Option E relies solely on wastewater treatment to achieve the required 6–7 log unit reduction. A typical sequence of wastewater treatment processes to achieve this would comprise conventional wastewater treatment (e.g. primary sedimentation, activated sludge, including secondary sedimentation) followed by chemical coagulation, flocculation, sedimentation, filtration and disinfection (chlorination or UV irradiation). Such a sequence is used, for example, in California, USA, to ensure compliance with the state water recycling criteria for unrestricted irrigation (≤2.2 total coliforms per 100 ml and a turbidity of ≤2 NTU) (State of California, 2001). However, this option does not take into account pathogen reduction due to (a) natural die-off between final irrigation and consumption and (b) specific food preparation practices such as washing, disinfection, peeling and/or cooking. Moreover, the very high costs and operational complexity of the wastewater treatment processes required for this option will generally preclude its application in many developing countries.

Option F in Figure 2.1 represents labour-intensive restricted irrigation; the health-based target of an additional disease burden of $\leq 10^{-6}$ DALY loss per person per year is achieved by a 4 log unit pathogen reduction.

Option G represents restricted irrigation using highly mechanized agricultural practices (e.g. tractors, automatic sprinklers, etc.); wastewater treatment to 10^5–10^6 *E. coli* per 100 ml is required (i.e. a pathogen reduction of 3 log units).

Option H in Figure 2.1 illustrates a typical single-household or institutional situation: minimal treatment in a septic tank (0.5 log unit pathogen reduction) followed by subsurface irrigation via the soil absorption system for the septic tank effluent. There is no contact between the crop and the pathogens in the septic tank effluent, so the subsurface irrigation system is credited with the remaining 6.5 log unit pathogen reduction required for root crops.

As stated previously, each country can and should establish national criteria and procedures that suit its epidemiological, social and economic needs. These should allow for the optimal combination of risk reduction elements to be designed and implemented at the system level. The WHO Committee of Experts that reviewed and endorsed these Guidelines felt that the in-depth risk analyses provided a sound epidemiological basis to conclude that options A, B, C and D provide a high degree of health risk reduction, which should meet the needs of most countries in a reasonably cost-effective manner. It concluded that these new risk assessment studies and the extensive review and evaluation carried out by the group generally validated the 1989 WHO recommended guidelines for unrestricted wastewater use in agriculture of 1000 *E. coli*/100 ml.

2.3.2 Aquaculture

Health-based targets for different waste-fed aquacultural hazards are presented in Table 2.7. Because the risks associated with waste-fed aquaculture are not well defined, it is more difficult to set a meaningful tolerable risk level. However, different health-based targets can be developed for the prevention of a particular disease outcome (e.g. clonorchiasis transmission) from waste-fed aquaculture. A health-based target would then include combinations of different health protection measures that would lead to this outcome — for example, wastewater/excreta treatment, produce restriction, post-harvest fish processing (drying, salting, acid solution) and/or cooking fish before consumption.

For each exposure route (e.g. consumption, contact and vector transmission), a different health-based target is developed based on a relevant health outcome. This is important, because health outcomes differ by exposure route, as do health protection measures. For example, wastewater and excreta treatment may be effective in reducing diseases related to food consumption or contact with the water, but will do nothing to prevent vector-borne disease transmission. Similarly, hygienic fish processing may reduce cross-contamination with bacteria and viruses but will not reduce the risk associated with the presence of encysted trematode metacercariae that remain infective.

2.3.3 Excreta and greywater use

The pathogen reduction that is needed in the on-site and off-site treatment of excreta is expressed as both guideline values and performance targets for the treated faecal fraction and for faecal sludge. The guideline values refer to the context of helminth eggs and *E. coli*, where the numbers are harmonized with what is presented in volume 2. Likewise, harmonized guideline values for these parameters are given for the greywater quality, with a precaution due to the possibility of regrowth of *E. coli* on easily degradable organics fractions in greywater. This allows for a relaxation of the guideline values, if the process is likely to occur or has been documented from similar conditions.

In addition, volume 4 emphasizes performance targets, to be accounted for both in the validation and verification monitoring, and of special value in operational monitoring. Performance targets are explicitly mentioned for source-separate urine, due to the possibility of false-negative results, if based on *E. coli*, as related to the die-off of pathogens. Performance targets are also used for treated faeces and faecal sludge. On-site treatment can never be fully monitored in relation to guideline values. Design criteria and validation will, on the other hand, take this into account. The performance target for treated excreta is based on a storage time of 6-24 months, depending on specific conditions. A withholding time of at least one month will further ensure safety of the agricultural produce for the consumers. This period applies where the treated excreta are applied as a fertilizer to soil conditioner, which differs from the wastewater values, where the water is mainly used for irrigation purposes.

Strauss & Blumenthal (1990) suggested that one year of storage was sufficient under tropical conditions (28–30 °C), whereas at lower average temperatures (17–20 °C) 18 months would be needed. Treatment of excreta, thermophilic digestion (50 °C for 14 days) and composting in aerated piles for one month at 55–60 °C (plus 2–4 months for further maturation) are procedures that will satisfy the reduction of pathogens to achieve the health-based target values.

In urine, faecal cross-contamination is the major source of microbial pathogens, if additional off-site treatment is applied. Measurements have indicated that it is usually less than 10^{-4} of excreta, thus similar to a 100-fold dilution of wastewater, with a need for a pathogen reduction of <4–5 log units as the performance target to achieve the tolerable additional disease burden of $\leq 10^{-6}$ DALY per person per year, in unrestricted irrigation.

For subsurface adsorption systems for greywater, no guidelines values apply. Siting should, however, not interfere with groundwater quality. Pond systems for greywater treatment carry the risk of mosquito vector breeding and much be evaluated on that account.

2.4 Health protection measures

To achieve the health-based targets described in section 2.3, the implementation of various health protection measures may be required. The regulatory framework should ensure that the correct measures are implemented in the correct settings.

Although in some cases one measure may be sufficient to achieve the health-based target (e.g. extensive treatment of wastewater), in practice it will usually be preferable to employ a combination of measures. For example, wastewater treatment plus a withholding period to allow pathogen die-off prior to harvest plus good food hygiene plus cooking of food may be sufficient to reduce health risks adequately. The combination of different health protection measures adds additional barriers for preventing exposures to the hazards and thus will reduce the potential health risks. The available health protection measures will vary according to the sociocultural, economic and environmental circumstances found in each situation. In practice, however, health protection measures can be taken to reduce potential health risks even in low-resource settings. In these situations, it may be necessary, however, to prioritize the health protection measures put into place so that exposure to the health hazards that pose the greatest risk (e.g. helminths in agriculture or foodborne trematodes in aquaculture) are dealt with first.

Detailed information on health protection measures is presented in Volumes 2, 3 and 4 of these Guidelines. An overview is presented in Table 2.8 below.

Table 2.6 Health-based targets for waste-fed aquaculture

Exposed group	Hazard	Health-based target[a]	Verification monitoring — pond water quality		Health protection measure
			E. coli (arithmetic mean number per 100 ml)	Viable trematode eggs (number per 100 ml)	
Consumers, workers and local communities	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^4$ (consumers) $\leq 10^3$ (contact)	Not detected	Wastewater treatment Excreta treatment Health and hygiene promotion Chemotherapy and immunization
Consumers	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^4$	Not detected	Produce restriction Waste application/ timing Depuration Food handling and preparation Produce washing/ disinfection Cooking foods
	Foodborne trematodes	Absence of trematode infections			
	Chemicals	Tolerable daily intakes as specified by the Codex Alimentarius Commission			
Workers and local communities	Excreta-related diseases	$\leq 10^{-6}$ DALY per person per year	$\leq 10^3$ (contact)		Access control Use of personal protective equipment Disease vector control Intermediate host control Access to safe drinking-water and sanitation at aquacultural facilities and in local communities Reducing vector contact (bed nets, repellents)
	Skin irritants	Absence of skin disease			
	Schistosomiasis	Absence of schistosomiasis		No viable schistosome eggs	
	Vector-borne diseases	Absence of vector-borne disease			

[a] Absence of disease associated with waste-fed aquaculture-related exposures.

2.5 Monitoring and system assessment

The three functions of monitoring are each used for different purposes at different times. Table 2.9 briefly describes each type of monitoring. *Validation* is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. *Operational monitoring* is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. *Verification* is used to show that the end product (e.g. treated wastewater and excreta; plant or fish) meets treatment targets (e.g. microbial quality specifications; no infective metacercariae in fish flesh) and ultimately the health-based targets (e.g. absence of trematode infections in the population exposed to waste-fed aquacultural activities). Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing). Table 2.10 presents the required verification monitoring of microbial water quality targets.

The most effective means of consistently ensuring safety in the use of wastewater, excreta and greywater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps from waste generation, treatment and use to product use and consumption. The following components of this approach are important in the context of regulation for achieving the health-based targets: system assessment; identifying health protection measures and methods for monitoring them; and developing a management plan.

The first step in developing a risk management system is to form a multidisciplinary team of experts with a thorough understanding of local wastewater, excreta and greywater use practices. Typically, such a team would include agricultural and/or aquacultural experts, engineers, water quality specialists, environmental health specialists, public health authorities and food safety experts. In most settings, the team would include members from several institutions, and there should be some independent members, such as from universities.

Effective management of wastewater, excreta and greywater use activities requires a comprehensive understanding of the system, the range and magnitude of hazards that may be present and the ability of existing processes and infrastructure to manage actual or potential risks. It also requires an assessment of capabilities to meet targets. When a new system or an upgrade of an existing system is being planned, the first step in developing a risk management plan is the collection and evaluation of all available relevant information and consideration of what risks may arise during the entire waste use process. Figure 2.2 illustrates the development of a risk management plan.

The assessment and evaluation of the use of wastewater, excreta and greywater are enhanced through the development of a flow diagram. Diagrams provide an overview description of the system, including the identification of sources of hazards and health protection measures. It is important that the representation of the waste use system be conceptually accurate. If the flow diagram is not correct, it is possible to overlook potential hazards that may be significant. To ensure accuracy, the flow diagram should be validated by visually checking the diagram against features observed on the ground.

Data on the occurrence of hazards in the system combined with information concerning the effectiveness of existing controls enable an assessment of whether health-based targets can be achieved with the existing health protection measures. They also assist in identifying health protection measures that would reasonably be expected to achieve those targets if improvements are required.

To ensure accuracy of the assessment, it is essential that all elements of the waste use system are considered concurrently and that interactions and influences between each element and their overall effect are taken into consideration.

Table 2.7 Pathogen reductions achievable by various health protection measures

Control measure	Pathogen reduction (log units)	Notes
Excreta storage without fresh additions	6	The required pathogen reduction to be achieved by excreta treatment refers to stated storage times without addition of fresh untreated excreta. Pathogen reductions for different treatment options are presented in chapter 5 of Volume 4.
Greywater treatment	1–>4	Values relate to the relevant treatment options. Generally, the highest exposure reduction is related to subsurface irrigation.
Localized (drip) irrigation with urine (high-growing crops)	2–4	Crops where the harvested parts have not been in contact with the soil
Materials directly worked into the soil	1	Should be done at the time when faeces or urine is applied as a fertilizer
Pathogen die-off (withholding time one month)	4–>6	A die-off of 0.5–2 log units per day is cited for wastewater irrigation. Reduction values cited are conservative to account for a slower die-off of a fraction of the remaining organisms.
Produce washing with water	1	Washing salad crops, vegetables and fruit with clean water
Produce disinfection	2	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water
Produce peeling	2	Fruits, root crops
Produce cooking	6–7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction

Sources: Beuchat (1998); Petterson & Ashbolt (2003); NRMMC & EPHCA (2005).

Table 2.8 Definitions of monitoring functions

Function	Definition
Validation	Testing the system and its individual components to prove that they are capable of meeting the specified targets (e.g. microbial reduction targets). Should take place when a new system is developed or new processes are added.
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a health protection measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.
Verification	The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

Table 2.9 Recommended minimum verification monitoring of microbial performance targets for wastewater and excreta use in agriculture and aquaculture

Activity/exposure	Water quality monitoring[a] parameters	
Agriculture	*E. coli* per 100 ml[b] (arithmetic mean)	Helminth eggs per litre[b] (arithmetic mean)
Unrestricted irrigation		
Root crops	$\leq 10^3$	≤ 1
Leaf crops	$\leq 10^4$	
Drip irrigation, high-growing crops	$\leq 10^5$	
Restricted irrigation		
Labour-intensive, high-contact agriculture	$\leq 10^4$	≤ 1
Highly mechanized agriculture	$\leq 10^5$	
Septic tank	$\leq 10^6$	
Aquaculture	*E. coli* per 100 ml[b] (arithmetic mean)	Viable trematode eggs per litre[b]
Produce consumers		
Pond	$\leq 10^4$	Not detected
Wastewater	$\leq 10^5$	Not detected
Excreta	$\leq 10^6$	Not detected
Workers, local communities		
Pond	$\leq 10^3$	No viable trematode eggs
Wastewater	$\leq 10^4$	No viable trematode eggs
Excreta	$\leq 10^5$	No viable trematode eggs

[a] Monitoring should be conducted at the point of use or the point of effluent discharge. Frequency of monitoring is as follows:

- Urban areas: one sample every two weeks for *E. coli* and one sample per month for helminth eggs.
- Rural areas: one sample every month for *E. coli* and one sample every 1–2 months for helminth eggs.

Five-litre composite samples are required for helminth eggs prepared from grab samples taken six times per day. Monitoring for trematode eggs is difficult due to a lack of standardized procedures. The inactivation of trematode eggs should be evaluated as part of the validation of the system.

[b] For excreta, weights may be used instead of volumes, depending on the type of excreta: 100 ml of wastewater is equivalent to 1–4 g of total solids; 1 litre = 10–40 g of total solids. The required *E. coli* or helminth numbers would be the same per unit of weight.

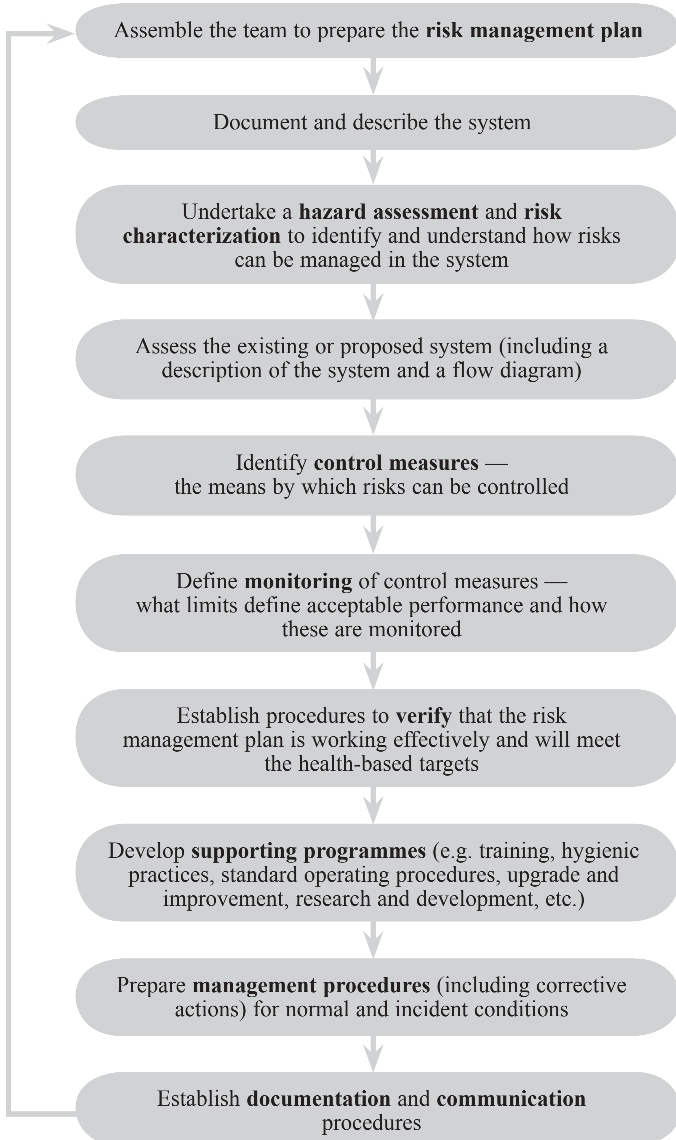

Figure 2.2
Development of a risk management plan (from WHO, 2004)

3
EXECUTIVE SUMMARY OF VOLUME 2

Volume 2 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of wastewater use in agriculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each vulnerable group, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume of the Guidelines is to ensure that the use of wastewater in agriculture is made as safe as possible, so that the nutritional and household food security benefits can be shared widely within communities whose livelihood depends on wastewater-irrigated agriculture. Thus, the adverse health impacts of wastewater use in agriculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever wastewater use in agriculture contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

Volume 2 of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with wastewater use in agriculture, as well as providing a framework for national and local decision-making. The information provided is applicable to the intentional use of wastewater in agriculture and is also relevant where faecally contaminated water is used for irrigation unintentionally.

The Guidelines provide an integrated preventive management framework for safety applied from the point of wastewater generation to the consumption of products grown with the wastewater and excreta. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or excreta or consuming products grown with wastewater or excreta and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include public health, agricultural and environmental scientists, agriculture professionals, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

3.1 Introduction

Wastewater is increasingly used for agriculture in both developing and industrialized countries, and the principal driving forces are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from improper disposal of wastewater;
- population increase and related increased demand for food and fibre;

- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the Millennium Development Goals (MDGs), especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

It is estimated that, within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity. Growing competition between the agricultural and urban uses of high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this ever scarcer resource.

The United Nations Population Division expects most population growth to occur in urban and periurban areas in developing countries. Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources.

Wastewater is often a reliable year-round source of water, and it contains the nutrients necessary for plant growth. The value of wastewater has long been recognized by farmers worldwide. The use of wastewater in agriculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on soil and water resources.

The United Nations General Assembly adopted the MDGs on 8 September 2000. The MDGs most directly related to the use of wastewater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of wastewater in agriculture can help communities to grow more food and conserve precious water and nutrient resources.

3.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

3.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial and chemical laboratory analysis, epidemiological studies and quantitative microbial (and chemical) risk assessment.

Wastewater contains a variety of different pathogens, many of which are capable of survival in the environment (in the wastewater, on the crops or in the soil) long enough to be transmitted to humans. Table 3.1 presents a summary of the information available from epidemiological studies of infectious disease transmission related to wastewater use in agriculture. In places where wastewater is used without adequate treatment, the greatest health risks are usually associated with intestinal helminths.

Table 3.2 presents a summary of the quantitative microbial risk assessment (QMRA) evidence for transmission of rotavirus infection due to different exposures. The risks for rotavirus transmission were always estimated to be higher than the risks associated with *Campylobacter* or *Cryptosporidium* infections.

Table 3.1 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health threats		
	Nematode infection	**Bacteria/viruses**	**Protozoa**
Consumers	Significant risk of *Ascaris* infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of *Ascaris* infection for both adults and children in contact with untreated wastewater; risk remains, especially for children, when wastewater treated to <1 nematode egg per litre; increased risk of hookworm infection in workers	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection was insignificant for contact with both untreated and treated wastewater; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

Less evidence is available for health risks from chemicals. The evidence that is available is based on quantitative risk assessment and indicates that the uptake of chemicals by plants is highly dependent on the types of chemicals and the physical and chemical properties of soils.

3.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as a DALY (e.g. 10^{-6} DALYs), or it can be based on an appropriate health outcome, such as the prevention of the transmission of vector-borne diseases resulting from exposures to wastewater used in agricultural practices. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved through a combination of health protection measures targeted at different components of the system. Figure

3.1 illustrates different combinations of health protection measures that can be used to achieve the 10^{-6} DALYs health-based target for excreta-related diseases.

Table 3.2 Summary of QMRA results for rotavirus[a] infection risks for different exposures

Exposure scenario	Water quality[b] (*E. coli*/100 ml wastewater or 100 g soil)	Median infection risks per person per year	Notes
Unrestricted irrigation (crop consumers)			
Lettuce	10^3–10^4	10^{-3}	100 g eaten raw per person every 2 days 10–15 ml wastewater remaining on crop
Onion	10^3–10^4	5×10^{-2}	100 g eaten raw per person per week for 5 months 1–5 ml wastewater remaining on crop
Restricted irrigation (farmers or other heavily exposed populations)			
Highly mechanized	10^5	10^{-3}	100 days' exposure per year 1–10 mg soil consumed per exposure
Labour intensive	10^3–10^4	10^{-3}	150–300 days' exposure per year 10–100 mg soil consumed per exposure

[a] Risks estimated for *Campylobacter* and *Cryptosporidium* are lower.
[b] Non-disinfected effluents.

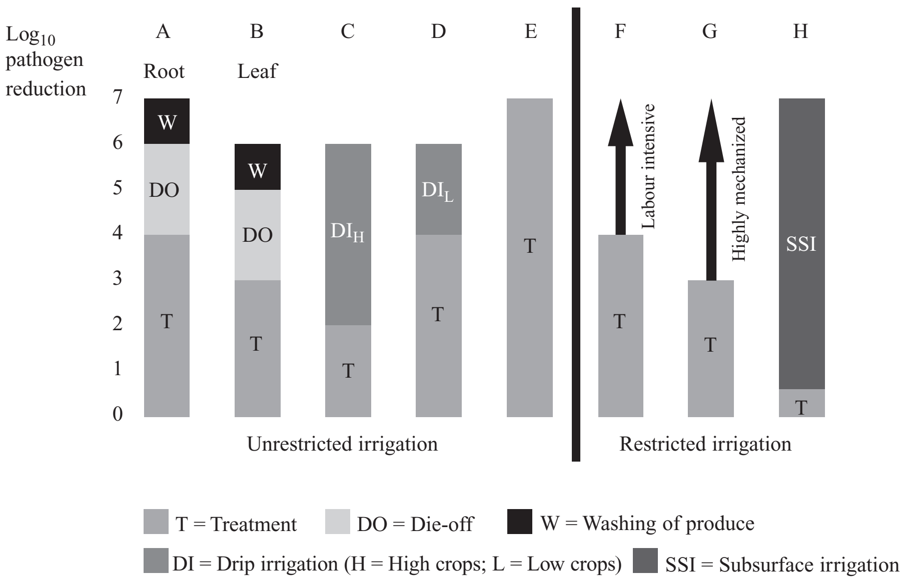

Figure 3.1
Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALYs per person per year

Table 3.3 describes health-based targets for agriculture. The health-based targets for rotavirus are based on QMRA indicating the $\log_{10}$ pathogen reduction required to achieve 10^{-6} DALY for different exposures. To develop health-based targets for helminth infections, epidemiological evidence was used. This evidence demonstrated that excess helminth infections (for both product consumers and farmers) could not be measured when wastewater quality of ≤1 helminth egg per litre was used for irrigation. This level of health protection could also be met by treatment of wastewater or by a combination of wastewater treatment and washing of produce to protect consumers of raw vegetables; or by wastewater treatment and the use of personal protective equipment (shoes, gloves) to protect workers. When children less than 15 years of age are exposed in the fields, either additional wastewater treatment (to achieve a wastewater quality of ≤0.1 helminth egg per litre) or the addition of other health protection measures (e.g. anthelminthic treatment) should be considered.

Table 3.3 Health-based targets for wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	$\log_{10}$ pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤1[b,c]
Onion		7	≤1[b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤1[b,c]
Labour intensive		4	≤1[b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤1[c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy).

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] No crops to be picked up from the soil.

Table 3.4 presents maximum soil concentrations for different chemicals based on health risk assessment. Concentrations of chemicals that impact agricultural productivity are described in Annex 1 of Volume 2.

3.5 Health protection measures

A variety of health protection measures can be used to reduce health risks to consumers, workers and their families and local communities.

Hazards associated with the consumption of wastewater-irrigated products include excreta-related pathogens and some toxic chemicals. The risk from infectious pathogens is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. The following health protection measures have an impact on product consumers:

Table 3.4 Maximum tolerable soil concentrations of various toxic chemicals based on human health protection

Chemical	Soil concentration (mg/kg)
Element	
Antimony	36
Arsenic	8
Barium[a]	302
Beryllium[a]	0.2
Boron[a]	1.7
Cadmium	4
Fluorine	635
Lead	84
Mercury	7
Molybdenum[a]	0.6
Nickel	107
Selenium	6
Silver	3
Thallium[a]	0.3
Vanadium[a]	47
Organic compound	
Aldrin	0.48
Benzene	0.14
Chlordane	3
Chlorobenzene	211
Chloroform	0.47
2,4-D	0.25
DDT	1.54
Dichlorobenzene	15
Dieldrin	0.17
Dioxins	0.000 12
Heptachlor	0.18
Hexachlorobenzene	1.40
Lindane	12
Methoxychlor	4.27
PAHs (as benzo[*a*]pyrene)	16
PCBs	0.89
Pentachlorophenol	14
Phthalate	13 733
Pyrene	41
Styrene	0.68
2,4,5-T	3.82
Tetrachloroethane	1.25
Tetrachloroethylene	0.54
Toluene	12
Toxaphene	0.0013
Trichloroethane	0.68

[a] The computed numerical limits for these elements are within the ranges that are typical for soils.

- wastewater treatment;
- crop restriction;
- wastewater application techniques that minimize contamination (e.g. drip irrigation);
- withholding periods to allow pathogen die-off after the last wastewater application;
- hygienic practices at food markets and during food preparation;
- health and hygiene promotion;
- produce washing, disinfection and cooking;
- chemotherapy and immunization.

Wastewater use activities may lead to the exposure of workers and their families to excreta-related diseases (including schistosomiasis), skin irritants and vector-borne diseases (in certain locations). Wastewater treatment is a control measure for excreta-related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures for workers and their families include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at farms;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to wastewater-irrigated fields. If they do not have access to safe drinking-water, they may use contaminated irrigation water for drinking or for domestic purposes. Children may also play or swim in the contaminated water. Similarly, if wastewater irrigation activities result in increased vector breeding, then local communities may be affected by vector-borne diseases, even if they do not have direct access to the irrigated fields. To reduce health hazards, the following health protection measures for local communities may be used:

- wastewater treatment;
- restricted access to irrigated fields and hydraulic structures;
- access to safe recreational water, especially for adolescents:
- access to safe drinking-water and sanitation facilities in local communities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

3.6 Monitoring and system assessment

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater; crops) meets treatment targets (e.g. microbial quality specifications) and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing).

The most effective means of consistently ensuring safety in the agricultural application of wastewater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process from waste generation to treatment and use of wastewater to product use or consumption. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan.

3.7 Sociocultural aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce wastewater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs vary so widely in different parts of the world that it is not possible to assume that any of the practices that have evolved in relation to wastewater use can be readily transferred elsewhere.

Closely associated with cultural beliefs is the public perception of wastewater use. Even when projects are technically well planned and all of the relevant health protection measures have been included, the project can fail if it does not account adequately for public perception.

3.8 Environmental aspects

Wastewater is an important source of water and nutrients for many farmers in arid and semi-arid climates. Sometimes it is the only water source available for agriculture. When wastewater use is well managed, it helps to recycle nutrients and water and therefore diminishes the cost of fertilizers or simply makes them accessible to farmers. Where wastewater treatment services are not provided, the use of wastewater in agriculture actually acts as a low-cost treatment method, taking advantage of the soil's capacity to naturally remove contamination. Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water bodies.

Nevertheless, wastewater use poses environmental risks. Possible effects and their relevance depend on each specific situation and how the wastewater is used. In many places, wastewater irrigation has arisen spontaneously and without planning — often the wastewater is untreated. In other situations, the use of wastewater in agriculture is strictly controlled. These practices will lead to different environmental impacts.

The properties of domestic wastewater and industrial wastewater differ. Generally, the use of domestic wastewater for irrigation poses less risk to the environment than the use of industrial wastewater, especially where industries use or produce highly toxic chemicals. Industrial discharges containing toxic chemicals are mixed with domestic wastewater in many countries, creating serious environmental problems and, where the wastewater is used for crop irrigation, endangering the health of the farmers and product consumers. Efforts should be made to reduce or eliminate practices that entail the mixing of industrial and domestic wastewater, particularly where wastewater is used for agriculture.

The use of wastewater in agriculture has the potential for both positive and negative environmental impacts. With careful planning and management, the use of wastewater in agriculture can be beneficial to the environment. Many of the environmental impacts (e.g. salinization of soil, contamination of water resources) can be reduced by good agricultural practices (as described in Annex 1 of Volume 2).

3.9 Economic and financial considerations

Economic factors are especially important when the viability of a new scheme for the use of wastewater is being appraised, but even an economically worthwhile project can fail without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of wastewater. Economic analysis seeks to establish the economic feasibility of a project and enables comparisons between different options. The cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) also need to be included in a cost analysis. This can be facilitated by the use of multiple-objective decision-making processes.

Financial planning looks at how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The possibility to profitably sell products grown with wastewater or to sell the treated wastewater also needs analysis.

3.10 Policy aspects

The safe management of wastewater in agriculture is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where wastewater use in agriculture takes place, these frameworks are lacking.

Policy is the set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations, economic measures, information and education programmes and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate safe wastewater use in agriculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for safe wastewater use practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that would otherwise lead to reinfection (e.g. with intestinal helminths and other pathogens).

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

The use of wastewater in agriculture can have one or more of several objectives. Defining these objectives is important for developing a national policy framework. The right policies can facilitate the safe use of wastewater in agriculture. Current policies often already exist that impact these activities, both negatively and positively. Conducting an assessment of current policies is often helpful for developing a new national policy or for revising existing policies. The assessment should take place at two levels: from the perspective of both a policy-maker and a project manager. Policy-makers will want to assess the national policies, legislation, institutional framework and regulations to ensure that they meet the national wastewater use objectives (e.g. maximize economic returns without endangering public health or the environment). Project coordinators will want to ensure that current and future waste use activities will be able to comply with all relevant national and local laws and regulations.

The main considerations are:

- *Policy*: Are there clear policies on the use of wastewater? Is wastewater use encouraged or discouraged?
- *Legislation*: Is the use of wastewater governed in legislation? What are the rights and responsibilities of different stakeholders? Does a defined jurisdiction exist on the use of wastewater?
- *Institutional framework*: Which ministry/agency, organizations, etc. have the authority to control the use of wastewater at the national level and at the district/community level? Are the responsibilities of different ministries/agencies clear? Is there one lead ministry, or are there multiple ministries/agencies with overlapping jurisdictions? Which ministry/agency is responsible for developing regulations? Which ministry/agency monitors compliance with regulations? Which ministry/agency enforces the regulations?
- *Regulations*: Do regulations exist? Are the current regulations adequate to meet wastewater use objectives (protect public health, prevent environmental damage, meet produce quality standards for domestic and international trade, preserve livelihoods, conserve water and nutrients, etc.)? Are the current regulations being implemented? Is regulatory compliance being enforced? Which ministry/agency enforces the regulations?

It is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce), it is important to plan for the institutions, staff and resources necessary to ensure that the regulations are followed. It is important to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country.

3.11 Planning and implementation

Planning and implementation of wastewater irrigation programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for developing national programmes should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of wastewater use in agriculture relies on the assessment and understanding of eight important criteria: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility.

4
EXECUTIVE SUMMARY OF VOLUME 3

Volume 3 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of waste-fed aquaculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each group at risk, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume is to ensure that waste-fed aquacultural activities are made as safe as possible so that the nutritional and household food security benefits can be shared widely in affected communities. Thus, the adverse health impacts of waste-fed aquaculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever waste-fed aquaculture contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

This volume of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with waste-fed aquaculture, as well as providing a framework for national and local decision-making.

The information provided is applicable to intentional waste-fed aquacultural practices but also should be relevant to the unintentional use of faecally contaminated waters for aquaculture.

The Guidelines provide an integrated preventive management framework for safety applied from the point of waste generation to the consumption of products grown with the wastewater and excreta. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or excreta or consuming products grown with wastewater or excreta and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

4.1 Introduction

A number of forces are both negatively and positively impacting the development of waste-fed aquacultural production. Many of the areas where waste-fed aquaculture has been traditionally practised are shrinking due to urbanization, increasing surface water pollution and the development of high-input aquaculture to produce cash crops. Most of the traditional waste-fed aquacultural production has occurred in parts of Asia. Although intentional waste-fed aquaculture is in decline, the unintentional use of contaminated water in aquaculture may be increasing in some areas.

4.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

4.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial and chemical laboratory analysis, epidemiological studies and quantitative microbial (and chemical) risk assessment. Overall, there are limited data on the health impacts associated with waste-fed aquacultural practices. The evidence suggests that pathogens are often present at significant levels in untreated wastewater and excreta; pathogens can survive long enough in the environment to be transmitted to humans; and waste-fed aquaculture-associated disease transmission can occur.

Foodborne trematode parasites, where they occur, pose significant health risks to consumers of raw or inadequately cooked fish or plants. Priority should be given to implementing control measures against the transmission of foodborne trematode infections, where relevant. Excreta-related pathogens pose health risks to product consumers and people who may have contact with the contaminated water. For product consumers, much of the health risk may be associated with poor fish cleaning practices that lead to cross-contamination between the gut contents and the edible flesh. Thus, improving market hygiene and fish processing/cleaning is an important health protection intervention.

4.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as the disability adjusted life year or DALY (e.g. 10^{-6} DALY), or it can be based on an appropriate health outcome, such as the prevention of the transmission of foodborne trematode infection associated with waste-fed aquacultural practices. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved through a combination of health protection measures targeted at different components of the waste-fed aquacultural system. Health-based targets for different waste-fed aquacultural hazards are presented in Table 4.1.

4.5 Health protection measures

A variety of health protection measures can be used to reduce health risks to product consumers, workers and their families and local communities.

Hazards associated with the consumption of waste-fed aquacultural products include excreta-related pathogens, foodborne trematodes and some toxic chemicals. The risk from infectious diseases is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. Special considerations for managing trematode parasites (including *Schistosoma* spp.) may be required where they are present. The following health protection measures impact product consumers:

Table 4.1 Health-based targets for waste-fed aquaculture

Exposed group	Hazard	Health-based target[a]	Health protection measure
Consumers, workers and local communities	Excreta-related diseases	10^{-6} DALY	Wastewater treatment Excreta treatment Health and hygiene promotion Chemotherapy and immunization
Consumers	Excreta-related diseases	10^{-6} DALY	Produce restriction Waste application/timing
	Foodborne trematodes	Absence of trematode infections	Depuration
	Chemicals	Tolerable daily intakes as specified by the Codex Alimentarius Commission	Food handling and preparation Produce washing/disinfection Cooking foods
Workers and local communities	Excreta-related pathogens	10^{-6} DALY	Access control Use of personal protective equipment
	Skin irritants	Absence of skin disease	Disease vector control
	Schistosomes	Absence of schistosomiasis	Intermediate host control
	Vector-borne pathogens	Absence of vector-borne disease	Access to safe drinking-water and sanitation at aquacultural facilities and in local communities Reduced vector contact (insecticide-treated nets, repellents)

[a] Absence of disease associated with waste-fed aquaculture-related exposures.

- wastewater and excreta treatment;
- produce restriction;
- waste application withholding periods;
- control of trematode intermediate hosts;
- depuration;
- hygienic food handling and preparation;
- post-harvest processing;
- health and hygiene promotion;
- produce washing, disinfection and cooking;
- chemotherapy and immunization.

Workers and their families may be exposed to excreta-related diseases, skin irritants, schistosomiasis and vector-borne diseases through waste-fed aquacultural activities or contact with the hazards. Wastewater treatment and excreta treatment are control measures for excreta-related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at aquacultural facilities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to waste-fed ponds. If they do not have access to safe drinking-water, they may use the contaminated water for drinking or for domestic purposes, such as washing clothes, dishes and themselves. Children may also play or swim in the contaminated water. Similarly, if waste-fed aquacultural activities result in increased vector breeding, then local communities can be affected by vector-borne diseases, even if they do not have access to the waste-fed aquacultural facilities. To reduce health hazards, the following health protection measures may be used:

- wastewater and excreta treatment;
- restricted access to aquacultural facilities;
- access to safe drinking-water and sanitation facilities at aquacultural facilities;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

4.6 Monitoring and system assessment

Monitoring has three different purposes: validation or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater/excreta/pond water; fish or plants) meets treatment targets (e.g. microbial reduction targets) and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. whether the efficiency of a specific process is improving or decreasing).

The most effective means of consistently ensuring safety in waste-fed aquaculture is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in waste-fed aquaculture, from the generation and use of wastewater and excreta to the product consumer. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment; identifying control measures and methods for monitoring them; and developing a management plan.

4.7 Sociocultural, environmental and economic aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce excreta or wastewater use schemes or to reduce disease transmission in existing schemes can be assessed only with a prior understanding of the cultural values attached to practices that appear to be social preferences, yet which facilitate disease transmission. Closely associated with cultural beliefs is the public perception of wastewater and excreta use.

Excreta and wastewater use schemes, if properly planned and managed, can have a positive environmental impact, as well as produce fish and plants. Environmental improvement may be related to:

- avoidance of surface water pollution;
- conservation or more rational use of freshwater resources, especially in arid and semi-arid areas: fresh water for urban demand, wastewater for aquacultural use;
- reduction in risks of flooding in urban areas, as wastewater-fed canals, ponds and lakes act as a "buffer" during heavy rains;
- reduced requirements for artificial fertilizers, with a concomitant reduction in energy expenditure and industrial pollution elsewhere.

The primary negative environmental impacts are often related to contamination of surface waters or groundwaters in proximity to waste-fed aquacultural facilities. Other impacts relate to general aquacultural practices (e.g. the introduction of non-indigenous species or destruction of mangroves) and are not specifically related to waste-fed aquaculture.

Economic factors are especially important when the viability of a new scheme for the use of wastewater and excreta is being appraised, but even an economically worthwhile project can fail without careful financial planning. Economic appraisal considers whether a project is worthwhile, whereas financial planning looks at how projects are to be paid for. Improvements to existing practices must be paid for in some way and therefore also require financial planning.

4.8 Policy aspects

The safe management of waste-fed aquacultural practices is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where waste-fed aquaculture takes place, these frameworks are lacking.

Policy is the set of procedures, rules, decision-making criteria and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations; economic measures; information and education programmes; and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate safe waste-fed aquaculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for safe waste-fed aquacultural practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that would otherwise lead to reinfection with foodborne trematodes or intestinal helminths.

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

4.9 Planning and implementation

Planning and implementation of waste-fed aquacultural programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for developing national programmes should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of waste-fed aquaculture relies on the assessment and understanding of eight important criteria: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility.

5
EXECUTIVE SUMMARY OF VOLUME 4

Volume 4 of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of excreta and greywater use in agriculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each group at risk, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume is to ensure that the use of excreta and greywater in agriculture is made as safe as possible so that the nutritional and household food security benefits can be shared widely in affected communities. Thus, the adverse health impacts of excreta and greywater use in agriculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever excreta and greywater use contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

Volume 4 of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with excreta and greywater use in agriculture, as well as providing a framework for national and local decision-making.

The information provided is applicable to the intentional use of excreta and greywater in agriculture, but it should also be relevant to their unintentional use.

The Guidelines provide an integrated preventive management framework for safety applied from the point of household excreta and greywater generation to the consumption of products grown with treated excreta applied as fertilizers or treated greywater used for irrigation purposes. They describe reasonable minimum requirements of good practice to protect the health of the people using treated excreta or greywater or consuming products grown with these for fertilization or irrigation purposes and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include public health, agricultural and environmental scientists, agriculture professionals, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

5.1 Introduction

Traditional waterborne sewerage will continue to dominate sanitation for the foreseeable future. Since only a fraction of existing wastewater treatment plants in the world are optimally reducing levels of pathogenic microorganisms and since a majority of people living in both rural and urban areas will not be connected to centralized wastewater treatment systems, alternative sanitation approaches need to be developed in parallel.

The United Nations General Assembly adopted the Millennium Development Goals (MDGs) on 8 September 2000 (United Nations General Assembly, 2000). The MDGs most directly related to the use of excreta and greywater in agriculture are “Goal 1: Eliminate extreme poverty and hunger” and “Goal 7: Ensure environmental sustainability.” The sanitation target in Goal 7 is to halve, by 2015, the proportion of people without access to adequate sanitation. Household- or community-centred source separation is one of the alternative approaches that is rapidly expanding in order to meet this target. It also helps to prevent environmental degradation and to promote sustainable recycling of the existing plant nutrients in human excreta for food production.

The principal forces driving the increase in use of excreta and greywater in agriculture are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from the improper disposal of wastewater, excreta and greywater;
- population increase and related increased demand for food and fibre;
- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the MDGs, especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

Growing competition between agricultural and urban areas for high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this increasingly scarce resource. Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources. Household-centred source separation and the safe use of excreta and greywater in agriculture will help to alleviate these pressures and help communities to grow more food and conserve precious water and nutrient resources. The additional advantages of nutrient use from excreta as fertilizers are that this “product” is less contaminated with industrial chemicals than when wastewater is used and that it saves water for other uses.

This volume focuses mainly on small-scale applications. It is applicable to both industrialized and developing countries.

5.2 The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

5.3 Assessment of health risk

Three types of evaluations are used to assess risk: microbial analysis, epidemiological studies and quantitative microbial risk assessment (QMRA). Human faeces contain a variety of different pathogens, reflecting the prevalence of infection in the population; in contrast, only a few pathogenic species may be excreted in urine. The risks associated with both reuse of urine as a fertilizer and the use of greywater for irrigation purposes are related to cross-contamination by faecal matter. Epidemiological data for the assessment of risk through treated faeces, faecal sludge, urine or greywater are scarce and unreliable, while ample evidence exists related to untreated faecal matter. In addition, microbial analyses are partly unreliable in the prediction of risk due to a more rapid die-off of indicator organisms such as *Escherichia coli* in urine, leading to an underestimation of the risk of pathogen transmission. The opposite may occur in greywater, where a growth of the indicator bacteria on easily degradable organic substances may lead to an overestimation of the risks. Based on the above limitations, QMRA is the main approach taken, due to the range of organisms with common transmission characteristics and their prevalence in the population. Factors accounted for include:

- epidemiological features (including infectious dose, latency, hosts and intermediate host);
- persistence in different environments outside the human body (and potential for growth);
- major transmission routes;
- relative efficiency of different treatment barriers;
- risk management measures.

5.4 Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as a disability adjusted life year or DALY (i.e. 10^{-6} DALY), or it can be based on an appropriate health outcome, such as the prevention of exposure to pathogens in excreta and greywater anytime between their generation at the household level and their use in agriculture. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved by combining health protection measures targeted at different steps in the process.

The health-based targets may be achieved through different treatment barriers or health protection measures. The barriers relate to verification monitoring, mainly in large-scale systems, as illustrated in Table 5.1 for excreta and greywater. Verification monitoring is not applicable to urine.

Table 5.1 Guideline values for verification monitoring in large-scale treatment systems of greywater, excreta and faecal sludge for use in agriculture

	Helminth eggs (number per gram total solids or per litre)	*E. coli* (number per 100 ml)
Treated faeces and faecal sludge	<1/g total solids	<1000/g total solids
Greywater for use in:		
• Restricted irrigation	<1/litre	$<10^5$ [a] Relaxed to $<10^6$ when exposure is limited or regrowth is likely
• Unrestricted irrigation of crops eaten raw	<1/litre	$<10^3$ Relaxed to $<10^4$ for high-growing leaf crops or drip irrigation

[a] These values are acceptable due to the regrowth potential of *E. coli* and other faecal coliforms in greywater.

The health-based targets may also relate to operational monitoring, such as storage as an on-site treatment measure or further treatment off site after collection. This is exemplified for faeces from small-scale systems in Table 5.2.

Table 5.2 Recommendations for storage treatment of dry excreta and faecal sludge before use at the household and municipal levels[a]

Treatment	Criteria	Comment
Storage; ambient temperature 2–20 °C	1.5–2 years	Will eliminate bacterial pathogens; regrowth of *E. coli* and *Salmonella* may need to be considered if rewetted; will reduce viruses and parasitic protozoa below risk levels. Some soil-borne ova may persist in low numbers.
Storage; ambient temperature >20–35 °C	>1 year	Substantial to total inactivation of viruses, bacteria and protozoa; inactivation of schistosome eggs (<1 month); inactivation of nematode (roundworm) eggs, e.g. hookworm (*Ancylostoma*/ *Necator*) and whipworm (*Trichuris*); survival of a certain percentage (10–30%) of *Ascaris* eggs (≥4 months), whereas a more or less complete inactivation of *Ascaris* eggs will occur within 1 year.
Alkaline treatment	pH >9 during >6 months	If temperature >35 °C and moisture <25%, lower pH and/or wetter material will prolong the time for absolute elimination.

[a] No addition of new material.

For collected urine, storage criteria apply that are derived mainly from compiled risk assessment studies. The information obtained has been converted to operational guidelines to limit the risk to a level below 10^{-6} DALY, also accounting for additional health protection measures. The operational guidelines are based on source separation of urine (Table 5.3). In case of heavy faecal cross-contamination, the suggested storage times may be lengthened. If urine is used as a fertilizer of crops for household consumption only, it can be used directly without storage. The likelihood of household disease transmission attributable to the lack of hygiene is much higher than that of transmission through urine applied as a fertilizer.

Table 5.3 Recommended storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crops for larger systems[c]

Storage temperature (°C)	Storage time (months)	Possible pathogens in the urine mixture after storage	Recommended crops
4	≥1	Viruses, protozoa	Food and fodder crops that are to be processed
4	≥6	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥1	Viruses	Food crops that are to be processed, fodder crops[d]
20	≥6	Probably none	All crops[e]

[a] Urine or urine and water. When diluted, it is assumed that the urine mixture has a pH of at least 8.8 and a nitrogen concentration of at least 1 g/l.

[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized as a cause of any infections of concern.

[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from whom the urine was collected.

[d] Not grasslands for production of fodder.

[e] For food crops that are consumed raw, it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

For all types of treated excreta, additional safety measures apply. These include, for example, a recommended withholding time of one month between the moment of application of the treated excreta as a fertilizer and the time of crop harvest (Figure 5.1). Based on QMRA, this time period has been shown to result in a probability of infection well below 10^{-4}, which is within the range of a 10^{-6} DALY level.

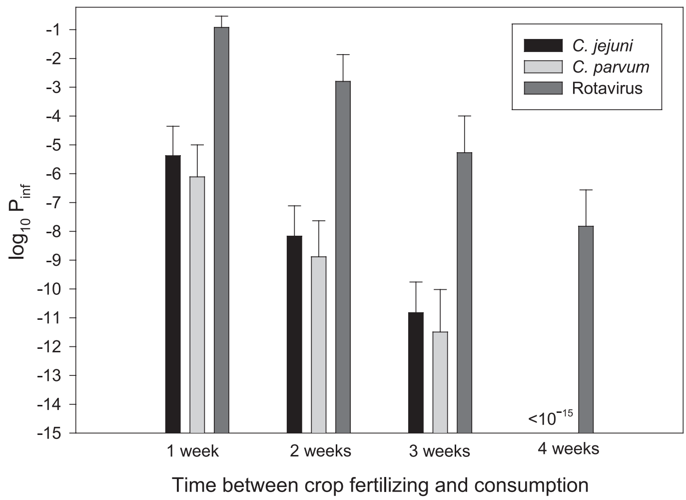

Figure 5.1
Mean probability of infection by pathogens following ingestion of crops fertilized with unstored urine with varying withholding periods (P_{inf} = probability of infection)

5.5 Health protection measures

A variety of health protection measures can be used to reduce health risks for local communities, workers and their families and for the consumers of the fertilized or irrigated products.

Hazards associated with the consumption of excreta-fertilized products include excreta-related pathogens. The risk from infectious diseases is significantly reduced if foods are eaten after proper handling and adequate cooking. The following health protection measures have an impact on product consumers:

- excreta and greywater treatment;
- crop restriction;
- waste application and withholding periods between fertilization and harvest to allow die-off of remaining pathogens;
- hygienic food handling and food preparation practices;
- health and hygiene promotion;
- produce washing, disinfection and cooking.

Workers and their families may be exposed to excreta-related and vector-borne pathogens (in certain locations) through excreta and greywater use activities. Excreta and greywater treatment is a measure to prevent diseases associated with excreta and greywater but will not directly impact vector-borne diseases. Other health protection measures for workers and their families include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at farms;
- health and hygiene promotion;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers. If they do not have access to safe drinking-water, they may use contaminated irrigation water for drinking or for domestic purposes. Children may also play or swim in the contaminated water. Similarly, if the activities result in increased vector breeding, then vector-borne diseases can affect local communities, even if they do not have direct access to the fields. To reduce health hazards, the following health protection measures for local communities may be used:

- excreta and greywater treatment;
- limited contact during handling and controlled access to fields;
- access to safe drinking-water and sanitation facilities in local communities;
- health and hygiene promotion;
- disease vector and intermediate host control;
- reduced vector contact.

5.6 Monitoring and system assessment

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated excreta or greywater; crops) meets treatment targets and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring in larger systems can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing).

The most effective means of consistently ensuring safety in the agricultural use of excreta and greywater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process from waste generation to treatment, use of excreta as fertilizers or use of greywater for irrigation purposes and product use or consumption. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan.

5.7 Sociocultural aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce excreta or greywater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs and public perceptions of excreta and greywater use vary so widely in different parts of the world that one cannot assume that any of the local practices that have evolved in relation to such use can be readily transferred elsewhere. Even when projects are technically well planned and all of the relevant health protection measures have been included, they can fail if cultural beliefs and public perceptions have not been adequately accounted for.

5.8 Environmental aspects

Excreta are an important source of nutrients for many farmers. The direct use of excreta and greywater on arable land tends to minimize the environmental impact in both the local and global context. Reuse of excreta on arable land secures valuable fertilizers for crop production and limits the negative impact on water bodies. The environmental impact of different sanitation systems can be measured in terms of the conservation and use of natural resources, discharges to water bodies, air emissions and the impacts on soils. In this type of assessment, source separation and household-centred use systems frequently score more favourably than conventional systems.

Application of excreta and greywater to agricultural land will reduce the direct impacts on water bodies. As for any type of fertilizer, however, the nutrients may percolate into the groundwater if applied in excess or flushed into the surface water after excessive rainfall. This impact will always be less than that of the direct use of water bodies as the primary recipient of excreta and greywater. Surface water bodies are affected by agricultural drainage and runoff. Impacts depend on the type of water body (rivers, agricultural channels, lakes or dams) and their use, as well as the hydraulic retention time and the function it performs within the ecosystem.

Phosphorus is an essential element for plant growth, and external phosphorus from mined phosphate is usually supplied in agriculture in order to increase plant productivity. World supplies of accessible mined phosphate are diminishing. Approximately 25% of the mined phosphorus ends up in aquatic environments or is buried in landfills or other sinks. This discharge into aquatic environments is damaging, as it causes eutrophication of water bodies. Urine alone contains more than 50% of the phosphorus excreted by humans. Thus, the diversion and use of urine in agriculture can aid crop production and reduce the costs of and need for advanced wastewater treatment processes to remove phosphorus from the treated effluents.

5.9 Economic and financial considerations

Economic factors are especially important when the viability of a new project is appraised, but even an economically worthwhile project can fail without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of excreta. Economic analysis seeks to establish the feasibility of a project and enables comparisons between different options. The cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) also need to be included in a cost analysis. This can be facilitated by the use of multiple-objective decision-making processes.

Financial planning considers how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The ability to profitably sell products fertilized with excreta or irrigated with greywater also needs analysis.

5.10 Policy aspects

Appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels facilitate safe excreta and greywater management practices. In many countries where such practices take place, these frameworks and regulations are lacking.

Policy is the set of procedures, rules, decision-making criteria and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations; economic measures; information and education programmes; and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate the safe use of excreta as fertilizer, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for adequate sanitation based on the WHO Guidelines will protect public health optimally when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water.

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

5.11 Planning and implementation

Planning and implementation of programmes for the agricultural use of excreta and greywater require a comprehensive, progressive and incremental approach that responds to the greatest health priorities first. This integrated approach should be based on an assessment of the current sanitary situation and should take into account the local aspects related to water supply and solid waste management. A sound basis for such an approach can be found in the Bellagio Principles, which prescribe that stakeholders be provided with the relevant information, enabling them to make "informed choices." Thus, a wider range of decision-making and evaluation criteria for sanitation services can be applied.

In addition, project planning requires consideration of several different issues, identified through the involvement of stakeholders applying participatory methods and considering treatment, crop restriction, waste application, human exposure control, costs, technical aspects, support services and training, both for risk reduction and for maximizing the benefits from an individual as well as a community point of view.

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Notes

1. **Bold type** indicates references to tables; *italic* indicates references to figures.
2. Management summaries are not indexed.

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Annex 1
Glossary of terms used in Guidelines

This glossary does not aim to provide precise definitions of technical or scientific terms, but rather to explain in plain language the meaning of terms frequently used in these Guidelines.

Abattoir – Slaughterhouse where animals are killed and processed into food and other products.

Advanced or tertiary treatment – Treatment steps added after the secondary treatment stage to remove specific constituents, such as nutrients, suspended solids, organics, heavy metals or dissolved solids (e.g. salts).

Anaerobic pond – Treatment pond where anaerobic digestion and sedimentation of organic wastes occur; usually the first type of pond in a waste stabilization pond system; requires periodic removal of accumulated sludge formed as a result of sedimentation.

Aquaculture – Raising plants or animals in water (water farming).

Aquifer – A geological area that produces a quantity of water from permeable rock.

Arithmetic mean – The sum of the values of all samples divided by the number of samples; provides the average number per sample.

Biochemical oxygen demand (BOD) – The amount of oxygen that is required to biochemically convert organic matter into inert substances; an indirect measure of the amount of biodegradable organic matter present in the water or wastewater.

Blackwater – Source-separated wastewater from toilets, containing faeces, urine and flushing water (and eventually anal cleansing water in "washing" communities).

Buffer zone – Land that separates wastewater, excreta and/or greywater use areas from public access areas; used to prevent exposures to the public from hazards associated with wastewater, excreta and/or greywater.

Cartage – The process of manually transporting faecal material off site for disposal or treatment.

Coagulation – The clumping together of particles to increase the rate at which sedimentation occurs. Usually triggered by the addition of certain chemicals (e.g. lime, aluminium sulfate, ferric chloride).

Constructed wetlands – Engineered pond or tank-type units to treat faecal sludge or wastewater; consist of a filtering body planted with aquatic emergent plants.

Cost–benefit analysis – An analysis of all the costs of a project and all of the benefits. Projects that provide the most benefits at the least cost are the most desirable.

Cyst – Environmentally resistant infective parasitic life stage (e.g. *Giardia*, *Taenia*).

Cysticercosis – Infection with *Taenia solium* (pig tapeworm) sometimes leads to cysticerci (an infective life stage) encysting in the brain of humans, leading to neurological symptoms such as epilepsy.

Depuration – Transfer of fish to clean water prior to consumption in an attempt to purge their bodies of contamination, potentially including some pathogenic microorganisms.

Diarrhoea – Loose, watery and frequent bowel movements, often associated with an infection.

Disability adjusted life years (DALYs) – Population metric of life years lost to disease due to both morbidity and mortality.

Disease – Symptoms of illness in a host, e.g. diarrhoea, fever, vomiting, blood in urine, etc.

Disinfection – The inactivation of pathogenic organisms using chemicals, radiation, heat or physical separation processes (e.g. membranes).

Drain – A conduit or channel constructed to carry off stormwater runoff, wastewater or other surplus water. Drains can be open ditches or lined, unlined or buried pipes.

Drip irrigation – Irrigation delivery systems that deliver drips of water directly to plants through pipes. Small holes or emitters control the amount of water that is released to the plant. Drip irrigation does not contaminate aboveground plant surfaces.

Dual-media filtration – Filtration technique that uses two types of filter media to remove particulate matter with different chemical and physical properties (e.g. sand, anthracite, diatomaceous earth).

Effluent – Liquid (e.g. treated or untreated wastewater) that flows out of a process or confined space).

Encyst – The development of a protective cyst for the infective stage of different parasites (e.g. helminths such as foodborne trematodes, tapeworms and some protozoa, such as *Giardia*).

Epidemiology – The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.

Escherichia coli **(*E. coli*)** – A bacterium found in the gut, used as an indicator of faecal contamination of water.

Excreta – Faeces and urine (see also faecal sludge, septage and nightsoil).

Exposure – Contact of a chemical, physical or biological agent with the outer boundary of an organism (e.g. through inhalation, ingestion or dermal contact).

Exposure assessment – The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent of exposure to one or more contaminated media.

Facultative pond – Aerobic pond used to degrade organic matter and inactivate pathogens; usually the second type of pond in a waste stabilization pond system.

Faecal sludge – Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Septage, the faecal sludge collected from septic tanks, is included in this term (see also excreta and nightsoil).

Flocculation – The agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means.

Geometric mean – A measure of central tendency, just like a median. It is different from the traditional mean (which is called the arithmetic mean) because it uses multiplication rather than addition to summarize data values. The geometric mean is a useful summary when changes in the data occur in a relative fashion.

Greywater – Water from the kitchen, bath and/or laundry, which generally does not contain significant concentrations of excreta.

Groundwater – Water contained in rocks or subsoil.

Grow-out pond – Pond used to raise adult fish from fingerlings.

Hazard – A biological, chemical, physical or radiological agent that has the potential to cause harm.

Health-based target – A defined level of health protection for a given exposure. This can be based on a measure of disease, e.g. 10^{-6} DALY per person per year, or the absence of a specific disease related to that exposure.

Health impact assessment – The estimation of the effects of any specific action (plans, policies or programmes) in any given environment on the health of a defined population.

High-growing crops – Crops that grow above the ground and do not normally touch it (e.g. fruit trees).

High-rate treatment processes – Engineered treatment processes characterized by high flow rates and low hydraulic retention times. Usually include a primary treatment step to settle solids followed by a secondary treatment step to biodegrade organic substances.

Hydraulic retention time – Time the wastewater takes to pass through the system.

Hypochlorite – Chemical frequently used for disinfection (sodium or calcium hypochlorite).

Indicator organisms – Microorganisms whose presence is indicative of faecal contamination and possibly of the presence of more harmful microorganisms.

Infection – The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea). Infection can be measured by detecting infectious agents in excreta or colonized areas or through measurement of a host immune response (i.e. the presence of antibodies against the infectious agent).

Intermediate host – The host occupied by juvenile stages of a parasite prior to the definitive host and in which asexual reproduction often occurs (e.g. for foodborne trematodes or schistosomes, the intermediate hosts are specific species of snails).

Legislation – Law enacted by a legislative body or the act of making or enacting laws.

Localized irrigation – Irrigation application technologies that apply the water directly to the crop, through either drip irrigation or bubbler irrigation. Generally use less water and result in less crop contamination and reduce human contact with the wastewater.

Log reduction – Organism removal efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.

Low-growing crops – Crops that grow below, on or near the soil surface (e.g. carrots, lettuce).

Low-rate biological treatment systems – Use biological processes to treat wastewater in large basins, usually earthen ponds. Characterized by long hydraulic retention times. Examples of low-rate biological treatment processes include waste stabilization ponds, wastewater storage and treatment reservoirs and constructed wetlands.

Maturation pond – An aerobic pond with algal growth and high levels of bacterial removal; usually the final type of pond in a waste stabilization pond system.

Median – The middle value of a sample series (50% of the values in the sample are lower and 50% are higher than the median).

Membrane filtration – Filtration technique based on a physical barrier (a membrane) with specific pore sizes that traps contaminants larger than the pore size on the top surface of the membrane. Contaminants smaller than the specified pore size may pass through the membrane or may be captured within the membrane by some other mechanism.

Metacercariae (infective) – Life cycle stage of trematode parasites infective to humans. Metacercariae can form cysts in fish muscle tissue or on the surfaces of plants, depending on the type of trematode species.

Multiple barriers – Use of more than one preventive measure as a barrier against hazards.

Nightsoil – Untreated excreta transported without water, e.g. via containers or buckets; often used as a popular term in an unspecific manner to designate faecal matter of any origin; its technical use is therefore not recommended.

Off-site sanitation – System of sanitation where excreta are removed from the plot occupied by the dwelling and its immediate surroundings.

On-site sanitation – System of sanitation where the means of storage are contained within the plot occupied by the dwelling and its immediate surroundings. For some systems (e.g. double-pit or vault latrines), treatment of the faecal matter happens on site also, through extended in-pit consolidation and storage. With other systems (e.g. septic tanks, single-pit or vault installations), the sludge has to be collected and treated off site (see also faecal sludge).

Oocyst – A structure that is produced by some coccidian protozoa (i.e. *Cryptosporidium*) as a result of sexual reproduction during the life cycle. The oocyst is usually the infectious and environmental stage, and it contains sporozoites. For the enteric protozoa, the oocyst is excreted in the faeces.

Operational monitoring – The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.

Overhanging latrine – A latrine that empties directly into a pond or other water body.

Pathogen – A disease-causing organism (e.g. bacteria, helminths, protozoa and viruses).

pH – An expression of the intensity of the basic or acid condition of a liquid.

Policy – The set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities and often allocate resources for their implementation. Policies are implemented through four types of policy instruments: laws and regulations; economic measures; information and education programmes; and assignment of rights and responsibilities for providing services.

Primary treatment – Initial treatment process used to remove settleable organic and inorganic solids by sedimentation and floating substances (scum) by skimming. Examples of primary treatment include primary sedimentation, chemically enhanced primary sedimentation and upflow anaerobic sludge blanket reactors.

Quantitative microbial risk assessment (QMRA) – Method for assessing risk from specific hazards through different exposure pathways. QMRA has four components: hazard identification; exposure assessment; dose–response assessment; and risk characterization.

Regulations – Rules created by an administrative agency or body that interpret the statute(s) setting out the agency's purpose and powers or the circumstances of applying the statute.

Restricted irrigation – Use of wastewater to grow crops that are not eaten raw by humans.

Risk – The likelihood of a hazard causing harm in exposed populations in a specified time frame, including the magnitude of that harm.

Risk assessment – The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences.

Risk management – The systematic evaluation of the wastewater, excreta or greywater use system, the identification of hazards and hazardous events, the assessment of risks and the development and implementation of preventive strategies to manage the risks.

Secondary treatment – Wastewater treatment step that follows primary treatment.

Involves the removal of biodegradable dissolved and colloidal organic matter using high-rate, engineered aerobic biological treatment processes. Examples of secondary treatment include activated sludge, trickling filters, aerated lagoons and oxidation ditches.

Septage – Sludge removed from septic tanks.

Septic tank – An underground tank that treats wastewater by a combination of solids settling and anaerobic digestion. The effluents may be discharged into soak pits or small-bore sewers.

Sewage – Mixture of human excreta and water used to flush the excreta from the toilet and through the pipes; may also contain water used for domestic purposes.

Sewer – A pipe or conduit that carries wastewater or drainage water.

Sewerage – A complete system of piping, pumps, basins, tanks, unit processes and infrastructure for the collection, transporting, treating and discharging of wastewater.

Sludge – A mixture of solids and water that settles to the bottom of latrines, septic tanks and ponds or is produced as a by-product of wastewater treatment (sludge produced from the treatment of municipal or industrial wastewater is not discussed).

Source separation – Diversion of urine, faeces, greywater or all, followed by separate collection (and treatment).

Subsurface irrigation – Irrigation below the soil surface; prevents contamination of aboveground parts of crops

Surface water – All water naturally open to the atmosphere (e.g. rivers, streams, lakes and reservoirs).

Thermotolerant coliforms – Group of bacteria whose presence in the environment usually indicates faecal contamination; previously called faecal coliforms.

Tolerable daily intake (TDI) – Amount of toxic substance that can be ingested on a daily basis over a lifetime without exceeding a certain level of risk

Tolerable health risk – Defined level of health risk from a specific exposure or disease that is tolerated by society, used to set health-based targets.

Turbidity – The cloudiness of water caused by the presence of fine suspended matter.

Ultraviolet (UV) radiation – Light waves shorter than visible blue-violet waves of the spectrum (from 380 to 10 nanometres) used for pathogen inactivation (bacteria, protozoa and viruses).

Unrestricted irrigation – The use of treated wastewater to grow crops that are normally eaten raw.

Upflow anaerobic sludge blanket reactor – High-rate anaerobic unit used for the primary treatment of domestic wastewater. Wastewater is treated during its passage through a sludge layer (the sludge “blanket”) composed of anaerobic bacteria. The treatment process is designed primarily for the removal of organic matter (biochemical oxygen demand).

Validation – Testing the system and its individual components to prove that it is capable of meeting the specified targets (i.e. microbial reduction targets). Should take place when a new system is developed or new processes are added.

Vector – Insect that carries disease from one animal or human to another (e.g. mosquitoes).

Vector-borne disease – Diseases that can be transmitted from human to human via insects (e.g. malaria).

Verification monitoring – The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

Waste-fed aquaculture – Use of wastewater, excreta and/or greywater as inputs to aquacultural systems.

Waste stabilization ponds (WSP) – Shallow basins that use natural factors such as sunlight, temperature, sedimentation, biodegradation, etc., to treat wastewater or faecal sludges. Waste stabilization pond treatment systems usually consist of anaerobic, facultative and maturation ponds linked in series.

Wastewater – Liquid waste discharged from homes, commercial premises and similar sources to individual disposal systems or to municipal sewer pipes, and which contains mainly human excreta and used water. When produced mainly by household and commercial activities, it is called domestic or municipal wastewater or domestic sewage. In this context, domestic sewage does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health or the environment.

Withholding period – Time to allow pathogen die-off between waste application and harvest.

The third edition of the WHO ***Guidelines for the safe use of wastewater, excreta and greywater*** has been extensively updated to take account of new scientific evidence and contemporary approaches to risk management. The revised Guidelines reflect a strong focus on disease prevention and public health principles.

This new edition responds to a growing demand from WHO Member States for guidance on the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Its target audience includes environmental and public health scientists, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The Guidelines are presented in four separate volumes: ***Volume 1: Policy and regulatory aspects; Volume 2:Wastewater use in agriculture; Volume 3: Wastewater and excreta use in aquaculture; and Volume 4: Excreta and greywater use in agriculture.***

Volume 1 of the Guidelines presents policy issues and regulatory measures distilled from the technical detail found in volumes 2, 3 and 4. Those faced with the need to expedite the development of policies, procedures and regulatory frameworks, at national and local government levels, will find the essential information in this volume. It also includes summaries of the other volumes in the series.

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SAFE USE OF WASTEWATER, EXCRETA AND GREYWATER

VOLUME II

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LIST OF ACRONYMS AND ABBREVIATIONS

ADI	acceptable daily intake
BOD	biochemical oxygen demand
2,4-D	2,4-dichlorophenoxyacetic acid
DALY	disability adjusted life year
DDT	dichlorodiphenyltrichloroethane
EC_{DW}	electrical conductivity of the drainage water
EC_W	electrical conductivity of the irrigation water
FAO	Food and Agriculture Organization of the United Nations
HIA	health impact assessment
ID_{50}	median infective dose
LF	leaching fraction
MDG	Millennium Development Goal
NOAEL	no-observed-adverse-effect level
OR	odds ratio
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PPPY	per person per year
QMRA	quantitative microbial risk assessment
SAR	sodium adsorption ratio
SAT	soil aquifer treatment
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
TC	total coliforms
TDI	tolerable daily intake
TDS	total dissolved solids
TN	total nitrogen
TOC	total organic carbon
TSS	total suspended solids
UASB	upflow anaerobic sludge blanket
WHO	World Health Organization
WTO	World Trade Organization

PREFACE

The United Nations General Assembly (2000) adopted the Millennium Development Goals (MDGs) on 8 September 2000. The MDGs that are most directly related to the use of wastewater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of wastewater in agriculture can help communities to grow more food and make use of precious water and nutrient resources. However, it should be done safely to maximize public health gains and environmental benefits.

To protect public health and facilitate the rational use of wastewater and excreta in agriculture and aquaculture, in 1973, the World Health Organization (WHO) developed guidelines for wastewater use in agriculture and aquaculture under the title *Reuse of effluents: Methods of wastewater treatment and health safeguards* (WHO, 1973). After a thorough review of epidemiological studies and other information, the guidelines were updated in 1989 as *Health guidelines for the use of wastewater in agriculture and aquaculture* (WHO, 1989). These guidelines have been very influential, and many countries have adopted or adapted them for their wastewater and excreta use practices.

Wastewater use in agriculture is increasingly considered a method combining water and nutrient recycling, increased household food security and improved nutrition for poor households. Interest in wastewater use in agriculture has been driven by water scarcity, lack of availability of nutrients and concerns about health and environmental effects. It was necessary to update the guidelines to take into account recent scientific evidence concerning pathogens, chemicals and other factors, including changes in population characteristics, changes in sanitation practices, better methods for evaluating risk, social/equity issues and sociocultural practices. There was a particular need to conduct a review of both risk assessment and epidemiological data.

In order to better package the guidelines for appropriate audiences, the third edition of the *Guidelines for the safe use of wastewater, excreta and greywater* is presented in four separate volumes: *Volume 1: Policy and regulatory aspects*; *Volume 2: Wastewater use in agriculture*; *Volume 3: Wastewater and excreta use in aquaculture*; and *Volume 4: Excreta and greywater use in agriculture.*

WHO water-related guidelines are based on scientific consensus and best available evidence and are developed through broad participation. The *Guidelines for the safe use of wastewater, excreta and greywater* are designed to protect the health of farmers (and their families), local communities and product consumers. They are meant to be adapted to take into consideration national, sociocultural, economic and environmental factors. Where the Guidelines relate to technical issues — for example, wastewater treatment — technologies that are readily available and achievable (from both technical and economic standpoints) are explicitly noted, but others are not excluded. Overly strict standards may not be sustainable and, paradoxically, may lead to reduced health protection, because they may be viewed as unachievable under local circumstances and, thus, ignored. The Guidelines therefore strive to maximize overall public health benefits and the beneficial use of scarce resources.

Following an expert meeting in Stockholm, Sweden, WHO published *Water quality: Guidelines, standards and health — Assessment of risk and risk management for water-related infectious disease* (Fewtrell & Bartram, 2001). This document presents a harmonized framework for the development of guidelines and standards for water-related microbial hazards. This framework involves the assessment of health risks prior to the setting of health targets, defining basic control approaches and evaluating the impact of these combined approaches on public health status. The framework is flexible and allows countries to take into consideration associated health risks that may result from microbial exposures through drinking-water or contact with recreational or occupational water. It is important that health risks from the use of wastewater in agriculture be put into the context of the overall level of disease within a given population.

This volume of the *Guidelines for the safe use of wastewater, excreta and greywater* provides information on the assessment and management of risks associated with microbial hazards and toxic chemicals. It explains requirements to promote the safe use of wastewater in agriculture, including minimum procedures and specific health-based targets, and how those requirements are intended to be used. This volume also describes the approaches used in deriving the guidelines, including health-based targets, and includes a substantive revision of approaches to ensuring microbial safety.

This edition of the Guidelines supersedes previous editions (1973 and 1989). The Guidelines are recognized as representing the position of the United Nations system on issues of wastewater, excreta and greywater use and health by "UN-Water," the coordinating body of the 24 United Nations agencies and programmes concerned with water issues. This edition of the Guidelines further develops concepts, approaches and information in previous editions and includes additional information on:

- the context of overall waterborne disease burden in a population and how the use of wastewater in agriculture may contribute to that burden;
- the Stockholm Framework for development of water-related guidelines and the setting of health-based targets;
- risk analysis;
- risk management strategies, including quantification of different health protection measures;
- chemicals;
- guideline implementation strategies.

The revised Guidelines will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health and water and waste management, including environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

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EXECUTIVE SUMMARY

This volume of the World Health Organization's (WHO) *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding the impact of wastewater use in agriculture on the health of product consumers, workers and their families and local communities. Health hazards are identified for each vulnerable group, and appropriate health protection measures to mitigate the risks are discussed.

The primary aim of the Guidelines is to maximize public health protection and the beneficial use of important resources. The purpose of this volume of the Guidelines is to ensure that the use of wastewater in agriculture is made as safe as possible, so that the nutritional and household food security benefits can be shared widely within communities whose livelihood depends on wastewater-irrigated agriculture. Thus, the adverse health impacts of wastewater use in agriculture should be carefully weighed against the benefits to health and the environment associated with these practices. Yet this is not a matter of simple trade-offs. Wherever wastewater use in agriculture contributes significantly to food security and nutritional status, the point is to identify associated hazards, define the risks they represent to vulnerable groups and design measures aimed at reducing these risks.

This volume of the Guidelines is intended to be used as the basis for the development of international and national approaches (including standards and regulations) to managing the health risks from hazards associated with wastewater use in agriculture, as well as providing a framework for national and local decision-making. The information provided is applicable to the intentional use of wastewater in agriculture and is also relevant where faecally contaminated water is used for irrigation unintentionally.

The Guidelines provide an integrated preventive management framework for safety applied from the point of wastewater generation to the consumption of products grown with the wastewater and excreta. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or excreta or consuming products grown with wastewater or excreta and provide information that is then used to derive health-based targets. Neither the minimum good practices nor the health-based targets are mandatory limits. The preferred approaches adopted by national or local authorities towards implementation of the Guidelines, including health-based targets, may vary depending on local social, cultural, environmental and economic conditions, as well as knowledge of routes of exposure, the nature and severity of hazards and the effectiveness of health protection measures available.

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health, water resources development and wastewater management. The target audience may include public health, agricultural and environmental scientists, agriculture professionals, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

Introduction

Wastewater is increasingly used for agriculture in both developing and industrialized countries, and the principal driving forces are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from improper disposal of wastewater;
- population increase and related increased demand for food and fibre;
- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the Millennium Development Goals (MDGs), especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

It is estimated that, within the next 50 years, more than 40% of the world's population will live in countries facing water stress or water scarcity (Hinrichsen, Robey & Upadhyay, 1998). Growing competition between the agricultural and urban uses of high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this ever scarcer resource.

Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). Population growth increases both the demand for fresh water and the amount of wastes that are discharged into the environment, thus leading to more pollution of clean water sources.

Wastewater is often a reliable year-round source of water, and it contains the nutrients necessary for plant growth. The value of wastewater has long been recognized by farmers worldwide. The use of wastewater in agriculture is a form of nutrient and water recycling, and this often reduces downstream environmental impacts on soil and water resources.

The United Nations General Assembly adopted the MDGs on 8 September 2000 (United Nations General Assembly, 2000). The MDGs most directly related to the use of wastewater in agriculture are "Goal 1: Eliminate extreme poverty and hunger" and "Goal 7: Ensure environmental sustainability." The use of wastewater in agriculture can help communities to grow more food and conserve precious water and nutrient resources.

The Stockholm Framework

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. This provides a harmonized framework for the development of health-based guidelines and standards in terms of water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health. The Stockholm Framework provides the conceptual framework for these Guidelines and other WHO water-related guidelines.

Assessment of health risk

Three types of evaluations are used to assess risk: microbial and chemical laboratory analysis, epidemiological studies and quantitative microbial (and chemical) risk assessment.

Wastewater contains a variety of different pathogens, many of which are capable of survival in the environment (in the wastewater, on the crops or in the soil) long enough to be transmitted to humans. Table 1 presents a summary of the information available from epidemiological studies of infectious disease transmission related to

Table 1. Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health risks		
	Helminth infections	**Bacterial/virus infections**	**Protozoal infections**
Consumers	Significant risk of *Ascaris* infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of *Ascaris* infection for both adults and children in contact with untreated wastewater; risk remains, especially for children, when wastewater treated to <1 nematode egg per litre; increased risk of hookworm infection in workers	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection was found insignificant for contact with both untreated and treated wastewater; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	*Ascaris* transmission not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 TC/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation not found to be associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

TC, total coliforms

wastewater use in agriculture. In places where wastewater is used without adequate treatment, the greatest health risks are usually associated with intestinal helminths.

Table 2 presents a summary of the quantitative microbial risk assessment (QMRA) evidence for transmission of rotavirus infection due to different exposures. The risks for rotavirus transmission were always estimated to be higher than the risks associated with *Campylobacter* or *Cryptosporidium* infections.

Table 2. Summary of QMRA results for rotavirus[a] infection risks for different exposures

Exposure scenario	Water quality[b] (*E. coli*/100 ml wastewater or 100 g soil)	Median infection risks per person per year	Notes
Unrestricted irrigation (crop consumers)			
Lettuce	10^3–10^4	10^{-3}	100 g eaten raw per person every 2 days
			10–15 ml wastewater remaining on crop
Onion	10^3–10^4	5×10^{-2}	100 g eaten raw per person per week for 5 months
			1–5 ml wastewater remaining on crop
Restricted irrigation (farmers or other heavily exposed populations)			
Highly mechanized	10^5	10^{-3}	100 days exposure per year
			1–10 mg soil consumed per exposure
Labour intensive	10^3–10^4	10^{-3}	150–300 days exposure per year
			10–100 mg soil consumed per exposure

[a] Risks estimated for *Campylobacter* and *Cryptosporidium* are lower.
[b] Non-disinfected effluents.

Less evidence is available for health risks from chemicals. The evidence that is available is based on quantitative risk assessment and indicates that the uptake of chemicals by plants is highly dependent on the types of chemicals and the physical and chemical properties of soils.

Health-based targets

Health-based targets define a level of health protection that is relevant to each hazard. A health-based target can be based on a standard metric of disease, such as a DALY (e.g. 10^{-6} DALYs), or it can be based on an appropriate health outcome, such as the prevention of the transmission of vector-borne diseases resulting from exposures to wastewater use in agricultural practices. To achieve a health-based target, health protection measures are developed. Usually a health-based target can be achieved through a combination of health protection measures targeted at different components of the system. Figure 1 illustrates different combinations of health protection measures that can be used to achieve the 10^{-6} DALYs health-based target for excreta-related diseases.

Table 3 describes health-based targets for agriculture. The health-based targets for rotavirus are based on QMRA indicating the $\log_{10}$ pathogen reduction required to achieve 10^{-6} DALY for different exposures. To develop health-based targets for helminth infections, epidemiological evidence was used. This evidence demonstrated that excess helminth infections (for both product consumers and farmers) could not be measured when wastewater quality of ≤1 helminth egg per litre was used for irrigation. This level of health protection could also be met by treatment of wastewater or by a combination of wastewater treatment and washing of produce to protect consumers of raw vegetables; or by wastewater treatment and the use of personal protective equipment (shoes, gloves) to protect workers. When children less than 15 years old are exposed in the fields, either additional wastewater treatment (to achieve a wastewater quality of ≤0.1 helminth egg per litre) or the addition of other health protection measures (e.g. anthelminthic treatment) should be considered.

Table 3. Health-based targets for wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤ 1 [b,c]
Onion		7	≤ 1 [b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤ 1 [b,c]
Labour intensive		4	≤ 1 [b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d]
Low-growing crops		4	≤ 1 [c]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction.

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy).

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre.

[d] No crops to be picked up from the soil.

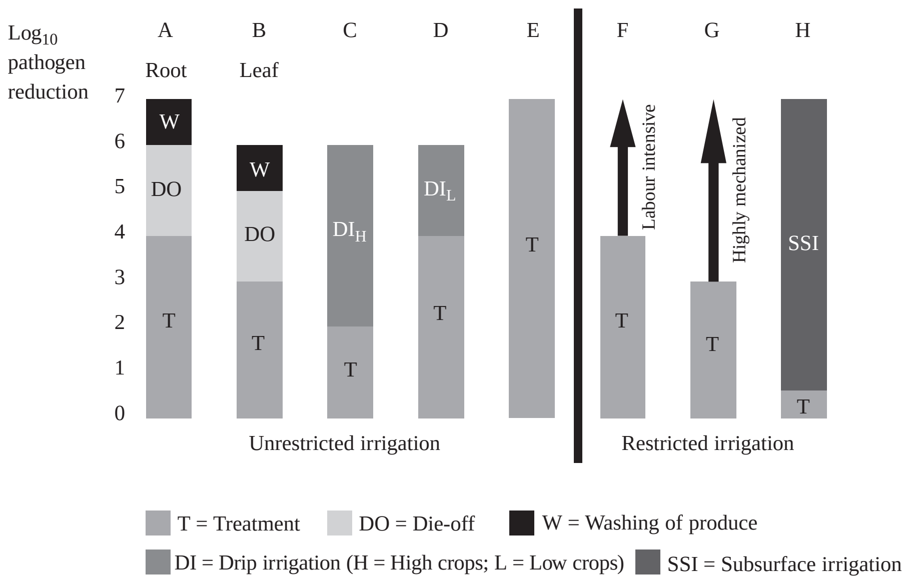

Figure 1

Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of $\leq 10^{-6}$ DALYs per person per year

Table 4. Maximum tolerable soil concentrations of various toxic chemicals based on human health protection

Chemical	Soil concentration (mg/kg)
Element	
Antimony	36
Arsenic	8
Barium[a]	302
Beryllium[a]	0.2
Boron[a]	1.7
Cadmium	4
Fluorine	635
Lead	84
Mercury	7
Molybdenum[a]	0.6
Nickel	107
Selenium	6
Silver	3
Thallium[a]	0.3
Vanadium[a]	47
Organic compound	
Aldrin	0.48
Benzene	0.14
Chlordane	3
Chlorobenzene	211
Chloroform	0.47
2,4-D	0.25
DDT	1.54
Dichlorobenzene	15
Dieldrin	0.17
Dioxins	0.000 12
Heptachlor	0.18
Hexachlorobenzene	1.40
Lindane	12
Methoxychlor	4.27
PCBs	0.89
PAHs (as benzo[*a*]pyrene)	16
Pentachlorophenol	14
Phthalate	13 733
Pyrene	41
Styrene	0.68
2,4,5-T	3.82
Tetrachloroethane	1.25
Tetrachloroethylene	0.54
Toluene	12
Toxaphene	0.0013
Trichloroethane	0.68

[a] The computed numerical limits for these elements are within the ranges that are typical for soils.

Table 4 presents maximum soil concentrations for different chemicals based on health risk assessment. Concentrations of chemicals that impact agricultural productivity are described in Annex 1.

Health protection measures

A variety of health protection measures can be used to reduce health risks to consumers, workers and their families and local communities.

Hazards associated with the consumption of wastewater-irrigated products include excreta-related pathogens and some toxic chemicals. The risk from infectious pathogens is significantly reduced if foods are eaten after thorough cooking. Cooking has little or no impact on the concentrations of toxic chemicals that might be present. The following health protection measures have an impact on product consumers:

- wastewater treatment;
- crop restriction;
- waste application techniques that minimize contamination (e.g. drip irrigation);
- withholding periods to allow pathogen die-off after the last wastewater application;
- hygienic practices at food markets and during food preparation;
- health and hygiene promotion;
- produce washing, disinfection and cooking;
- chemotherapy and immunization.

Wastewater use activities may lead to the exposure of workers and their families to excreta-related diseases (including schistosomiasis), skin irritants and vector-borne diseases (in certain locations). Wastewater treatment is a control measure for excreta-related diseases, skin irritants and schistosomiasis but may not have much impact on vector-borne diseases. Other health protection measures for workers and their families include:

- use of personal protective equipment;
- access to safe drinking-water and sanitation facilities at farms;
- health and hygiene promotion;
- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Local communities are at risk from the same hazards as workers, especially if they have access to wastewater-irrigated fields. If they do not have access to safe drinking-water, they may use contaminated irrigation water for drinking or for domestic purposes. Children may also play or swim in the contaminated water. Similarly, if wastewater irrigation activities result in increased vector breeding, then local communities may be affected by vector-borne diseases, even if they do not have direct access to the irrigated fields. To reduce health hazards, the following health protection measures for local communities may be used:

- wastewater treatment;
- restricted access to irrigated fields and hydraulic structures;
- access to safe recreational water, especially for adolescents;
- access to safe drinking-water and sanitation facilities in local communities;
- health and hygiene promotion;

- chemotherapy and immunization;
- disease vector and intermediate host control;
- reduced vector contact.

Monitoring and system assessment

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process to ensure that the system is achieving the specified targets.

The three functions of monitoring are each used for different purposes at different times. Validation is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater; crops) meets treatment targets (e.g. microbial quality specifications) and ultimately the health-based targets. Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing).

The most effective means of consistently ensuring safety in the agricultural application of wastewater is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process from waste generation to treatment and use of wastewater to product use or consumption. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan.

Sociocultural aspects

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce wastewater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs vary so widely in different parts of the world that it is not possible to assume that any of the practices that have evolved in relation to wastewater use can be readily transferred elsewhere.

Closely associated with cultural beliefs is the public perception of wastewater use. Even when projects are technically well planned and all of the relevant health protection measures have been included, the project can fail if it does not account adequately for public perception.

Environmental aspects

Wastewater is an important source of water and nutrients for many farmers in arid and semi-arid climates. Sometimes it is the only water source available for agriculture. When wastewater use is well managed, it helps to recycle nutrients and water and therefore diminishes the cost of fertilizers or simply makes them accessible to farmers. Where wastewater treatment services are not provided, the use of wastewater in agriculture actually acts as a low-cost treatment method, taking advantage of the soil's capacity to naturally remove contamination. Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water bodies.

Nevertheless, wastewater use poses environmental risks. Possible effects and their relevance depend on each specific situation and how the wastewater is used. In many places, wastewater irrigation has arisen spontaneously and without planning — often the wastewater is untreated. In other situations, the use of wastewater in agriculture is strictly controlled. These practices will lead to different environmental impacts.

The properties of domestic wastewater and industrial wastewater differ. Generally, the use of domestic wastewater for irrigation poses less risk to the environment than the use of industrial wastewater, especially where industries use or produce highly toxic chemicals. Industrial discharges containing toxic chemicals are mixed with domestic wastewater in many countries, creating serious environmental problems and, where the wastewater is used for crop irrigation, endangering the health of the farmers and product consumers. Efforts should be made to reduce or eliminate practices that entail the mixing of domestic and industrial wastewater, particularly where wastewater is used for agriculture.

The use of wastewater in agriculture has the potential for both positive and negative environmental impacts. With careful planning and management, the use of wastewater in agriculture can be beneficial to the environment. Many of the environmental impacts (e.g. salinization of soil, contamination of water resources) can be reduced by good agricultural practices (as described in Annex 1).

Economic and financial considerations

Economic factors are especially important when the viability of a new scheme for the use of wastewater is being appraised, but even an economically worthwhile project can fail without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of wastewater. Economic analysis seeks to establish the economic feasibility of a project and enables comparisons between different options. The cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) also need to be included in a cost analysis. This can be facilitated by the use of multiple objective decision-making processes.

Financial planning looks at how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The possibility to profitably sell products grown with wastewater or to sell the treated wastewater also needs analysis.

Policy aspects

The safe management of wastewater in agriculture is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where wastewater use in agriculture takes place, these frameworks are lacking.

Policy is the set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and associated strategies allocate resources for their implementation. Policies are implemented through four types of instruments: laws and regulations, economic measures, information and education programmes and assignments of rights and responsibilities for providing services.

In developing a national policy framework to facilitate safe wastewater use in agriculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach. National approaches for safe wastewater use practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that would otherwise lead to reinfection (e.g. with intestinal helminths and other pathogens).

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but they should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced.

The use of wastewater in agriculture can have one or more of several objectives. Defining these objectives is important for developing a national policy framework. The right policies can facilitate the safe use of wastewater in agriculture. Current policies often already exist that impact these activities, both negatively and positively. Conducting an assessment of current policies is often helpful for developing a new national policy or for revising existing policies. The assessment should take place at two levels: from the perspective of both a policy-maker and a project manager. Policy-makers will want to assess the national policies, legislation, institutional framework and regulations to ensure that they meet the national wastewater use objectives (e.g. maximize economic returns without endangering public health or the environment). Project coordinators will want to ensure that current and future waste use activities will be able to comply with all relevant national and local laws and regulations.

The main considerations are:

- *Policy:* Are there clear policies on the use of wastewater? Is wastewater use encouraged or discouraged?
- *Legislation:* Is the use of wastewater governed in legislation? What are the rights and responsibilities of different stakeholders? Does a defined jurisdiction exist on the use of wastewater?
- *Institutional framework:* Which ministry/agency, organizations, etc. have the authority to control the use of wastewater at the national level and at the district/community level? Are the responsibilities of different ministries/agencies clear? Is there one lead ministry, or are there multiple ministries/agencies with overlapping jurisdictions? Which ministry/agency is responsible for developing regulations? Which ministry/agency monitors compliance with regulations? Which ministry/agency enforces the regulations?
- *Regulations:* Do regulations exist? Are the current regulations adequate to meet wastewater use objectives (protect public health, prevent environmental damage, meet produce quality standards for domestic and international trade, preserve livelihoods, conserve water and nutrients, etc.)? Are the current regulations being implemented? Is regulatory compliance being enforced?

It is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce), it is important to plan for the institutions, staff and resources necessary to ensure that the regulations are followed. It is important to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country.

Planning and implementation

Planning and implementation of wastewater irrigation programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for developing national programmes should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of wastewater use in agriculture relies on the assessment and understanding of eight important criteria: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility.

1 INTRODUCTION

This volume of the *Guidelines for the safe use of wastewater, excreta and greywater* describes the present state of knowledge regarding possible health impacts of wastewater use in agriculture. This chapter describes the objectives and general considerations related to the Guidelines and their target audience. It also provides some definitions and presents an overview of what World Health Organization (WHO) water-related guidelines are and how they relate to wastewater use in agriculture. Driving forces that impact wastewater use in agriculture are also described.

1.1 Objectives and general considerations

The primary objective of these Guidelines is to maximize the public health benefits of wastewater use in agriculture. To achieve this objective, strategies are needed, in the context of wastewater use, to minimize the transmission of infectious agents and the exposure to toxic chemicals for farmers and their families, for local communities and for product consumers. This can be achieved by minimizing human exposure to pathogens and toxic chemicals in the wastewater. Other objectives include, for example, managing the use of wastewater to maximize crop production and minimize environmental impacts. For these aspects, the reader is referred to publications by the Food and Agriculture Organization of the United Nations (FAO) (e.g. Ayers & Westcot, 1985; Pescod, 1992; Ongley, 1996; Westcot, 1997a, 1997b; Allen et al., 1998; Tanji & Kielen, 2002; see also Annex 1) and the United Nations Environment Programme's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (http://www.gpa.unep.org/).

The Guidelines are based on the development and use of health-based targets. Health-based targets establish a goal of attaining a certain level of health protection in an exposed population. This level of health can then be achieved by using a combination of management approaches (e.g. crop restriction, application techniques, human exposure control) and water quality targets to arrive at the specified health outcome. Achieving the health-based targets requires monitoring and system assessment, defining institutional and supervisory responsibilities, system documentation and independent confirmation that the system is working. Thus, the guidelines consist of both good practice advice and water quality specifications and may include:

- a level of management;
- a concentration of a constituent that does not represent a significant risk to the health of members of important user groups;
- a condition under which such transmissions or exposures are unlikely to occur; or
- a combination of the last two.

The Guidelines provide an integrated preventive management framework (see Box 1.1 and discussion on the Stockholm Framework in chapter 2) for safety applied from the point of waste generation to consumption of products grown with the wastewater. They describe reasonable minimum requirements of good practice to protect the health of the people using wastewater or consuming products grown with it, and they derive health-based targets and explain their adaptation. Neither the minimum good practices nor the health-based targets are mandatory limits. In order to define such limits, it is necessary to consider the Guidelines in the context of national environmental, social, economic and cultural conditions (WHO, 2004a).

Box 1.1 What are the Guidelines?

The WHO Guidelines are an integrated preventive management framework for maximizing the public health benefits of wastewater use in agriculture. The Guidelines are built around a health component and an implementation component. Health protection is dependent on both elements.

Health component:

- defines a level of health protection that is expressed as a health-based target for each hazard;
- identifies health protection measures that, used collectively, can achieve the specified health-based target.

Implementation component:

- establishes monitoring and system assessment procedures;
- defines institutional and supervisory responsibilities;
- requires system documentation;
- requires confirmation by independent surveillance.

The approach followed in these Guidelines is intended to support the establishment of national standards and regulations that can be readily implemented and enforced and are protective of public health. Each country should review its needs and capacities in developing a regulatory framework. Successful implementation of the Guidelines will require a broad-based policy framework that includes positive and negative incentives to alter behaviour and monitor and improve situations. Intersectoral coordination and cooperation at national and local levels and the development of suitable skills and expertise will facilitate implementation of the Guidelines.

In many situations, it will not be possible to fully implement the Guidelines at once. The Guidelines set target values designed in such a way as to allow progressive implementation. They are to be achieved over time in an orderly manner, depending on the current reality and the existing resources of each individual country or region. The greatest threats to health should be given the highest priority and addressed first. Over time, it should be possible to adjust risk management strategies to strive for the continual improvement of public health.

Ultimately, the judgement of safety — or what is a tolerable level of risk in particular circumstances — is a matter in which society as a whole has a role to play. The final judgement as to whether the benefit from using any of the guidelines and health-based targets as national or local standards justifies the cost is for each country to decide, in the context of national public health, environmental and socioeconomic realities and international trade regulations.

1.2 Target audience, definitions and scope

The revised *Guidelines for the safe use of wastewater, excreta and greywater* will be useful to all those concerned with issues relating to the safe use of wastewater, excreta and greywater, public health and water and waste management. The target audience may include environmental and public health scientists, educators, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

This volume of the Guidelines addresses the use of wastewater in agriculture. These Guidelines focus on wastewater consisting of domestic sewage that does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health or the environment. The ability to use wastewater with significant concentrations of industrial chemicals in agriculture should be determined on a case-by-case basis. Sludge derived from the treatment of municipal or industrial wastewater is not included in the scope of this document. Definitions of common terms used in this volume are presented in the glossary in Annex 4.

The public health aspects and the health-based targets for wastewater-irrigated agriculture are applicable to cases where wastewater is used indirectly (i.e. discharged into surface water, which is then abstracted and used for agriculture). In many areas, surface waters such as rivers used for irrigation may be highly contaminated, with properties similar to those of diluted wastewater.

1.3 Driving forces behind increasing wastewater use

Wastewater is being increasingly used for the irrigation of agricultural crops in both developing and industrialized countries. The principal forces driving the increasing use of wastewater are:

- increasing water scarcity and stress, and degradation of freshwater resources resulting from improper disposal of wastewater;
- population increase and related increased demand for food and fibre;
- a growing recognition of the resource value of wastewater and the nutrients it contains;
- the Millennium Development Goals (MDGs), especially the goals for ensuring environmental sustainability and eliminating poverty and hunger.

1.3.1 Increasing water scarcity and stress

Fresh water is already scarce in many parts of the world, and population growth in water-scarce regions will further increase its value. In 1995, 31 countries were classified as water-scarce or water-stressed, and it is estimated that 48 and 54 countries will fall into these categories by 2025 and 2050, respectively. These numbers do not include people living in arid regions of large countries where there is enough water but it is poorly distributed — e.g. China, India and the United States of America (China is predicted to reach water scarcity by 2050 and India by 2025) (Hinrichsen, Robey & Upadhyay, 1998). Growing competition between agriculture and urban areas for high-quality freshwater supplies, particularly in arid, semi-arid and densely populated regions, will increase the pressure on this resource.

1.3.2 Increasing population

Within the next 50 years, it is estimated that more than 40% of the world's population will live in countries facing water stress or water scarcity (Figure 1.1). Most population growth is expected to occur in urban and periurban areas in developing countries (United Nations Population Division, 2002). For example, most of the 19 cities predicted to grow the most rapidly during 2000–2015 (with populations expected to more than double in this period) are in chronically water-short regions of developing countries (United Nations Population Division, 2002).

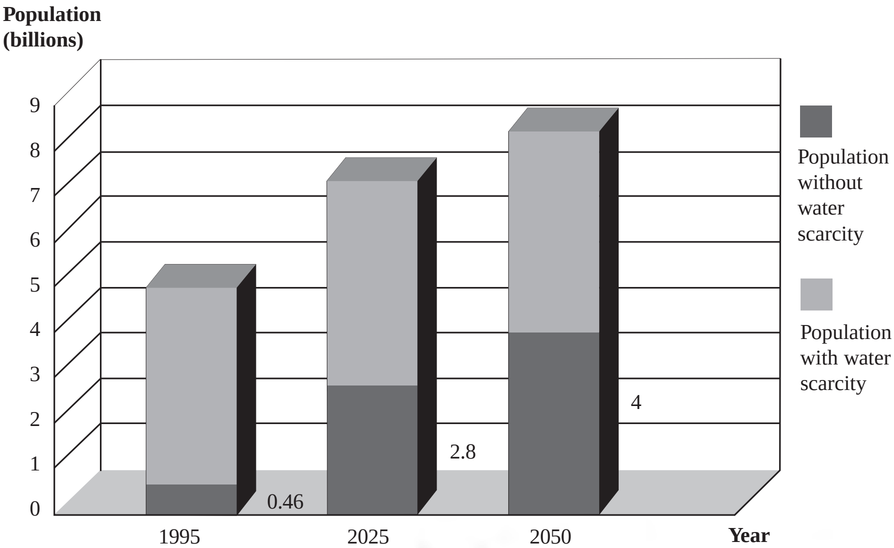

Figure 1.1
Population living in water-scarce and water-stressed countries, 1995–2050
(Hinrichsen, Robey & Upadhyay, 1998; United Nations Population Division, 2000)

As populations grow and become more urban, water use and consequent wastewater generation increase. For example, water usage in North America increased by approximately 800% during 1900–1995, and global water use in 2000 was estimated to be nearly three times what it was in 1950 (Shiklomanov, 1998). Annual household water consumption ranges from approximately 1 m^3 per person in the rural tropics without piped water supplies to >200 m^3 per person in urban areas in the United States of America (Gleick, 2000).

The growth of urban populations, especially in developing countries, will influence the production, treatment and use of wastewater in several ways:

- Higher population densities in urban and periurban areas will generate more waste (much of which will be discharged into the environment with little or no treatment).
- Urban populations consume more water than rural populations, which also increases the amount of wastewater produced.
- Sewerage systems become dominant in urban areas, because on-site waste disposal is not always feasible in many densely populated areas.
- Urban agriculture (with wastewater as a common water source) will play a more important role in supplying food to cities.
- Municipal wastewater will become the sole water source for many farmers in water-stressed areas close to cities.

1.3.3 Wastewater as a resource

Agriculture is the single largest user of fresh water in the world, accounting for nearly 70% (>90% in some countries) of all extractions of fresh water worldwide (Gleick, 2000; FAO, 2002). As fresh water becomes increasingly scarce due to population growth, urbanization and climate change, the use of wastewater in agriculture will increase even more.

At least 10% of the world's population is thought to consume foods produced by irrigation with wastewater (Smit & Nasr, 1992). The water and nutrient value of wastewater are important resources for farmers in both industrialized and developing countries. For example, in California, USA, approximately 67% of wastewater is reclaimed and used for crop or landscape irrigation (California State Water Resources Control Board, 2003), and in Israel the figure is approximately 75% (Arlosoroff, 2002). Wastewater is approximately 99% water. Where households are connected to piped water supplies, wastewater is generated at a rate of 35–200 litres per person per day (12–70 m^3 per person per year), depending on the water supply service level, climate and water availability (Helmer & Hespanhol, 1997). In a semi-arid area, a city of one million people would produce enough wastewater to irrigate approximately 1500–3500 ha.

The use of wastewater for crop irrigation reduces the use of artificial fertilizers and is thus an important form of nutrient recycling. At an irrigation rate of 1.5 m/year (i.e 1.5 m^3 of irrigation water per m^2 of field area per year), a typical requirement in a semi-arid climate, treated municipal wastewater can supply 225 kg of nitrogen and 45 kg of phosphorus per hectare per year. Thus, supplementary fertilization needs can be reduced (or even eliminated) for some crops, with a consequent increase in farmers' income. Additionally, using the nutrients available in wastewater reduces the environmental impacts associated with the mining (phosphorus) and production of artificial fertilizers.

1.3.4 The Millennium Development Goals

The United Nations General Assembly adopted the MDGs on 8 September 2000 (United Nations General Assembly, 2000). The MDGs most relevant to the agricultural use of wastewater are Goals 1 and 7.

Goal 1: Eliminate extreme poverty and hunger

Wastewater irrigation can contribute to the achievement of this MDG, as more food crops can be produced, allowing farmers' incomes to rise. Irrigation with wastewater is potentially very profitable for farmers. For example, in some areas in Pakistan, farmers willingly pay higher fees (US$ 350–940 per year) for access to wastewater compared with access to fresh water (US$ 170 per year), since it allows them to harvest three crops per year instead of one. Despite the higher fees, farmers with access to wastewater earn US$ 300 more per year than farmers using fresh water (Ensink, Simmons & van der Hoek, 2004). In the Guanajuato River basin in Mexico, 140 ha of land are irrigated with wastewater, which provides local farmers with nutrients estimated to be worth US$ 135 per hectare per year. For poor farmers, this is a substantial amount of money, which would otherwise have been used to purchase chemical fertilizers or resulted in lower yields (Future Harvest, 2001).

Irrigation with wastewater produces higher crop yields than irrigation with fresh water, even when artificial fertilizers are used. For example, in Nagpur, India, irrigation with waste stabilization pond effluents yielded 28, 8, 47, 30 and 42% more wheat, moong beans (type of lentils), rice, potato and cotton, respectively, than irrigation with fresh water supplemented with fertilizer containing nitrogen, phosphorus and potassium (Shende et al., 1985). In Dakar, Senegal, farmers who used only wastewater for irrigation had higher yields for most vegetable crops than farmers who used piped water and chemical fertilizers. Moreover, using wastewater resulted in a shorter crop production time for some crops (e.g. lettuce), and thus farmers who used wastewater could produce nine lettuce crops per year compared with six for farmers who used groundwater (Faruqui, Niang & Redwood, 2004).

Higher yields of food crops mean improved food availability. The economics of supply and demand indicate that the more food there is, the lower its price; thus, more people (especially poor people) can buy more food and be at least less hungry. Currently, poor households spend a larger proportion (50–80%) of their income on food and water compared with non-poor households (Lipton, 1983; World Food Programme, 1995). For example, based on household surveys in India, Buechler & Devi (2003) found that per capita expenditure on food averaged 30, 44 and 66% in urban, periurban and rural areas, respectively. Without access to resources such as wastewater, many poor families would not be able to meet their nutritional needs or would have to spend more money on food and less on other health-promoting activities, such as primary health care or education. It is therefore important to use a risk–benefit approach when developing guidelines for wastewater and excreta use in agriculture. This approach is followed in chapter 4 of these Guidelines.

Goal 7: Ensure environmental sustainability

Wastewater irrigation contributes to environmental sustainability by using the nutrients and water in wastewaters beneficially for increased crop production. Consequently, the quantity of untreated wastewater discharged into the aquatic environment will be reduced. It would otherwise lead to the degradation of water quality and act as a vehicle for disease transmission to users of polluted waters. The recognition of wastewater as an integral and reliable component of a nation's water resources (see section 1.3.3) and its equitable distribution as a preferred water for irrigation are essential for the efficient allocation and use of freshwater resources, especially in water-short and water-scarce areas.

Wastewater can also be used to protect groundwater for irrigation uses. When the water in coastal aquifers is pumped out at excessive rates, salt water from the ocean or sea flows into the aquifer, replacing the extracted fresh water. Treated wastewater can act as a barrier to saline intrusion when it is pumped into the aquifer, thus preventing the water from becoming brackish and preserving its value for food production. Aquifer recharge with treated wastewater is becoming more common in many coastal areas where aquifers are depleted through overextraction (Mills et al., 1998; National Research Council, 1998).

1.4 Organization of this Guidelines document

The structure of this volume is illustrated in Figure 1.2. Chapter 2 provides an overview of the Stockholm Framework. Chapter 3 provides the epidemiological, microbial and risk assessment bases for the Guidelines, which are formally developed in chapter 4 as health-based targets. Chapter 5 reviews the health protection measures that can be used to achieve the health-based targets. Chapter 6 reviews monitoring requirements. Chapter 7 presents the sociocultural and public perception aspects that need to be considered in wastewater use in agriculture. Chapter 8 describes environmental aspects of wastewater use in agriculture. Chapter 9 presents information on economic and financial aspects that need to be considered. Chapter 10 discusses policy aspects, and Chapter 11 reviews planning and implementation issues. Annex 1 briefly discusses good agricultural practice in relation to wastewater irrigation, and Annex 2 presents a summary of studies concerning the impact of heavy metals on the environment associated with wastewater irrigation. Health impact assessment with regard to wastewater use in agriculture is discussed in Annex 3.

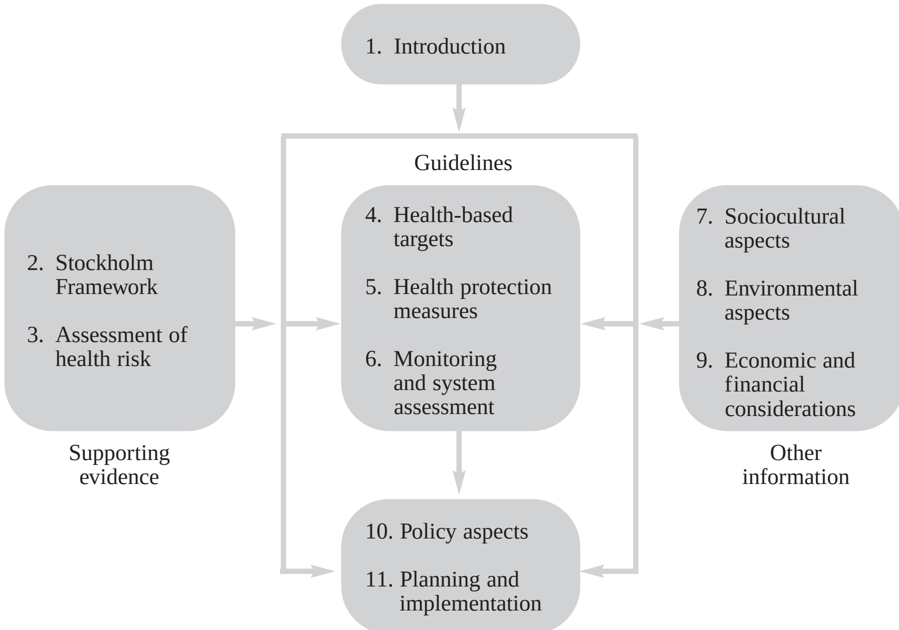

Figure 1.2
Structure of Volume 2 of the *Guidelines for the safe use of wastewater, excreta and greywater*

Annex 4 is a glossary of terms used in the *Guidelines for the safe use of wastewater, excreta and greywater*.

2
THE STOCKHOLM FRAMEWORK

The Stockholm Framework is an integrated approach that combines risk assessment and risk management to control water-related diseases. Although it was developed for infectious diseases, it can be applied to illnesses resulting from water-related exposures to toxic chemicals. This chapter contains a summary of the components of the Framework and how it applies to assessing and managing risks associated with the use of wastewater in agriculture. Specific components of the Framework are discussed in more detail in other chapters.

2.1 A harmonized approach to risk assessment/management

Following an expert meeting in Stockholm, Sweden, WHO published *Water quality: Guidelines, standards and health — Assessment of risk and risk management for water-related infectious disease* (Fewtrell & Bartram, 2001). This report provides a harmonized framework for the development of health-based guidelines and standards for water- and sanitation-related microbial hazards. The Stockholm Framework involves the assessment of health risks prior to the setting of health-based targets and the development of guideline values, defining basic control approaches and evaluating the impact of these combined approaches on public health (Figure 2.1; Table 2.1).

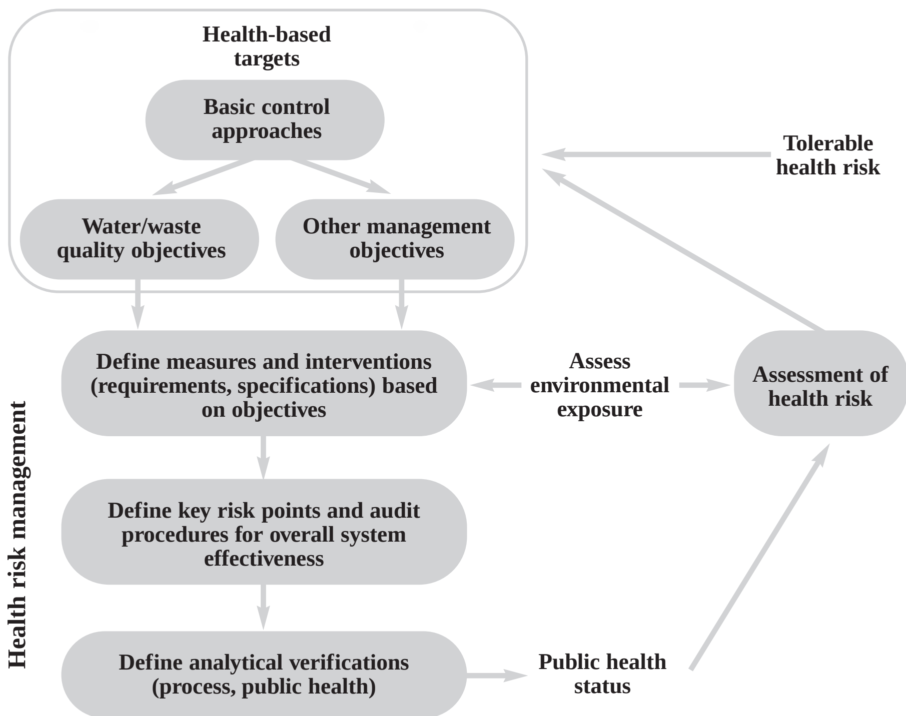

Figure 2.1
The Stockholm Framework for developing harmonized guidelines for the management of water-related infectious disease (adapted from Bartram, Fewtrell & Stenström, 2001)

Table 2.1 Elements and important considerations of the Stockholm Framework

Framework component	Process	Considerations
Assessment of health risk	Epidemiological studies QMRA	Best estimate of risk — not overly conservative Health outcomes presented in DALYs facilitates comparison of risks across different exposures and priority setting Assessment of risk is an iterative process — risk should be periodically reassessed based on new data or changing conditions Risk assessment (QMRA) is a tool for estimating risk and should be supported by other data (e.g. outbreak investigations, epidemiological evidence and studies of environmental behaviour of microbes) Process dependent on quality of data Risk assessment needs to account for short-term underperformance
Tolerable health risk/health-based targets	Health-based target setting linked to risk assessment	Needs to be realistic and achievable within the constraints of each setting Set based on a risk–benefit approach; should consider cost-effectiveness of different available interventions Should take sensitive subpopulations into account Reference pathogens should be selected for relevance to contamination, control challenges and health significance (it may be necessary to select more than one reference pathogen) Health-based targets establish a desired health outcome
Health risk management	Define water/waste quality objectives Define other management objectives Define measures and interventions Define key risk points and audit procedures Define analytical verifications	Health-based targets should be the basis for selecting risk management strategies; exposure prevention occurs through a combination of good practices (e.g. wastewater treatment, use of personal protective equipment, etc.) and appropriate water quality objectives (e.g. *Escherichia coli* and helminth eggs; see chapter 4) Risk points should be defined and used to anticipate and minimize health risks; parameters for monitoring can be set up around risk points A multiple-barrier approach should be used Risk management strategies need to address rare or catastrophic events Validation of the effectiveness of the health protection measures is needed to ensure that the system is capable of meeting the health-based targets; validation is needed when a new system is developed or additional barriers/technologies are added Monitoring — overall emphasis should be given to periodic inspection/auditing and to simple measurements that can be rapidly and frequently made to inform management Analytical verifications may include testing wastewater and/or plants for *E. coli* or helminth eggs to confirm that the treatment processes are working to the desired level Verification data can be used to make necessary adjustments to the risk management process to improve safety

Table 2.1 (continued)

Framework component	Process	Considerations
Public health status	Public health surveillance	Need to evaluate effectiveness of risk management interventions on specific health outcomes (through both investigation of disease outbreaks and evaluation of background disease levels)
		Public health outcome monitoring provides the information needed to fine-tune the risk management process through an iterative process; procedures for estimating the burden of disease will facilitate monitoring health outcomes due to specific exposures
		Burden of disease estimates can be used to place water-related exposures in the wider public health context to enable prioritization of risk management decisions

Source: Adapted from Carr & Bartram (2004).

The Framework encourages countries to take into consideration their local social, cultural, economic and environmental circumstances and compare the wastewater- and excreta-associated health risks with risks that may result from microbial exposures through other water and sanitation routes and additional exposures (e.g. through food, hygienic practices, etc.). This approach facilitates the management of infectious diseases in an integrated, holistic fashion and not in isolation from other diseases or exposure routes. Disease outcomes from different exposure routes can be compared by using a common metric, such as disability adjusted life years (DALYs), or normalized for a population over a time period (see Box 2.1).

Box 2.1 Disability adjusted life years (DALYs)

DALYs are a measure of the health of a population or burden of disease due to a specific disease or risk factor. DALYs attempt to measure the time lost because of disability or death from a disease compared with a long life free of disability in the absence of the disease. DALYs are calculated by adding the years of life lost to premature death to the years lived with a disability. Years of life lost are calculated from age-specific mortality rates and the standard life expectancies of a given population. Years lived with a disability are calculated from the number of cases multiplied by the average duration of the disease and a severity factor ranging from 1 (death) to 0 (perfect health) based on the disease (e.g. watery diarrhoea has a severity factor ranging from 0.09 to 0.12, depending on the age group) (Murray & Lopez, 1996; Prüss & Havelaar, 2001). DALYs are an important tool for comparing health outcomes, because they account not only for acute health effects but also for delayed and chronic effects — including morbidity and mortality (Bartram, Fewtrell & Stenström, 2001).

When risk is described in DALYs, different health outcomes (e.g. cancer vs giardiasis) can be compared and risk management decisions can be prioritized.

WHO water- and sanitation-related guidelines have been developed in accordance with the principles of the Stockholm Framework. The third edition of the WHO *Guidelines for drinking-water quality* (WHO, 2004a) and volumes 1 and 2 of the WHO *Guidelines for safe recreational water environments* (WHO, 2003a, 2005) have both incorporated its harmonized approach to risk assessment and management. The following sections describe the individual elements of the Stockholm Framework, as illustrated in Figure 2.1, and how they specifically relate to the use of wastewater.

Some of the elements related to wastewater use in agriculture are discussed in more detail in subsequent chapters of this document.

2.2 Assessment of environmental exposure

The assessment of environmental exposure is an important input to both risk assessment and risk management. Environmental exposure assessment is a process that looks at the hazards in the environment and evaluates different transmission and exposure routes to human (or animal) populations. Table 2.2 describes the hazards associated with the use of wastewater in agriculture, the primary hazards being pathogens and certain chemicals. Treatment of wastewater to varying degrees can significantly reduce the concentrations of some contaminants (e.g. excreta-derived pathogens and some chemicals) (see chapter 5) and thus the risk of disease transmission. Other strategies are necessary to prevent the transmission of vector-borne diseases.

Table 2.2 Examples of hazards associated with wastewater use in agriculture

Hazard	Exposure route	Relative importance	Comments
Excreta-related pathogens			
Bacteria (*E. coli*, *Vibrio cholerae*, *Salmonella* spp., *Shigella* spp.)	Contact Consumption	Low–high	Can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks. Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease.
Helminths			
- Soil-transmitted (*Ascaris*, hookworms, *Taenia* spp.)	Contact Consumption	Low–high	Present in areas where sanitation and hygiene standards are low. Risk depends on how wastewater is treated, if shoes are worn, if food is cooked before eating, etc. Eggs can survive for a very long time in the environment.
- Schistosomes (trematode bloodflukes)	Contact	Nil–high	Schistosomes are present only in certain geographic regions and require suitable intermediate hosts. Schistosomiasis is transmitted through contact with contaminated water in endemic areas.
Protozoa (*Giardia intestinalis*, *Cryptosporidium*, *Entamoeba* spp.)	Contact Consumption	Low–medium	Can survive in the environment long enough to pose health risks. Limited evidence of disease outbreaks. Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease.
Viruses (hepatitis A virus, hepatitis E virus, adenovirus, rotavirus, norovirus)	Contact Consumption	Low– high	Can survive in the environment long enough to pose health risks. Contamination of crops has led to disease outbreaks.

Table 2.2 (continued)

Hazard	Exposure route	Relative importance	Comments
Viruses (hepatitis A virus, hepatitis E virus, adenovirus, rotavirus, norovirus) *(continued)*			Produce washing/disinfection and cooking reduce the risk. Poor personal hygiene after wastewater contact will increase the risk of infection/disease. In areas with poor sanitation and hygiene standards, most people are infected as children and develop immunity. May pose more of a health risk for local people who are not exposed as children or for tourists without immunity to local diseases.
Skin irritants	Contact	Medium–high	Skin diseases such as contact dermatitis (eczema) have been reported after heavy contact with untreated wastewater. Cause has not yet been determined but is likely due to a mixture of microbial and chemical agents. May also be caused by cyanobacterial toxins in some situations.
Vector-borne pathogens (*Plasmodium* spp., dengue virus, *Wuchereria bancrofti*, Japanese encephalitis virus)	Vector contact	Nil–medium	Limited to geographic areas where the pathogen is endemic and suitable vectors are present. Risk is mainly associated with water resource development (i.e. development of reservoirs and irrigation systems) and usually not specifically with wastewater use in agriculture. Lymphatic filariasis is the exception, as its vectors breed in organically polluted water.
Chemicals			
Heavy metals (arsenic, cadmium, lead, mercury)	Consumption	Low	Heavy metals may accumulate in some plants, but rarely to levels considered unsafe.
Halogenated hydrocarbons (dioxins, furans, PCBs)	Consumption	Low	Concentration of these substances is generally low in wastewater (but may be higher in sludge). These substances are usually adsorbed by soil particles and not taken up by plants.
Pesticides (aldrin, DDT)	Contact Consumption	Low	Risk is related to agricultural practices. Wastewater generally does not contain high concentrations of these substances.

Sources: Blumenthal et al. (2000a, 2000b); WHO (2004q); van der Hoek et al. (2005).

Raw wastewater contains a variety of human pathogens (see chapter 3). The concentrations of pathogens vary from region to region and over time. Pathogen concentrations will be at the highest levels in areas where faecal–oral disease is widely endemic. If excreta-related disease outbreaks occur, then concentrations of the causative pathogen may also reach higher levels in the wastewater and excreta.

Many pathogens are capable of survival (and sometimes multiplication) in the environment (e.g. water, plants, soil) for periods long enough to allow transmission to humans. Several factors influence their die-off, including temperature, moisture, exposure to ultraviolet radiation, time, absence of appropriate intermediate hosts, type of plant, etc.

The primary pathways of transmission of or exposure to pathogens or contaminants associated with the use of wastewater in agriculture are:

- human contact with the wastewater (or contaminated crops) before, during or after irrigation (farmers, their families, vendors, local communities);
- inhalation of wastewater aerosols (workers, local communities);
- consumption of contaminated wastewater-irrigated products;
- consumption of drinking-water contaminated as a result of wastewater use activities (e.g. chemical or pathogen contamination of aquifers or surface waters);
- consumption of animals (e.g. beef or pork) or animal products (e.g. milk) that have been contaminated through exposure to wastewater;
- vector-borne disease transmission resulting from the development and management of wastewater irrigation schemes and waste stabilization ponds.

The concentrations of toxic chemicals will vary from place to place and will usually depend on the number and types of industries that discharge their wastes into the wastewater and the degree to which they treat their wastes prior to discharge.

2.3 Assessment of health risk

Assessing the risk associated with human exposure to pathogens in wastewater for agriculture can be carried out with information gained from epidemiological studies and quantitative microbial risk assessments (QMRA). As they can provide complementary information, ideally, risk assessment is carried out with both.

Epidemiological studies aim to assess the health risks associated with the use of wastewater by comparing the level of disease in the exposed population (which uses wastewater or consumes products grown with it) with that in an unexposed or control population. The difference in disease levels may then be attributed to the practice of using the wastewater, provided that the two populations compared are similar in all other respects, including socioeconomic status and ethnicity. Confounding factors and bias that may affect results need to be addressed in the study by careful selection of the study participants. Blumenthal & Peasey (2002) conducted a review of epidemiological studies concerning the use of wastewater in agriculture, the results of which are presented in chapter 3.

QMRA can be used to estimate the risk to human health by predicting infection or illness rates given densities of particular pathogens, measured or estimated rates of ingestion and appropriate dose–response models for the exposed population. QMRA provides a technique for estimating the risks from a specific pathogen associated with a specific exposure pathway. It is a sensitive tool that can estimate risks that would be difficult and costly to measure and therefore provides an important complement to epidemiological investigations, which are less sensitive and more difficult to perform. QMRA consists of four steps, which are outlined in Table 2.2. Examples of QMRAs used to estimate health risks for the use of wastewater under different scenarios are provided in chapter 3.

Table 2.2 Risk assessment paradigm for any human health effect[a]

Step	Aim
1. Hazard identification	To describe acute and chronic human health effects associated with any particular hazard, including pathogens or toxic chemicals
2. Hazard characterization	Dose–response assessment, to characterize the relationship between various doses administered and the incidence of the health effect, including underlying mechanisms and extrapolation from model systems to humans
3. Exposure assessment	To determine the size and nature of the population exposed and the route, amount and duration of the exposure
4. Risk characterization	To integrate the information from exposure, dose–response and hazard identification steps in order to estimate the magnitude of the public health problem and to evaluate variability and uncertainty

Source: Adapted from WHO (2003a).
[a] Can be used for both chemicals and microbial pathogens.

2.4 Tolerable health risk

The management of health risk is context-specific; there is no universally applicable risk management formula. In setting guidelines for the use of wastewater, logic dictates that the overall levels of health protection should be comparable with those for other water-related exposures (e.g. through drinking-water). Standards for drinking-water consider illnesses that might result from exposures to both chemicals and microbial pathogens. The comparison of different adverse health outcomes, such as cancer, diarrhoea, etc., is facilitated by the use of a common metric (i.e. DALYs; see Box 2.1 and chapter 4). Significant experience has now been gained in such comparisons (WHO, 2003a).

For carcinogenic chemicals in drinking-water, WHO guideline values have been set at a 10^{-5} upper-bound excess risk (WHO, 2004a). This means that there would be a maximum of one excess case of cancer per 100 000 of the population ingesting drinking-water that contained the chemical at the guideline concentration over a lifetime. The disease burden associated with this level of risk and adjusted for the severity of the illness is approximately 1×10^{-6} DALY (1 µDALY) per person per year (WHO, 2004a). This level of disease burden can be compared with a mild but more frequent illness, such as self-limiting diarrhoea caused by a microbial pathogen. The estimated disease burden associated with mild diarrhoea (e.g. with a case fatality rate of approximately 1×10^{-5}) at an annual disease risk of 1 in 1000 (10^{-3}) (1 in 10 lifetime risk) is also about 1×10^{-6} DALY (1 µDALY) per person per year (WHO, 2004a).

2.5 Health-based targets

Health-based targets should be part of overall public health policy, taking into account status and trends and the contribution of wastewater use to the transmission of infectious disease, both in individual settings and within overall health management. The purpose of setting targets is to mark milestones to guide and chart progress towards a predetermined health goal. To ensure effective health protection and improvement, targets need to be realistic and relevant to local conditions, including financial, technical and institutional resources. Such conditions include the nature and seriousness of local illness, population behaviour, exposure patterns and sociocultural, economic, environmental and technical aspects, as well as health risks from other diseases, including those that are not associated with wastewater use (WHO, 2003a). This normally implies periodic review and updating of priorities and targets and, in turn, that norms and standards should be revised to take account of these factors and the changes in available information (WHO, 2004a).

A health-based target uses the tolerable risk of disease as a baseline to set specific performance targets that will reduce the risk of disease to this level. Exposure to different concentrations of pathogens or toxic chemicals through wastewater contact or through consumption of wastewater-irrigated products is associated with a certain level of risk. Reducing this risk thus involves minimizing exposures to pathogens and chemicals.

Health-based targets can be specified in terms of combinations of different components or single parameters, including:

- *Health outcome:* as determined by epidemiological studies, public health surveillance or QMRA (DALYs or absence of a specific disease);
- *Wastewater quality:* such as concentrations of viable intestinal nematode eggs and/or *E. coli*;
- *Performance:* such as a performance target for removal of microbial or chemical contaminants (e.g. a percentage removal of pathogens through a combination of treatment requirements, water quality standards and wastewater application techniques; see chapters 4 and 5); performance may be assessed through validation (see chapter 6) or approximated by other parameters — retention time in ponds; turbidity; suspended solids, etc., for monitoring purposes;
- *Specified technology:* specified treatment process, etc., either in general or with reference to specific circumstances of use.

2.6 Risk management

Risk management strategies can be developed to ensure achievement of health-based targets. Pollution prevention, especially for chemicals, should also be considered in risk management strategies. Measures and interventions will be different based on the wastewater use objective. The most effective means of consistently ensuring safety in wastewater use in agriculture is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process, from the generation and use of wastewater to product consumption. This approach is captured in the Stockholm Framework. Three components of this approach are important for achieving the health-based targets: system assessment, identifying control measures and methods for monitoring them and developing a management plan (these procedures are discussed in more detail in chapter 6).

Performance targets to achieve exposure reductions for unrestricted versus restricted irrigation will vary. For example, it may be determined that a 99.99% reduction in exposure to pathogens is needed to achieve the health-based target for unrestricted irrigation, while a 99% reduction is needed to achieve the health-based target for restricted irrigation. The targets in the first case could be met by a combination of treatment plus localized irrigation and in the second case by just treatment (plus exposure prevention for workers and local communities) (see Figure 2.2). Chapters 4 and 5 present more information on exposure reductions that may be achieved by specific management approaches.

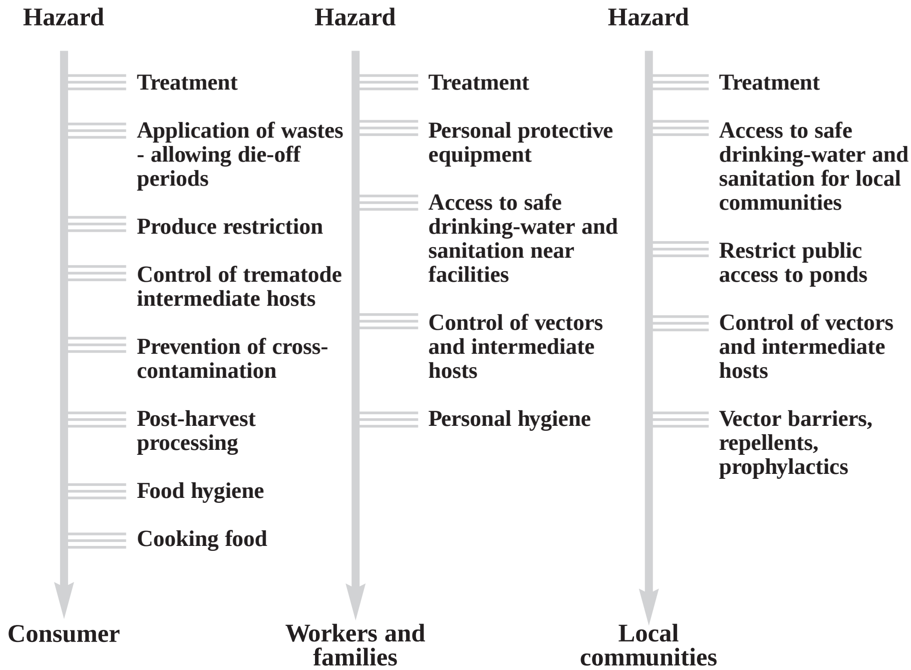

Figure 2.2
Examples of hazard barriers for wastewater use in agriculture

Figure 2.2 shows examples of risk management strategies for wastewater use in agriculture to prevent exposures to pathogens and toxic chemicals by constructing multiple barriers (additional strategies are discussed in chapter 5). They may include combinations of the following:

- *Wastewater treatment:* to remove pathogens and toxic chemicals to levels that do not exceed tolerable risks or that can be combined with other measures to achieve the health-based targets;
- *Produce restriction:* growing plants that either are not eaten directly by humans or are always processed (cooked) prior to consumption;
- *Application:* using wastewater/excreta application techniques that reduce exposures of workers and contamination of products, or allowing adequate periods between waste application and harvest to allow pathogen die-off (e.g. drip irrigation, withholding periods, buffer zones);
- *Exposure control methods:* limiting public access to irrigated fields, workers wearing protective clothing, good personal hygienic practices, such as hand-washing with soap to remove contaminants after contact with wastewater or products contaminated with them;
- *Produce washing/disinfection/cooking:* normal washing of produce in the houseold with safe drinking-water or using chemical disinfectants can reduce contamination and potential exposures to pathogens and some chemicals; cooking food thoroughly prior to consumption will inactivate most, if not all, pathogens.

Information concerning the efficiency of processes in preventing exposures (e.g. drip irrigation, withholding periods and other health protection measures) combined with data on the occurrence of pathogens and chemicals in wastewaters allow for the definition of operating conditions that would reasonably be expected to achieve the health-based targets (see chapter 4). Information on process efficiency and pathogen occurrence should take account of steady-state performance and performance during maintenance and periods of unusual load. While the indicator systems required to verify adequate performance may require the use of laboratory-based analytical measures (e.g. for *E. coli* or helminth egg analysis), relatively greater emphasis should be given to periodic inspection and simple analytical tests providing rapid results to inform system operation. External supervision of the system is an important feature to ensure that the system is working as described and that regulations are complied with (see chapter 6) (Bartram, Fewtrell & Stenström, 2001).

2.7 Public health status

Section 2.2 identifies different hazards associated with wastewater use in agriculture. The hazards most likely to cause disease are the excreta-related pathogens (including the intestinal helminths and schistosomes), skin irritants and vector-borne pathogens. Risks from most chemicals are thought to be low and would be difficult to associate with exposure through wastewater use in agriculture because of the long exposure times required to cause illnesses in most cases. Table 2.4 illustrates examples of mortality and morbidity estimates for some diseases of possible relevance to wastewater use in agriculture.

Table 2.4 Global mortality and DALYs due to some diseases of relevance to wastewater use in agriculture

Disease	Mortality (deaths/year)	Burden of disease (DALYs/year)	Comments
Diarrhoea	1 798 000	61 966 000	99.8% of deaths occur in developing countries; 90% of deaths occur in children
Typhoid	600 000	N/A	Estimated 16 million cases per year
Schistosomiasis	15 000	1 702 000	Found in 74 countries; 200 million people worldwide are estimated to be infected, 20 million with severe consequences
Ascariasis	3 000	1 817 000	Estimated 1.45 billion infections, of which 350 million suffer adverse health effects
Hookworm disease	3 000	59 000	Estimated 1.3 billion infections, of which 150 million suffer adverse health effects
Lymphatic filariasis	0	5 777 000	Mosquito vectors of filariasis breed in organically polluted water; does not cause death but leads to severe disability
Hepatitis A	N/A	N/A	Estimated 1.4 million cases per year worldwide; serological evidence of prior infection ranges from 15% to nearly 100%

N/A, not available
Sources: WHO (2000c, 2002, 2003b, 2003c, 2004b).

2.7.1 Excreta-related diseases

Excreta-related infections (see Table 2.5) are communicable diseases whose causative agents (pathogenic viruses, bacteria, protozoa and helminths) are released from the bodies of infected persons (or animals in some cases) in their excreta (faeces, urine). The causative agents eventually reach other people and enter either via the mouth (e.g. when contaminated crops are eaten) or via the skin (e.g. hookworm infection and schistosomiasis). The diseases of most relevance differ from area to area, depending on the general status of sanitation and hygiene in an area and the level to which wastewater is treated prior to use in agriculture. In places where hygiene and sanitary standards are poor, intestinal helminths frequently pose the greatest health risks.

Table 2.5 Excreta-related diseases

Agent	Disease
Bacteria	
Campylobacter jejuni	Gastroenteritis, long-term sequelae (e.g. arthritis)
Escherichia coli	Gastroenteritis
E. coli O157:H7	Bloody diarrhoea, haemolytic uraemic syndrome
Leptospira spp.	Leptospirosis
Salmonella (many serotypes)	Salmonellosis, gastroenteritis, diarrhoea, long-term sequelae (e.g. arthritis)
Salmonella typhi	Typhoid fever
Shigella (several serotypes)	Shigellosis (dysentery), long-term sequelae (e.g. arthritis)
Vibrio cholerae	Cholera
Yersinia enterocolitica	Yersiniosis, gastroenteritis, diarrhoea, long-term sequelae (e.g. arthritis)
Helminths	
Ancylostoma duodenale and *Necator americanus* (hookworm)	Hookworm infection
Ascaris lumbricoides (roundworm)	Ascariasis
Clonorchis sinensis (liver fluke)	Clonorchiasis
Diphyllobothrium latum (fish tapeworm)	Diphyllobothriasis
Fasciola hepatica and *F. gigantica* (liver fluke)	Fascioliasis
Fasciolopsis buski (intestinal fluke)	Fasciolopsiasis
Opisthorchis viverrini (liver fluke)	Opisthorchiasis
Paragonimus westermani (lung fluke)	Paragonimiasis
Schistosoma spp. (blood fluke)	Schistosomiasis, bilharzia[a]
Taenia saginata and *T. solium* (tapeworm)	Taeniasis
Trichuris trichuria (whipworm)	Trichuriasis
Protozoa	
Balantidium coli	Balantidiasis (dysentery)
Cryptosporidium parvum	Cryptosporidiosis, diarrhoea, fever
Cyclospora cayetanensis	Persistent diarrhoea
Entamoeba histolytica	Amoebiasis (amoebic dysentery)
Giardia intestinalis	Giardiasis

Table 2.5 (continued)

Agent	Disease
Viruses	
Adenovirus (many types)	Respiratory disease, eye infections
Astrovirus (many types)	Gastroenteritis
Calicivirus (several types)	Gastroenteritis
Coronavirus	Gastroenteritis
Coxsackievirus A	Herpangina, aseptic meningitis, respiratory illness
Coxsackievirus B	Fever, paralysis, respiratory, heart and kidney disease
Echovirus	Fever, rash, respiratory and heart disease, aseptic meningitis
Enteroviruses (many types)	Gastroenteritis, various
Hepatitis A virus	Infectious hepatitis
Hepatitis E virus	Infectious hepatitis
Norovirus	Gastroenteritis
Parvovirus (several types)	Gastroenteritis
Poliovirus	Paralysis, aseptic meningitis
Reovirus (several types)	Not clearly established
Rotavirus (several types)	Gastroenteritis

Sources: Sagik, Moor & Sorber (1978); Hurst, Benton & Stetler (1989); Edwards (1992); National Research Council (1998).
[a] See also section 2.7.2.

In many countries, excreta-related infections are common, and excreta and wastewater contain correspondingly high concentrations of pathogens. The failure to properly treat and manage wastewater and excreta worldwide is directly responsible for adverse health and environmental effects. Human excreta have been implicated in the transmission of many infectious diseases, including cholera, typhoid, hepatitis, polio, schistosomiasis and infections by helminths (e.g. *Ascaris*, hookworms, tapeworms). Most of these excreta-related illnesses occur in children living in poor countries. Overall, WHO estimates that diarrhoea alone is responsible for 3.2% of all deaths and 4.2% of overall disease burden expressed in DALYs worldwide (WHO, 2004b). In addition to diarrhoea, WHO estimates that each year, 16 million people contract typhoid and over 1 billion people suffer from intestinal helminth infections (see Table 2.4).

Diarrhoea or gastrointestinal disease is often used as a proxy for waterborne infectious diseases. Mead et al. (1999) estimated that the average person (including all age groups) in the United States of America suffers from 0.79 episode of acute gastroenteritis (characterized by diarrhoea, vomiting or both) per year. The rates of acute gastroenteritis among adults worldwide are generally within the same order of magnitude (Table 2.6). However, children — especially those living in high-risk situations, where poor hygiene, sanitation and water quality prevail — generally have a higher rate of gastrointestinal illness. Kosek, Bern & Guerrant (2003) found that children under the age of five in developing countries experienced a median of 3.2 episodes of diarrhoea per year.

Table 2.6 Diarrhoeal disease incidence per person per year in 2000, by region and age

Region	Diarrhoeal disease incidence, all ages	Diarrhoeal disease incidence, 0–4 years	Diarrhoeal disease incidence, 5–80+ years
Developed regions	0.2	0.2–1.7	0.1–0.2
Developing regions	0.8–1.3	2.4–5.2	0.4–0.6
World average	0.7	3.7	0.4

Source: Adapted from Mathers et al. (2002).

2.7.2 Schistosomiasis

Schistosomiasis is an important parasitic disease in various parts of the world. It differs from other excreta-related diseases (see section 2.7.1) in that it requires certain species of aquatic or amphibian snail hosts to complete its life cycle, its distribution is limited by the presence or absence of these snails and it affects only people who are in direct contact with contaminated water or wastewater. The disease is endemic in 74 countries in the Eastern Mediterranean region and parts of Asia and the Americas, but most of the infections occur in sub-Saharan Africa. Schistosomiasis is an infection of the blood vessels draining the urinary bladder or the intestinal tract. The disease is caused by *Schistosoma haematobium*, *S. mansoni*, *S. japonicum*, *S. intercalatum* and *S. mekongi*. The life cycle requires replication in a snail intermediate host. Snails become infected by a larval stage of the parasite, known as a miracidium, which develops from eggs passed out in the urine or faeces of infected people. Cercariae released by the snails penetrate the skin of people in the water. Light infections may be asymptomatic, but heavier infections may lead to enlargement of the spleen or liver, blood loss and bladder cancer, depending on the parasite species.

2 7.3 Vector-borne diseases

Vector-borne diseases such as malaria and lymphatic filariasis are not specifically associated with the use of wastewater, but they should be considered among possible health risks in endemic areas. As part of the planning of water resource development and management projects (including wastewater irrigation projects), a health impact assessment should be conducted (see Annex 3) (WHO, 2000b). As Table 2.7 indicates, activities related to some wastewater irrigation activities could increase the population of disease vectors. However, only certain mosquitoes, especially the vectors of filariasis (e.g. *Culex quinquefasciatus*), can breed in organically polluted water. There have been reports from Pakistan about malaria vector breeding at the cleaner end of a chain of wastewater stabilization ponds. A variety of measures to reduce the breeding of vectors in wastewater use programmes are described in chapter 5.

2.7.4 Measuring public health status

The impacts of risk management actions can be measured only if the baseline health status of the affected population is known or can be approximated. Similarly, tolerable risk and health-based targets can be set only with some knowledge of:

- the incidence and prevalence of disease in the community;
- the types of diseases that may result from the use of wastewater;
- the vulnerability of different subsections of the population (e.g. people with reduced immune function or those susceptible to specific hazards).

Table 2.7 Vector-borne diseases of possible relevance to wastewater use in agriculture

Disease	Vector	Relative risk of wastewater use in agriculture	Comments
Dengue	*Aedes aegypti*	Low	Vectors breed in standing water (e.g. tires, cans, bottles, etc.). Present in South-east Asia but not China.
Filariasis	*Culex quinquefasciatus*	Medium	Vectors breed in organically polluted water. Endemic in many countries where wastewater use in agriculture is practised.
Japanese encephalitis	*Culex* spp.	Medium	Vectors breed in flooded rice fields. Endemic in many countries where wastewater use in agriculture is practised.
Malaria	*Anopheles* spp.	Low	Vectors breed in uncontaminated water; 90% of malaria cases occur in Africa. *Anopheles* breeding has been reported from serial waste stabilization ponds.

Sources: WHO (1988); TDR (2004).

It is important to understand the role that wastewater plays in the transmission of water-related disease in a community. For example, studies in Mexico indicated that a very high percentage of the Ascaris infections and diarrhoea in certain exposed communities was due to the use of wastewater in agriculture. Reducing the exposures to the pathogens in the wastewater by improving wastewater treatment had a significant impact on the improvement of public health (Cifuentes, 1998; Cifuentes et al., 2000a). If only a small proportion of water-associated ill health in a specific community can be attributed to the use of wastewater in agriculture, however (e.g. if the main route of transmission is through drinking-water), then it is not cost-effective to invest limited resources in measures intended to make that use safer. Addressing the main exposure routes first is normally more cost-effective — in this example, providing access to safe drinking-water would have a larger positive impact on public health at lower cost than building a new wastewater treatment facility.

Initial information on background levels of faecal–oral disease in the population might be based on information collected from local health-care facilities, public health surveillance, laboratory analysis, epidemiological studies or specific research conducted in a project area. Seasonal fluctuations in disease incidence should be considered — for example, rotavirus infections peak in the cold season. In evaluating the use of wastewater in a certain area, it is important to evaluate disease incidence trends. High background disease levels (e.g. intestinal worm infections) or disease outbreaks (e.g. cholera) might indicate that risk management procedures were not being implemented adequately and would need to be strengthened or reconsidered.

3
ASSESSMENT OF HEALTH RISK

Wastewater can both be a resource and present a hazard. This chapter presents the current evidence of health effects associated with the use of wastewater in agriculture from both infectious agents and chemicals. Systematic assessment of the positive health benefits of the use of wastewater in agriculture has not been conducted. The health benefits will vary in different situations. It is possible that subsistence-level farmers will benefit most from the positive health impacts in terms of food security and improved nutrition as well as be at the highest risk of negative health impacts — especially where untreated wastewater is used for irrigation.

The assessment of risk relies on two types of information: epidemiological studies and QMRA. Microbial analysis provides data for both epidemiological studies and QMRA. Each type of assessment has limitations, but, used together, they can provide complementary information (see Table 3.1). Evidence from each category is presented in this section.

Table 3.1 Data used for the assessment of health risk

Type of study	Contributions	Limitations
Microbial analysis	Determines concentrations of different excreted organisms in wastewater or on products Provides data on pathogen die-off rates Information used in QMRA to assess risk Can help to identify sources of pathogens Used to link pathogen to infection/disease (e.g. through analysis of stool samples or detection of seropositive individuals)	Expensive Collection of samples may be time-consuming Needs trained staff and laboratory facilities Obtaining laboratory results takes time Lack of standardized procedures for the detection of some pathogens or their recovery from food products Recovery percentages may show high variability Some methods do not determine viability
Epidemiological study	Measures actual disease in an exposed population Can be used to test different exposure hypotheses	Expensive Bias can affect results Sample sizes needed to measure statistically significant health outcomes may be large Need to strike a balance between power of the study in relation to its sensitivity
QMRA	Can estimate very low levels of risk of infection/disease Low-cost method of predicting risk of infection/disease Facilitates comparisons of different exposure routes	Exposure scenarios can vary significantly and are difficult to model Validated data inputs are not available for every exposure scenario Predicts risks from exposure to one type of pathogen at a time

Epidemiological studies can determine either the excess prevalence of infection (as measured by the proportion of infected or seropositive individuals) in an exposed group compared with that in a control group or the excess prevalence or incidence of disease (occurring during a specified time period) in an exposed group compared with a control group. Epidemiological studies need to use an adequate sample size based on the:

- required level of statistical significance of the expected result;
- acceptable chance of missing a real effect;
- magnitude of the effect under investigation;
- amount of disease in the population;
- relative sizes of the groups being compared.

Generally, the larger the sample size, the more power the study has to find associations between disease and exposure factors. Sample size is determined by logistic and financial considerations, and normally a compromise has to be made between sample size and costs (Beaglehole, Bonita & Kjellström, 1993).

In the context of these Guidelines, individuals eating wastewater-irrigated salad crops, working (or playing) in wastewater-irrigated fields or living near wastewater-irrigated fields (especially where spray irrigation is used) are exposed groups, and those not meeting these criteria belong to control groups.

QMRA estimates the risk of infection in an exposed group, and this can be extended to estimate the risk of disease in that group by knowing (or making an assumption about) the likely proportion of infected individuals who develop the disease.

3.1 Microbial analysis

Microbial evidence can be used to indicate that a hazard exists in the environment. Microbial analysis is an important process for providing data for the assessment of risk. Information concerning the types and numbers of different pathogens in wastewater and on irrigated produce can be used to quantify risk. These factors will vary according to region, climate, season, etc. and thus should be measured, whenever possible, on a site-specific basis.

Untreated wastewater contains a variety of excreted organisms, including pathogens, with types and numbers that vary depending on the background levels of infection in the population. Disease outbreaks result in increased concentrations of the causative agents in the wastewater and excreta. Table 3.2 shows ranges of concentrations for different excreted organisms that may be found in wastewater. Because pathogen types and concentrations can vary over a large range, it is helpful to collect local data to evaluate risk and develop risk management strategies.

Pathogens are rarely measured directly in wastewater, because their concentrations vary and analytical procedures are often difficult or expensive to perform. Instead, indicators of faecal contamination, such as *E. coli* or thermotolerant coliforms, have been used as proxies for pathogens with similar properties that may be present in wastewater. Usually, but not always, their presence in water is proportionately related to the amount of faecal contamination present. For wastewater, indicators can show how much treatment or natural purification has taken place and thus give a rough estimate of the risk associated with its use. Standardized analytical procedures have been developed for *E. coli* and thermotolerant coliforms and are widely used.

Table 3.2 Excreted organism concentrations in wastewater

Organism	Numbers in wastewater (per litre)
Bacteria	
Thermotolerant coliforms	10^8–10^{10}
Campylobacter jejuni	10–10^4
Salmonella spp.	1–10^5
Shigella spp.	10–10^4
Vibrio cholerae	10^2–10^5
Helminths	
Ascaris lumbricoides	1–10^3
Ancylostoma duodenale / Necator americanus	1–10^3
Trichuris trichiura	1–10^2
Schistosoma mansoni	ND
Protozoa	
Cryptosporidium parvum	1–10^4
Entamoeba histolytica	1–10^2
Giardia intestinalis	10^2–10^5
Viruses	
Enteric viruses	10^5–10^6
Rotavirus	10^2–10^5

ND, no data

Sources: Feachem et al. (1983); Mara & Silva (1986); Oragui et al. (1987); Yates & Gerba (1998).

Unfortunately, there is no perfect indicator organism for wastewater, especially for non-faecal bacterial pathogens, helminths, viruses and protozoa, as the concentrations of faecal indicator bacteria often do not correspond to concentrations of these organisms. If the wastewater effluents have been chlorinated, this will significantly reduce the numbers of bacteria but does not reduce concentrations of viruses, protozoa or helminths to the same degree.

Table 3.3 provides some examples of indicator organisms that have been used to assess the risks associated with the use of wastewater in agriculture in different situations. However, many of these indicators have been used in research studies and are not suitable for use in routine monitoring, due to the expense incurred and the need for adequate equipment. The *E. coli*/thermotolerant coliform group of bacteria is used in most water-related guidelines, as these bacteria are the most commonly monitored of the indicators that are related to faecal contamination. For further discussion of the advantages and disadvantages of different faecal indicators, see WHO (2004a) and Jiménez (2003).

Table 3.3 Examples of indicator organisms for human pathogens in wastewaters

Human pathogen	Indicator organisms	Comment
Bacteria		
Shigella, enterotoxigenic *E. coli*, *Campylobacter*, *Vibrio cholerae* (cholera)	*E. coli*, thermotolerant coliforms, intestinal enterococci	The *E. coli* /thermotolerant coliform group of bacteria has been used for more than 100 years as a model for pathogenic bacteria. Behaviour of *E. coli* and intestinal enterococci (not total coliforms) under environmental conditions is expected to reflect enteric pathogens, but not environmental bacteria such as *Legionella or Mycobacterium*.
Viruses		
Adenovirus, rotavirus, enteroviruses, hepatitis A virus, norovirus	Bacteriophages: somatic coliphages or F-RNA coliphages	Bacteriophages are viruses that infect bacteria, are considered to be non-pathogenic to humans and can be readily cultured and enumerated in the laboratory. Generally present in faeces of warm-blooded animals, but certain strains may be specific to humans.
Protozoa		
Cryptosporidium oocysts, *Giardia* cysts	*Clostridium perfringens*	*Clostridium perfringens* is a spore-forming bacterium that is highly resistant to environmental conditions. It has been shown to be a useful model for *Cryptosporidium* oocysts and *Giardia* cysts. Aerobic (*Bacillus*) spores could also be used, but are likely to grow in treatment systems and slough off surfaces, providing misleading numbers. Because protozoa are much larger than *Clostridium* spores, they will be removed in different ways during wastewater treatment processes. Validation testing should be performed with protozoan (oo)cysts or particles that are similar in size.
Helminths		
Ascaris lumbricoides and *Trichuris trichiura* ova	*Ascaris* ova	*Ascaris* and some other helminth ova (e.g. *Trichuris*, *Taenia*) can be measured directly. Viability of ova can be determined.

Source: Adapted from Petterson & Ashbolt (2003).

3.1.1 Survival of pathogens in soil and on crops

Many pathogens can survive for long enough periods of time in soil or on crop surfaces to be transmitted to humans or animals. The pathogens most resistant in the environment are helminth eggs, which in some cases can survive for several years in the soil. Pathogen survival depends on a number of factors, as outlined in Table 3.4. Data on pathogen survival in soil and on different crops are presented in Table 3.5. Pathogen inactivation is much more rapid in hot, sunny weather than in cool, cloudy or rainy conditions. Low temperatures prolong pathogen survival. This is particularly relevant for post-harvest storage. If plants are harvested and then transported and stored in refrigerated conditions (e.g. 4 °C), pathogens may be able to survive long enough to infect product consumers. For example, experiments on lettuce spiked with *Cryptosporidium* oocysts showed that after three days of incubation at 20 °C, no viable oocysts could be detected, while three days at 4 °C yielded 10% viable oocysts (Warnes & Keevil, 2003). Table 3.4 also shows that pathogens die off on crops more quickly than they die off in soil. Recontamination of the crops, especially root crops and crops close to the soil, can occur — particularly after rainfall.

Table 3.4 Factors that affect pathogen survival in the environment

Factor	Comment
Humidity	Humid environments favour pathogen survival. Dry environments facilitate pathogen die-off.
Soil content	Clay soils and soils with high organic content favour survival of pathogens.
Temperature	Most important factor in pathogen die-off. High temperatures lead to rapid die-off, and low temperatures lead to prolonged survival. Freezing temperatures can also cause pathogen die-off.
pH	Some viruses survive longer in lower-pH soils, while alkaline soils are associated with more rapid die-off of viruses; neutral to slightly alkaline soils favour bacterial survival.
Sunlight (ultraviolet radiation)	Direct sunlight leads to rapid pathogen inactivation through desiccation and exposure to ultraviolet radiation.
Foliage/plant type	Certain plants have sticky surfaces (e.g. zucchini) or can absorb pathogens from the environment (e.g. lettuce, sprouts), leading to prolonged survival of some pathogens; root crops such as onions are more prone to contamination and facilitate pathogen survival.
Competition with native flora and fauna	Antagonistic effects from bacteria or algae may enhance die-off; bacteria may be preyed upon by protozoa.

Sources: Strauss (1985); Jimenéz (2003).

Table 3.5 Survival of various organisms in selected environmental media at 20–30 °C

Organism	Survival times (days)		
	Fresh water and sewage	**Crops**	**Soil**
Viruses			
Enteroviruses[a]	<120, usually <50	<60, usually <15	<100, usually <20
Bacteria			
Thermotolerant coliforms	<60, usually <30	<30, usually <15	<70, usually <20
Salmonella spp.	<60, usually <30	<30, usually <15	<70, usually <20
Shigella spp.	<30, usually <10	<10, usually <5	ND
V. cholerae	ND	<5, usually <2	<20, usually <10
Protozoa			
E. histolytica cysts	<30, usually <15	<10, usually <2	<20, usually <10
Cryptosporidium oocysts	<180, usually <70	<3, usually <2	<150, usually <75
Helminths			
Ascaris eggs	Years	<60, usually <30	Years
Tapeworm eggs	Many months	<60, usually <30	Many months

ND, no data

Sources: Feachem et al. (1983); Strauss (1985); Robertson, Campbell & Smith (1992); Jenkins et al. (2002); Warnes & Keevil (2003).

[a] Poliovirus, echovirus and coxsackievirus.

The greatest health risks are associated with crops that are eaten raw — for example, salad crops, especially if they are root crops (e.g. radish, onion) — or that grow close to the soil (lettuce, zucchini). Certain crops may be more susceptible to contamination than others — for example, onions (Blumenthal et al., 2003), zucchini (Armon et al., 2002) and lettuce (Solomon, Yaron & Matthews, 2002). Generally, crops that have certain surface properties (e.g. hairy, sticky, crevices, rough, etc.) protect pathogens from exposure to radiation and make them more difficult to wash off with rain or by post-harvest washing. The amount of water each crop holds is also an important factor in exposure to pathogens. For example, Shuval, Lampert & Fattal (1997) estimated that lettuce retains 10.8 ml of irrigation water, while a cucumber holds only 0.36 ml — i.e. approximately 3% of the volume of water the lettuce retains. A study by Stine et al. (2005) showed that lettuce and cantaloupe surfaces retained pathogens from irrigation water spiked with *E. coli* and a bacteriophage (PRD1), but bell peppers, which are smooth, did not.

Bacteria

A summary of the results of the selected studies on bacteria survival in crops, discussed in more detail below, is given in Table 3.6.

Table 3.6 Summary of selected microbial evidence of effect of water quality on crop contamination with bacteria

Treatment type and effluent quality; thermotolerant coliforms/100 ml	Summary of evidence	Reference
Trickling filter; 10^6	The lettuces irrigated in uncovered plots had high levels of bacterial contamination, unless a period of cessation of irrigation occurred before harvest (e.g. 7–12 days).	Vas da Costa Vargas, Bastos & Mara (1996)
Waste stabilization pond; 10^3–10^4	The quality of irrigated radishes and lettuces was 10^3 and 10^4 *E. coli* per 100 g (worst case) in dry weather; contamination increased after rainfall, and *Salmonella* bacteria were isolated.	Bastos & Mara (1995)
(i) Wastewater storage reservoir; 10^7; (ii) wastewater storage reservoir; 10^2	Improving the water quality to 200 thermotolerant coliforms/100 ml improved the quality of vegetables from 10^5 to $<10^3$ thermotolerant coliforms/100 ml.	Armon et al. (1994)
(i) Raw wastewater; 10^7; (ii) waste stabilization pond; 10^5; (iii) river water; 10^2	The percentage of crops with detectable salmonella decreased as water quality increased; leafy salad crops growing near the soil were the most contaminated; cessation of irrigation 8 days before harvest improved crop quality.	Castro de Esparza & Vargas (1990, cited in Peasy et al., 2000)

Studies in Portugal (Vaz da Costa Vargas, Bastos & Mara, 1996) showed that when a poor-quality wastewater (trickling filter effluent with 10^6 thermotolerant coliforms per 100 ml) was used to spray-irrigate lettuces, initial concentrations of indicator bacteria exceeded 10^5 thermotolerant coliforms per 100 g fresh weight. Once irrigation ceased, no *Salmonella* could be detected after five days, and after 7–12 days, thermotolerant coliform levels were similar to or just above the level seen in lettuces irrigated with fresh water. The crop quality was better than that of lettuces irrigated with surface waters on sale in the local markets (10^6 thermotolerant coliforms per 100 g), presumably because of recontamination in the market through the use of contaminated freshening water.

Studies of drip and furrow irrigation of lettuces and radishes (Bastos & Mara, 1995) with waste stabilization pond effluent (1700−5000 thermotolerant coliforms per 100 ml) indicated that crop quality was better under dry weather conditions: 10^3 and 10^4 *E. coli* per 100 g for radishes and lettuces and no *Salmonella* was present. The crop quality was better than that of locally sold lettuces (10^6 *E. coli* per 100 g). However, when rainfall occurred, *E. coli* numbers increased, and *Salmonella* bacteria were isolated from lettuce surfaces

Studies in Israel (Armon et al., 1994) showed that, when vegetables and salad crops were irrigated with poor-quality effluent from wastewater storage reservoirs (up to 10^7 thermotolerant coliforms per 100 ml), high levels of faecal indicator bacteria were detected on crop surfaces (up to 10^5 thermotolerant coliforms per 100 ml). However, when vegetables were irrigated with better-quality effluent (0−200 thermotolerant coliforms per 100 ml) from a different storage reservoir, thermotolerant coliform levels on crops were generally $<10^3$ per 100 g and often lower. In Peru, Castro de Esparza & Vargas (1990, cited in Peasy et al., 2000) found that the percentage of crops with detectable *Salmonella* decreased as water quality improved, from 10^7 thermotolerant coliforms in raw wastewater (10^3 *Salmonella* per 100 ml) to 10^5 thermotolerant coliforms ($<10^2$ *Salmonella*) in treated effluent from a wastewater stabilization pond. No *Salmonella* was detected on crops irrigated with river water (200 thermotolerant coliforms and no *Salmonella* detected). The most contaminated crop was lettuce, followed by parsley, spinach and carrots. Allowing eight days between the last irrigation and harvest ensured a 25% increase in crop samples having <10 *E. coli* and no detectable *Salmonella* per gram.

Overall, these studies indicate that (i) irrigating salad crops with wastewater containing $>10^5$ thermotolerant coliforms per 100 ml in uncovered plots results in high levels of bacterial contamination of crops, unless a period of cessation of irrigation occurs before harvest; (ii) improving the quality to 10^2–10^3 thermotolerant coliforms per 100 ml results in crops with low levels of contamination ($<10^3$ thermotolerant coliforms per 100 ml); and (iii) crop recontamination occurs frequently in markets.

Helminths

A summary of the data presented in this section is given in Table 3.7.

Table 3.7 Summary of selected microbial evidence of effect of water quality on crop contamination with helminths

Treatment type and effluent quality; number of nematode eggs per litre	Summary of evidence	Reference
(i) Raw wastewater; >100 (ii) Waste stabilization pond; >10 (iii) Waste stabilization pond; <0.5 (iv) Waste stabilization pond; 0	Lettuce contamination levels at harvest were: (i) up to 60 eggs/plant (ii) 0.6 egg/plant (iii) 0 eggs/plant (iv) 0 eggs/plant	Ayres et al. (1992a)
(i) Waste stabilization pond; 50 (ii) Waste stabilization pond; 10 (iii) Waste stabilization pond; ≤1	Lettuce contamination levels at harvest were: (i) up to 2.2 eggs/plant (ii) maximum 1.5 eggs/plant (iii) 0.3 egg/plant	Stott et al. (1994)

Studies in Brazil (Ayres et al., 1992a) indicated that when lettuce was spray-irrigated with effluent from waste stabilization ponds, the levels of crop contamination decreased with increased pond retention time, from the anaerobic pond through to the maturation pond. Levels of nematode contamination of lettuce were 0.6 egg per plant at harvest from the anaerobic pond (>10 eggs per litre), and no nematode eggs were detected on lettuces irrigated with effluent from the facultative pond (<0.5 egg per litre) or the maturation pond (0 eggs per litre, i.e. eggs were not detectable), despite growing in heavily contaminated soil containing >1200 *Ascaris* eggs per 100 g. Irrigation with fresh water successfully removed small levels of contamination on crops, whereas rainfall events significantly reduced levels of contamination on crops.

Studies carried out in greenhouses in the United Kingdom (Stott et al., 1994) with seeded effluent (*Ascaridia galli*) indicated that irrigation with wastewater containing 10 eggs per litre resulted in low levels of nematode contamination on lettuce (maximum of 1.5 eggs per plant), and improving wastewater quality further to ≤1 egg per litre resulted in very slight contamination of some plants (0.3 egg per plant). However, no transmission of *A. galli* infection was found from wastewater-irrigated crops using animal studies, although the infective dose was very low at <5 embryonated eggs.

The collective outcome of these microbial analyses shows that irrigation with wastewater at a quality of ≤1 egg per litre results in no detectable contamination of lettuce at harvest or at most only a very slight contamination on some plants (6%) with eggs that were either degenerate or not infective. However, a few nematode eggs on harvested plants were viable but not yet embryonated, indicating that crops with a long shelf life could represent a potential risk to consumers if the eggs had sufficient time to become infective.

Protozoa

In general, limited evidence concerning crop contamination with protozoa resulting from wastewater irrigation is available. Armon et al. (2002) found that zucchini spray-irrigated with poor-quality wastewater (>100 oocysts per litre) accumulated higher levels of *Cryptosporidium* oocysts (80–10 000 oocysts per 0.5 kg) on the surface than other types of crops. Zucchini have hairy, sticky surfaces and grow close to the ground and therefore may concentrate certain types of pathogens on the surface.

In Peru, *Entamoeba coli* was the most common protozoan and was identified on 38% of crops irrigated with wastewater and other contaminated surface water sources (Castro de Esparza & Vargas, 1990, cited in Peasey et al., 2000). *Cryptosporidium* and *Cyclospora* oocysts have been identified on produce sold in markets in Peru (Ortega et al., 1997) and Costa Rica (Calvo et al., 2004). In these cases, no water quality data were available, and contamination was more likely to have been caused by the use of sewage-contaminated surface water for irrigation rather than the direct use of wastewater for irrigation. The presence of *Cyclospora cayetanensis* in wastewater from the area where crops were produced in Peru has been confirmed by Sturbaum et al. (1998).

Viruses

A number of studies concerning viral die-off on crops have been conducted. In general, survival of viruses is influenced by the same parameters as described in Table 3.4. Petterson et al. (2001a) modelled the inactivation of enteric viruses on lettuce and carrots using data collected on crops grown under greenhouse conditions

Table 3.8 Viral inactivation on different crops

Crops	T_{99} (days)	Data source	References
Artichoke, broccoli, celery and lettuce	1.45	Seeded poliovirus inactivation over four days in an environmental chamber	Engineering Science (1987); Asano et al. (1992)
Celery (environmental chamber)	1.82[a]	Poliovirus seeded onto plants and time for 99% removal were recorded in both an environmental chamber and under field conditions	Sheikh, Cooper & Israel (1999)
Iceberg lettuce (environmental chamber)	3.3[a]		
Romaine lettuce (field conditions)	1.25[a]		
Butter lettuce (field conditions)	1.7[a]		
Winter triumph lettuce	0.4 (fast phase) 2 (slow phase) subpopulation size 0.12%[b]	Plants spray-irrigated at maturity with wastewater seeded with *B. fragilis* bacteriophage B40-8; experiment undertaken in uncontrolled greenhouse conditions	Petterson et al. (2001b)
Carrot	1.25 (fast phase) 20 (slow phase) subpopulation size 2%[b]	Plants grown in pots and irrigated at maturity with wastewater seeded with *B. fragilis* bacteriophage B40-8; experiment undertaken in uncontrolled greenhouse conditions	Petterson et al. (2001b)

T_{99}, time required for a 99% (2-log) reduction

[a] Estimated value of inactivation coefficient assuming log-linear relationship ($C_t = C_0e^{-bt}$) and time for 2 log virus removal. Added here for the purpose of comparison; not included in cited paper.

[b] The data showed evidence of biphasic decay (Petterson et al., 2001b).

and irrigated with wastewater seeded with a model virus *Bacteroides fragilis* B40-8. The results showed evidence for biphasic inactivation and notably the presence of a persistent subpopulation of viruses. Ward & Irving (1987) observed survival times of 1–13 days when the irrigation water contained between 5.1×10^2 and 2.6×10^5 type 1 poliovirus VU per litre.

Most of the studies conducted with viruses have been based on wastewater or water seeded with viruses. However, Hernandez et al. (1997) found hepatitis A viruses and rotaviruses in market lettuce irrigated with contaminated water in Costa Rica.

Table 3.8 illustrates some experimentally determined viral inactivation rates on different types of vegetables (Petterson & Ashbolt, 2003).

3.2 Epidemiological evidence

Shuval et al. (1986) conducted a review of the available epidemiological evidence from studies of wastewater use in agriculture. The evidence at that time suggested that the use of untreated wastewater in agriculture presented a high risk of transmission of intestinal nematodes and bacterial infections, especially to produce consumers and farm workers; there was limited evidence that the health of people living near wastewater-irrigated fields was affected. There was less evidence for the transmission of viruses and no evidence for the transmission of parasitic protozoa to farm workers,

Table 3.9 Summary of health risks associated with the use of wastewater for irrigation

Group exposed	Health risks		
	Helminth infections	**Bacterial/virus infections**	**Protozoal infections**
Consumers	Significant risk of helminth infection for both adults and children with untreated wastewater	Cholera, typhoid and shigellosis outbreaks reported from use of untreated wastewater; seropositive responses for *Helicobacter pylori* (untreated); increase in non-specific diarrhoea when water quality exceeds 10^4 thermotolerant coliforms/100 ml	Evidence of parasitic protozoa found on wastewater-irrigated vegetable surfaces, but no direct evidence of disease transmission
Farm workers and their families	Significant risk of helminth infection for both adults and children in contact with untreated wastewater; increased risk of hookworm infection for workers who do not wear shoes; risk for helminth infection remains, especially for children, even when wastewater is treated to <1 helminth egg per litre; adults are not at increased risk at this helminth concentration	Increased risk of diarrhoeal disease in young children with wastewater contact if water quality exceeds 10^4 thermotolerant coliforms/100 ml; elevated risk of *Salmonella* infection in children exposed to untreated wastewater; elevated seroresponse to norovirus in adults exposed to partially treated wastewater	Risk of *Giardia intestinalis* infection reported to be insignificant for contact with both untreated and treated wastewater; however, another study in Pakistan has estimated a threefold increase in risk of *Giardia* infection for farmers using raw wastewater compared with irrigation with fresh water; increased risk of amoebiasis observed with contact with untreated wastewater
Nearby communities	Transmission of helminth infections not studied for sprinkler irrigation, but same as above for flood or furrow irrigation with heavy contact	Sprinkler irrigation with poor water quality (10^6–10^8 total coliforms/100 ml) and high aerosol exposure associated with increased rates of infection; use of partially treated water (10^4–10^5 thermotolerant coliforms/100 ml or less) in sprinkler irrigation is not associated with increased viral infection rates	No data on transmission of protozoan infections during sprinkler irrigation with wastewater

Sources: Shuval, Yekutiel & Fattal (1984); Fattal et al. (1986); Shuval et al. (1989); Blumenthal et al. (2000a); Armon et al. (2002); Blumenthal & Peasey (2002); J.H.J. Ensink, W. van der Hoek & F.P. Amerasinghe (unpublished data, 2005).

consumers or nearby communities. The evidence also indicated that irrigation with treated wastewater did not lead to excess intestinal nematode infections among fieldworkers or consumers. The information from this review informed the development of the second edition of the WHO Guidelines (WHO, 1989).

Blumenthal & Peasey (2002) completed a critical review of all the epidemiological evidence of the health effects of wastewater and excreta use in agriculture for WHO. A summary of the main epidemiological evidence is presented in the following section, which has been abstracted from Blumenthal & Peasey (2002), and further summarized in Table 3.9 (summarized in Carr, Blumenthal & Mara, 2004). For studies where prevalence data were reported, a crude relative risk and 95% confidence interval were calculated where there was no calculation of a measure of association between exposure and infection. In the summary tables (see Tables 3.10–3.13 below), significance levels were reported using P-values at three levels ($P < 0.05$ denoted by *, $P < 0.01$ denoted by **, $P < 0.001$ denoted by ***). In the original study, studies were then evaluated according to their epidemiological quality, where analytical studies were better than descriptive studies, prospective studies better than retrospective studies and cohort studies better than cross-sectional studies. Most credence was given to a subset of analytical epidemiological studies that included the following features: well defined exposure and disease, risk estimates calculated after allowance for confounding factors, statistical testing of associations between exposure and disease and evidence of causality (where available). These studies are given more prominence in the text, and the overall results reported for each section give more credence to the results from these analytical studies.

3.2.1 Risks to consumers of crops eaten uncooked

Table 3.10 (pages 36-37) summarizes the studies that were reviewed on risks of helminth, bacterial and viral infections to consumers of crops eaten uncooked. The results of comparison of exposed and non-exposed groups are given as relative risks or odds ratios in the table (ratio of exposed to non-exposed) and reported as attributable risks in the text (difference between exposed and non-exposed).

Helminth infections

Descriptive studies (Khalil, 1931; Baumhogger, 1949; Krey, 1949; Shuval, Yekutiel & Fattal, 1984) of the association between consumption of uncooked vegetables irrigated with untreated wastewater and *Ascaris* infection produced estimates of relative risks between 7.0 and 35.0 (Table 3.10); the proportion of *Ascaris* infection in the study populations that was attributed to consumption of uncooked vegetables irrigated with wastewater (the attributable risk) varied between 34% and 60%. An analytical cross-sectional study (Cifuentes, 1998) provided an estimate of relative risk of 1.4, but it is not clear how much this is a measure of the risk of the use of untreated or treated wastewater, as stratum-specific estimates were not reported.

A prospective cohort study (Peasey, 2000), however, produced adjusted odds ratios (OR) of 3.9 (men) and 2.4 (children) for consumption of vegetables irrigated with wastewater by farming families, when allowance was made for potential confounding factors for *Ascaris* such as age, gender, socioeconomic status and direct wastewater contact. The attributable risk from consumption was 25% for children and 14% for adult men. The proportion of infection in the whole study population that was attributable to exposure and could be eliminated if the exposure were removed (the preventable fraction) was 53% and 35% for children and adult men, respectively.

There is some evidence in adult men that consumption of vegetables irrigated with untreated wastewater (>100 eggs per litre) had a greater effect than irrigation with treated wastewater (<1 egg per litre) (OR = 2.7, $P = 0.074$ and OR = 0.6, $P = 0.68$, respectively), but this did not reach statistical significance. In children, irrigation of vegetables with untreated wastewater was associated with an increased risk of infection (OR = 4.2, $P < 0.001$), and use of treated wastewater (<1 nematode egg per litre) was also associated with an increased risk of infection (OR = 3.7, $P = 0.056$). A descriptive (ecological) study (Baumhogger, 1949; Krey, 1949) provides suggestive evidence that treatment using sedimentation and biological oxidation reduces the risks of *Ascaris* among consumers of uncooked vegetables to below the levels seen where no wastewater irrigation takes place.

Bacterial and viral infections

There are several studies of the risk of specific bacterial or viral infections associated with consumption of vegetable crops irrigated with untreated wastewater. A study in Santiago, Chile (Hopkins et al., 1993) showed that the consumption of raw vegetables coming from an area where untreated wastewater is used for irrigation was related to an increase in seroprevalence to *Helicobacter pylori* (relative risk 3.3, $P < 0.001$), when allowance was made for confounding factors.

Analytical cross-sectional studies of symptomatic diarrhoeal disease in Mexico (Blumenthal et al., 2003) indicated that there was a twofold or greater risk of diarrhoeal disease associated with medium or high frequencies of consumption of uncooked onions irrigated with wastewater that had been stored in a single reservoir (water quality 10^4 thermotolerant coliforms per 100 ml). For adults, the attributable risk was 4.3% (weekly prevalence), which is equivalent to an annual rate of 0.66 per person (allowing for an eight-month dry season). A prospective cohort study in the same area showed that there was a twofold increase in seroresponse to norovirus (Mexico strain) associated with the consumption of green tomatoes irrigated with the same water when allowance was made for confounding factors, but no increased risk of seroresponse to enterotoxigenic *E. coli* infection associated with vegetable consumption. In this study, over 50% of the diarrhoeal disease in the study population who ate onions (which was over half the study group) was attributable to consumption of onions, such that over 25% of all diarrhoea in adults and young children in the study population in the dry season was attributable to wastewater irrigation of vegetables.

Evidence from disease outbreaks

Study of disease outbreaks provides further information on risks to consumers from irrigating vegetables with wastewater. From disease outbreaks in Chile and Israel, there is evidence of the transmission of cholera (Shuval, Yekutiel & Fattal, 1984; Fattal, Yekutiel & Shuval, 1986), typhoid (Shuval, 1993) and shigellosis (Porter et al., 1984) when vegetables are irrigated with untreated wastewater.

Summary

There is evidence to suggest that the use of untreated wastewater to irrigate vegetables can lead to increased helminth infection (mainly *Ascaris lumbricoides* infection), bacterial and viral infections (typhoid, cholera, *Helicobacter pylori*, norovirus) and symptomatic diarrhoeal disease in consumers. The studies of *Ascaris* infection among consumers indicate that treatment is needed to reduce the risk of *Ascaris* infection to consumers of crops irrigated with untreated wastewater. It is not possible to determine the extent of treatment that is needed from the available data, but an analytical study indicated that treatment to ≤1 nematode egg per litre may not be sufficient in certain circumstances, especially where children are exposed. When wastewater is partially treated, there is evidence that the risk of enteric infections (bacterial and viral origin) is still significant when consumers eat some types of uncooked vegetables (mainly root crops) irrigated by water with 10^4 thermotolerant coliforms per 100 ml.

3.2.2 Risks to agricultural workers and their families

Table 3.11 summarizes the studies that were reviewed on risks of transmission of intestinal parasitic infections to agricultural workers, their families and nearby populations. Table 3.12 summarizes the studies that were reviewed on the prevalence of reported enteric disease in agricultural workers, their families and nearby populations. Table 3.13 summarizes the serological studies that were reviewed on risks of transmission of enteric viruses and bacteria to agricultural workers and nearby populations.

Research conducted in Phnom Penh, Cambodia, indicated that there may be an association between exposure to wastewater and skin problems such as contact dermatitis (eczema) (van der Hoek et al., 2005). In a survey of households engaged in the cultivation of aquatic vegetables in a lake heavily contaminated by untreated sewage, 22% of the people living in the households reported skin problems. In a survey of similar households living around a lake with no wastewater inputs, only 1% of the people reported skin problems. Skin problems were most likely to be reported on the hands (56%), feet (36%) and legs (34%). The cause of the skin problems was not determined but was likely due to a mixture of agents (i.e. both chemical and biological) in the wastewater.

Intestinal parasitic infections

There is evidence to suggest that direct contact with untreated wastewater can lead to increased helminth infection (mainly *Ascaris* and hookworm infection) and that this effect is more pronounced in children than in adult farm workers. When flood or furrow irrigation with wastewater is used, the effect of direct contact with untreated wastewater on *Ascaris* infection varies according to area and the initial prevalence, from attributable risks of between 9% and 30% in children (Bouhoum & Schwartzbrod, 1998; Habbari et al., 2000; Peasey, 2000; Blumenthal et al., 2001) and between 7% and 33% in adults (Krishnamoorthi, Abdulappa & Anwikar, 1973; Cifuentes, 1998; Peasey, 2000; Blumenthal et al., 2001). For hookworm infection, the effect of exposure to untreated wastewater among farm workers varies from attributable risks of between 37% (Krishnamoorthi, Abdulappa & Anwikar, 1973) and 14% (Ensink et al., 2005) in adults.

There is some evidence from analytical studies that *Ascaris* infection can be reduced when wastewater is partially treated before use, but the effect depends on the extent of treatment. In studies in Mexico, where wastewater retention was ensured in a single reservoir for a minimum of one month during the year preceding the study (achieving 2 log nematode egg removal, to <1 nematode egg per litre), there was no increased risk of *Ascaris* infection in adults associated with exposure to wastewater irrigation (Peasey, 2000); in children, however, there was still a significant increased attributable risk of 14% (Peasey, 2000; Blumenthal et al., 2001). However, retention in two reservoirs in series for a period of one or two months in each reservoir (achieving a 2–3 log nematode egg removal) resulted in no detected excess risk of *Ascaris* in children (Cifuentes, 1998).

There are very few data on the effect of contact with wastewater in agriculture on protozoan infections. Studies in India (Sehgal & Mahajan, 1991) and Mexico (Cifuentes et al., 2000b) have produced similar results; that is, there is no significant risk of *Giardia intestinalis* infection related to contact with untreated or treated wastewater for irrigation. However, a study in Pakistan estimated a threefold increase in risk of *Giardia* infection when farmers using raw wastewater were compared with farmers using regular (non-wastewater) irrigation water (J.H.J. Ensink, W. van der Hoek & F.P. Amerasinghe, unpublished data, 2005). The attributable risk was 28%.

Table 3.10 Studies of risks to consumers: Prevalence of infection and relative risks or odds ratios in populations consuming or not consuming uncooked vegetables irrigated with wastewater

Health outcome and outcome measure	Wastewater quality	Age group (years)	Prevalence of outcome measure (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
Ascariasis (prevalence)	Untreated	Adults	70 vs 10	7.0[b]	Prison population eating vegetables irrigated with wastewater vs village population not using wastewater or nightsoil in agriculture	Khalil (1931)[a]
Ascariasis (prevalence — routine data)	Untreated	All ages	50 vs 6	8.3[b]	City where untreated wastewater used to irrigate vegetables vs average of five cities with no wastewater irrigation	Baumhogger (1949); Krey (1949)[a]
Ascariasis (prevalence — routine data)	Untreated	All ages	(i) 35 vs 1 (ii) 13 vs 1	(i) 35.0 (32.56–37.62)[b] (ii) 13.0[b]	General population eating wastewater-irrigated vegetables vs general population not consuming wastewater-irrigated vegetables (i) 1935–1947 vs 1948–1966 (ii) 1968–1970 vs 1975–1982	Shuval, Yekutiel & Fattal (1984)
Ascariasis (prevalence)	Untreated and treated (storage reservoirs)	5+	4.9 vs 2.9	1.43 (1.07–1.92)**	Consumption of local vegetables (wastewater-irrigated fields) vs vegetables grown outside village	Cifuentes (1998)
Ascariasis (prevalence)	(i) Untreated and treated (ii) Untreated (iii) Treated <1 nematode egg per litre	<15	(i) 41.1 vs 16.4 (ii) 46.5 vs 17.3 (iii) 36.5 vs 13.3	(i) 2.41 (1.07–5.44)* (ii) 4.15 (1.89–9.41)[c]*** (iii) 3.74 (0.80–17.38)	Consumption of uncooked vegetables from local (wastewater-irrigated) field or garden vs no consumption	Peasey (2000)
		>15 male	(i) 22.4 vs 8.8 (ii) 22.4 vs 9.5 (iii) 8.0 vs 12.5	(i) 3.93 (1.01–15.24) (ii) 2.74 (0.84–8.81) (iii) 0.61 (0.06–5.81)		
Ascariasis (prevalence)	Treated (sedimentation and biological oxidation)	All ages	2.2 vs 6.1	0.36[b]	City where treated wastewater used to irrigate vegetables vs average of five cities with no wastewater irrigation	Baumhogger (1949); Krey (1949)[a]

Table 3.10 (continued)

Health outcome and outcome measure	Wastewater quality	Age group (years)	Prevalence of outcome measure (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
Helicobacter pylori infection (seroprevalence)	Untreated	<35	38 vs 9	3.25 (1.94–5.71)***	Consumption of uncooked vs cooked vegetables	Hopkins et al. (1993)
Diarrhoeal disease (self-reported two-weekly prevalence)	Untreated and treated	5+	19.0 vs 10.0	2.00 (1.37–2.93)***	Family grows salad crops (wastewater irrigated) vs family does not grow salad crops	Cifuentes (1998)
Diarrhoeal disease (self-reported weekly prevalence)	Treated (storage reservoirs); 10^4 faecal coliforms/100 ml	1–4	<1/week, 2.6 1/week, 9.5 >1/week, 5.8	1.00 3.80 (1.24–11.68) 2.19 (0.54–8.89) $P = 0.05$	Medium and high frequencies of consumption of uncooked onions vs low frequency	Blumenthal et al. (2003)
		15+	<1/month, 2.4 1–3/month, 8.7 1/week, 6.0 >1/week, 5.5	1.00 3.99 (1.62–9.82) 2.58 (1.05–6.39) 2.24 (0.88–5.71) $P < 0.01$		
Norovirus infection (Mexico strain) (seroresponse)	Treated (storage reservoirs); 10^4 faecal coliforms/100 ml	5–14	0/2 weeks, 13.6 1/2 weeks, 20.6 2–14/2 weeks, 29.6	1.00 1.44 (0.76–2.75) 2.52 (1.03–6.13)	Different frequencies of consumption of uncooked green tomatoes	Blumenthal et al. (2003)

Significance levels: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

[a] Described in Shuval et al. (1986).
[b] Crude relative risk calculated from prevalence data reported.
[c] Crude odds ratios and 95% confidence intervals calculated for prevalence data reported: (i) adjusted odds ratios; (ii) and (iii) crude odds ratios.

Table 3.11 Studies of risks to workers and nearby populations: Prevalence and relative risks of parasitic infections in populations exposed or not exposed to wastewater used for irrigation

Health outcome	Wastewater quality	Age group (years)	Prevalence of infection (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
(i) Ascariasis (ii) Hookworm infection	Untreated	Adults	(i) 46.8 vs 13.4 (ii) 69.7 vs 32.6	(i) 3.48 (2.69–4.51) ***[b] (ii) 2.14 (1.84–2.48)***[b]	Sewage farm workers vs farm workers exposed to clean water	Krishnamoorthi, Abdulapp & Anwikar (1973)[a]
(i) Ascariasis (ii) Trichuriasis	Untreated	School children	(i) 33 vs 2 (ii) 17 vs 2	(i) 16.5[c] (ii) 8.5[c]	School children in urban area where sewage use in irrigation vs where sewage not used	Bouhoum & Schwartzbrod (1998)
Ascariasis	Untreated	7–14	35.1 vs 19.1	1.79 (1.13–2.84)*[b]	Contact with wastewater vs no contact with wastewater	Habbari et al. (2000)
(i) Parasitic infection (ii) Hookworm	Untreated, plus health protection measures	Adult	(i) 81.6 vs 26.2 (ii) 25.1 vs 7.7	(i) 3.1[c] (ii) 3.3[c]	(i) Sewage farm workers with poor personal hygiene vs good hygiene (ii) Sewage farm workers barefoot vs wearing shoes	Srivastava & Pandey (1986)
Ascariasis	(i) Untreated (ii) Treated (one storage reservoir) <1 nematode egg per litre	0–4	(i) 10.0 vs 0.6 (ii) 11.8 vs 0.6	(i) 18.01 (4.10–79.16)*** (ii) 21.22 (5.06–88.93)***	Farm workers or their children (i) in direct contact with raw wastewater vs not using wastewater for irrigation (dry season) (ii) in direct contact with wastewater stored in one reservoir vs not using wastewater for irrigation	Blumenthal et al. (2001)
		5+	(i) 7.2 vs 0.4 (ii) 4.6 vs 0.4	(i) 13.49 (6.35–28.63)*** (ii) 9.42 (4.45–19.94)***		
Ascariasis	(i) Untreated (ii) Treated (two storage reservoirs) 0 nematode eggs per litre	0–4		(i) 5.71 (2.44–13.36)*** (ii) 1.29 (0.49–3.39)	Farm workers or their children (i) in direct contact with raw wastewater vs not using wastewater for irrigation (rainy season) (ii) in direct contact with wastewater stored in two reservoirs vs not using wastewater for irrigation	Cifuentes (1998)

Table 3.11 (continued)

Health outcome	Wastewater quality	Age group (years)	Prevalence of infection (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
Ascariasis *(continued)*		5+	(i) 9.1 vs 0.7 (ii) 1.5 vs 0.7	(i) 13.18 (7.51–23.12)*** (ii) 1.94 (1.01–3.71)*		
	(i) Untreated (ii) Treated (one storage reservoir) <1 nematode egg per litre	<15	(i) 50.0 vs 30.0 (ii) 44.1 vs 30.0	(i) 1.50 (0.59–3.79) (ii) 2.61 (1.10–6.15)**	Farm workers or their children (i) in direct contact with raw wastewater vs not in direct contact with wastewater (dry season) (ii) in direct contact with wastewater stored in one reservoir vs not in direct contact with wastewater [Direct contact was through (a) play (<15 years), (b) work relating to chili production (male >15 years), (c) tending livestock in wastewater-irrigated fields (female >15 years)]	Peasey (2000)
		>15 male	(i) 39.3 vs 9.0 (ii) 12.5 vs 9.0	(i) 5.37 (1.79–16.10)** (ii) 1.56 (0.13–18.59)		
		>15 female	(i) 37.5 vs 15.6 (ii) 3.9 vs 15.6	(i) 4.39 (1.08–17.81)* (ii) 0.70 (0.06–8.33)		
Giardiasis	(i) Untreated (ii) Treated	Not specified	(i) 12.3 vs 11.5 (ii) 15.5 vs 11.5	(i) 1.07 (0.85–1.35)[b] (ii) 1.35 (0.99–1.86)[b]	(i) General population in villages using raw wastewater for irrigation vs general population in control village not using sewage (ii) General population in villages using treated wastewater for irrigation vs general population in control village not using sewage	Sehgal & Mahajan (1991)
Giardiasis	(i) Untreated (ii) Treated (two storage reservoirs)	All ages	(i) 8.1 vs 7.8 (ii) 10.9 vs 7.8	(i) 1.01 (0.84–1.36) (ii) 1.22 (0.94–1.58)	Farm workers and their families (i) in direct contact with raw wastewater vs not using wastewater for irrigation (ii) in direct contact with wastewater stored in two reservoirs vs not using wastewater for irrigation	Cifuentes et al. (2000b)

Significance levels: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

[a] Described in Shuval et al. (1986).

[b] Relative risk and 95% confidence interval calculated from prevalence or incidence rates and population data reported.

[c] Crude relative risk calculated from prevalence or incidence data reported.

Table 3.12 Studies of risks to workers and nearby populations: Prevalence of reported enteric infections and relative risks in populations exposed or not exposed to wastewater used for irrigation

Health outcome and outcome measure	Wastewater quality	Age group (years)	Prevalence or incidence of infection (%)	Relative risk or odds ratio (95% confidence interval)	Study group and comparison	Reference
(i) Salmonellosis (ii) Shigellosis (iii) Typhoid fever (iv) Infectious hepatitis (Incidence per 100 000 population)	Treated Stabilization ponds 3–7 days retention	All ages	(i) 23.4 vs 6.3 (ii) 100.2 vs 45.5 (iii) 1.16 vs 0.27 (iv) 8.8 vs 4.4	(i) 3.7 (ii) 2.2 (iii) 4.3 (iv) 2.0	Population in kibbutzim using wastewater for irrigation vs not using wastewater	Katzenelson, Buiu & Shuval (1976)
Enteric disease (Incidence per 100 person-years)	Treated Stabilization ponds 5–10 days retention 10^6–10^8 total coliforms/100 ml	(i) 0–4 (ii) 5–18 (iii) ≥19	(i) 51.8 vs 27.4 (ii) 11.2 vs 6.6 (iii) 4.7 vs 1.8	(i) 1.91 (1.30–2.80) (ii) 1.23 (0.46–3.25) (iii) 2.06 (0.69–6.16)	Comparison of enteric disease rates in kibbutzim when using wastewater for sprinkler irrigation vs when not using wastewater for irrigation, with allowance made for rate of control diseases and other factors; results from irrigation season	Fattal et al. (1986a)
Enteric disease (Incidence per 100 person-years)	Treated Stabilization ponds 5–10 days retention 10^4–10^5 total coliforms/100 ml	All ages 0–5	L 11.0 M 9.4 H 11.6 L 26.4 M 20.0 H 26.0	L 1.00[a] M 0.85 H 1.05 L 1.00 M 0.76 H 0.98	Comparison of rates in kibbutzim population with wastewater sprinkler irrigation within 300–600 m (High = H) or kibbutzim with wastewater use but no aerosols (Medium = M) vs kibbutzim with no use of wastewater (Low = L) [No excess enteric disease was seen in wastewater contact workers or their families compared with the unexposed]	Shuval et al. (1989)
Clinical illness (Incidence per worker-month)	Treated Storage lagoons (over winter)	Adults	0.54 vs 0.58	0.93[a]	Comparison of illness rates in spray irrigation workers vs road commission workers (no significant differences found with level of exposure)	Linnemann et al. (1984)

Table 3.12 (continued)

Health outcome and outcome measure	Wastewater quality	Age group (years)	Prevalence or incidence of infection (%)	Relative risk or odds ratio (95% confidence interval)	Study group and comparison	Reference
Clinical viral infections (% with infection episode in irrigation season)	Treated (summer 1982: trickling filter plant effluent 8×10^6 faecal coliforms/100 ml, 3.2 enteroviruses/100 ml; summer 1983: effluent from trickling filter plant and storage reservoirs 10^3–10^4 faecal coliforms/100 ml, 0.4 enteroviruses/100 ml)	Adults and children <13	Summer 1982 (i) 8 (ii) 8 (iii) 24 Summer 1983 (i) 0 (ii) 8 (iii) 5	$P = 0.06$ $P > 0.05$	Comparison of faecal donors with (i) low aerosol exposure (ii) medium aerosol exposure (iii) high aerosol exposure	Camann & Moore (1987)
Diarrhoeal disease (two-weekly prevalence)	(i) Untreated (ii) Treated (one storage reservoir) 10^5 faecal coliforms/100 ml	0–4 5+	(i) 19.4 vs 13.6 (ii) 15.6 vs 13.6 (i) 7.1 vs 5.9 (ii) 8.1 vs 5.9	(i) 1.75 (1.10–2.78)** (ii) 1.13 (0.70–1.83) (i) 1.34 (1.00–1.78)* (ii) 1.50 (1.15–1.96)**	Farm workers or their children (i) in direct contact with raw wastewater vs not using wastewater for irrigation (dry season) (ii) in direct contact with wastewater stored in one reservoir vs not using wastewater for irrigation	Blumenthal et al. (2001)
Diarrhoeal disease (two-weekly prevalence)	(i) Untreated (ii) Treated (two storage reservoirs) 10^3–10^4 faecal coliforms/100 ml	0–4 5+	(i) 29.0 vs 23.0 (ii) 26.8 vs 23.0 (i) 11.8 vs 9.8 (ii) 10.5 vs 9.8	1.33 (0.96–1.85) 1.17 (0.85–1.60) 1.10 (0.88–1.38) 1.06 (0.86–1.29)	Farm workers or their children (i) in direct contact with raw wastewater vs not using wastewater for irrigation (rainy season) (ii) in direct contact with wastewater stored in two reservoirs vs not using wastewater for irrigation	Cifuentes (1998)

Table 3.12 (continued)

Health outcome and outcome measure	Wastewater quality	Age group (years)	Prevalence or incidence of infection (%)	Relative risk or odds ratio (95% confidence interval)	Study group and comparison	Reference
Diarrhoeal disease (weekly prevalence)	Treated (two reservoirs) 10^4 faecal coliforms/100 ml	5–14	(i) 11.0 vs 4.0 (ii) 7.4 vs 3.2	(i) 3.05 (1.67–5.58)** (ii) 2.34 (1.20–4.57)*	Children of farm workers with (i) high level of contact with wastewater vs no contact (rainy season) (ii) contact with wastewater vs no contact (dry season)	Blumenthal et al. (2003)

Significance levels: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

[a] Crude relative risk calculated from prevalence or incidence data reported.

Table 3.13 Studies of risks to workers and nearby populations: Enteric viruses and bacteria — seroprevalence and seroconversion and relative risks in populations exposed or not exposed to wastewater used for irrigation

Health outcome	Wastewater quality	Age group (years)	Seroprevalence (%) or seroconversion (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
Echovirus type 4 infection (% seroprevalence and % seroconversion)	Treated Stabilization ponds 5–10 days retention 10^4–10^5 total coliforms/100 ml	(i) 0–5 (ii) 6–17 (iii) 25+	Seroprevalence (i) 83 vs 33 (ii) 73 vs 37 Seroconversion (iii) 63 vs 20	(i) 2.5[a] *** (ii) 2.0** (iii) 3.2**	Comparison of rates in kibbutzim population exposed to aerosolized wastewater from kibbutz itself and nearby towns vs kibbutzim not exposed to wastewater (other comparisons given in paper) [Data from 1980 presented; after national outbreak of echovirus 4] No significant differences were found for all other enteroviruses	Fattal et al. (1987)
Poliovirus infection (i) Polio 1 (ii) Polio 2 (iii) Polio 3 (% seroprevalence)	Treated Stabilization ponds 5–10 days retention	<1–60+	(i) 82 vs 86 (ii) 88 vs 91 (iii) 80 vs 82	(i) 0.95[a] (ii) 0.97 (iii) 0.98	1980 data shown Comparison of rates in kibbutzim population exposed to aerosolized wastewater from kibbutz itself and nearby towns vs kibbutzim not exposed to wastewater	Margalith, Morag & Fattal (1990)
Legionellosis (% seroprevalence)	Treated Stabilization ponds 5–7 days retention 10^6–10^7 total coliforms/100 ml	18+	4.3 vs 1.4	3.14 (0.89–11.85)[b]	Sewage contact workers vs non-irrigation workers	Fattal et al. (1985)

Table 3.13 (continued)

Health outcome	Wastewater quality	Age group (years)	Seroprevalence (%) or seroconversion (%)	Relative risk or odds ratio (95% CI)	Study group and comparison	Reference
Infection with enteric viruses (seroconversion incidence densities)	Treated Trickling filter effluent 10^6 faecal coliforms/100 ml (1982) Reservoir effluent 10^3–10^4 faecal coliforms/100 ml (1983)	All ages	(i) 5.37 vs 2.55 (ii) 8.34 vs 1.32 (iii) 8.34 vs 5.46 (iv) 8.34 vs 4.68	2.10 (1.56–2.03) [b]*** 6.31 (2.52–15.76)*** 1.56 (0.86–2.84) 1.78 (1.03–3.09)*	(i) Irrigation vs baseline (ii) High exposure: irrigation vs baseline (iii) Irrigation: High aerosol exposure (index >5) vs low (index <1) (iv) Irrigation: High aerosol exposure vs intermediate aerosol exposure (1 ≤ index ≤5)	Camann et al. (1986a)
Rotavirus infection (% seroconversion)	Treated: trickling filter plant, then storage reservoirs	All ages	(i) 1.99 vs 5.34 (ii) 1.54 v 2.50	(i) 0.37 (0.23–0.62)[b]*** (ii) 1.63 (0.70–3.78)[b]	(i) 20 months after start of spray irrigation vs 20 months before irrigation (ii) 10 months spray irrigation with reservoir effluent vs 10 months spray irrigation with trickling filter plant effluent	Ward et al. (1989)
Enteroviruses: coxsackievirus B5 infection (% seroprevalence)	Treated: storage lagoons (over autumn and winter)	Adults	100 vs 52	1.93 (1.36–2.75)[b]*	Comparison of seropositivity in spray irrigation workers vs spray nozzle cleaners No significant differences were found for all other enteroviruses	Linnemann et al. (1984)
Norwalk-like virus: Mexico infection (% seroresponse)	Treated 10^4 faecal coliforms/100 ml	>15	33.3 vs 11.4	4.21 (1.62–10.96)**	Farm workers with high level of contact with wastewater vs no contact	Blumenthal et al. (2003)
Salmonellosis (prevalence)	Untreated	<15	39.3 vs 24.6	1.60**	Children of agriculturalists vs children from non-agricultural families	Ait Melloul & Hassani (1999)

Significance levels: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

[a] Crude relative risk calculated from seroprevalence or seroconversion data reported.

[b] Crude relative risk and 95% confidence interval calculated from seroprevalence or seroconversion.

Reported diarrhoeal disease

Analytical studies in Mexico of the effect of direct contact with wastewater indicate that there are risks of diarrhoeal disease related to contact with untreated wastewater, particularly in the dry season (relative risk 1.75), and that the risk is reduced when the wastewater is stored in storage reservoirs before use (Cifuentes, 1998; Blumenthal et al., 2001).

When wastewater was partially treated in a single reservoir (10^5 thermotolerant coliforms per 100 ml) (Blumenthal et al., 2001), there was still an excess risk of diarrhoeal disease in the dry season in children older than five (relative risk 1.5). When it was treated in two reservoirs in series (10^3–10^4 thermotolerant coliforms per 100 ml), no excess risk of diarrhoeal disease was detected in the rainy season (Cifuentes, 1998), unless there were high levels of contact (Blumenthal et al., 2003), but an increased risk was found in school-aged children in the dry season (relative risk 2.3).

Serological studies

In a study in Mexico (Blumenthal et al., 2003), farm workers who had a high level of direct contact with wastewater that had been stored in a single reservoir (quality 10^4 thermotolerant coliforms per 100 ml) had a fourfold increase in seroresponse to norovirus (Mexico strain) infection after allowance for confounding factors.

3.2.3 Risks to local communities from sprinkler irrigation

Table 3.12 summarizes the studies that were reviewed on risks of reported enteric disease to agricultural workers and nearby populations, and Table 3.13 summarizes the serological studies that were reviewed on risks of enteric viruses and bacteria to agricultural workers and nearby populations.

Reported enteric infections

Several studies in Israel have investigated the effect of exposure of the general population to wastewater aerosols from sprinkler irrigation of partially treated wastewater from waste stabilization ponds (short retention times). The most recent study, a prospective cohort study (Shuval et al., 1989), found that episodes of enteric disease were similar in kibbutzim most exposed to treated wastewater aerosols from waste stabilization ponds (10^4–10^5 total coliforms per 100 ml; sprinkler irrigation within 300–600 m of residential areas) and in those not exposed to wastewater in any form. This supersedes the results of the first (Katzenelson, Buiu & Shuval, 1976) and second studies (Fattal et al., 1986), which reported high risks of enteric disease related to exposure to wastewater (10^6–10^8 total coliforms per 100 ml), but which were methodologically flawed.

When effluent from a trickling filter plant in Lubbock in the United States of America was used for irrigation (10^6 thermotolerant coliforms per 100 ml, 100–1000 enteroviruses per 100 ml), there was a borderline association between high aerosol exposure and viral illness ($P = 0.06$), but this disappeared after allowance was made for confounding factors (Camann & Moore, 1987). Exposure to higher-quality wastewater from storage reservoirs (10^3–10^4 thermotolerant coliforms per 100 ml) had no significant effect on viral illness (Moore et al., 1988). Another study in the same country (Linneman et al., 1984) using effluent from storage lagoons (where storage was for about six months) had similar results.

Serological studies of viral and bacterial infections

Serological studies from kibbutzim in Israel (Fattal et al., 1985, 1987; Margalith, Morag & Fattal, 1990) indicate that there is no excess endemic viral infection related to exposure to wastewater aerosols through sprinkler irrigation from 5- to 10-day waste stabilization ponds (wastewater quality 10^6–10^8 total coliforms per 100 ml). There was no significant increase in levels of antibodies to echovirus types 7 and 9, coxsackievirus types A9, B1, B3 and B4 and hepatitis A virus (Fattal et al., 1987) or to poliovirus types 1, 2 and 3 (Margalith, Morag & Fattal, 1990). There was a significant increase in levels of antibodies to echovirus type 4 (but no additional disease incidence), however, in kibbutzim that had been exposed to aerosols of partially treated wastewater from nearby towns (Fattal et al., 1987). This could be attributed to a major epidemic of echovirus 4 in Israel at the time.

In the Lubbock Infection Surveillance Study (Camann et al., 1986a), wastewater irrigation was significantly associated with new viral infections when seroconversion incidence densities for coxsackievirus B and echoviruses were compared before and after irrigation started (Camann et al., 1986a, 1986b), especially in those who had a high degree of aerosol exposure.

Infection episodes ($n = 5$) that were significantly associated with aerosol exposure occurred mainly when effluent from a trickling filter plant (quality 10^6 thermotolerant coliforms per 100 ml, 100–1000 enteroviruses per 100 ml) was being used for irrigation, but not when effluent from storage reservoirs (quality 10^3–10^4 thermotolerant coliforms per 100 ml, <10 enteroviruses per 100 ml) were used. When allowance was made for potential confounding factors, however, the association between exposure and infection was significant ($P < 0.05$) only for two of the five episodes reported (Camann et al., 1986b) where the agents of infection were poliovirus 1 and coxsackievirus B (first episode) and echoviruses (second episode).

In an earlier study (Linneman et al., 1984), no significant differences in seroresponse to infections were found in spray irrigation workers exposed to effluent from storage lagoons except for those who cleaned the nozzles (and were frequently soaked with wastewater), who had higher seroprevalences of coxsackievirus B5.

3.2.4 Overall results for farming families and local communities

There is evidence to suggest that direct contact with untreated wastewater through flood or furrow irrigation can lead to increased helminth infection (mainly *Ascaris* infection) and that this effect is more pronounced in children than in adults. There is some evidence that *Ascaris* infection related to direct contact with wastewater can be reduced when the wastewater is partially treated before use and that the effect depends on the extent of treatment. Treatment may need to achieve concentrations below one egg per litre where children under 15 are exposed, perhaps combined with measures to restrict the contact of children with wastewater through play or work.

Studies of diarrhoeal disease related to direct contact with wastewater suggest that:

- there is an increased risk of diarrhoeal disease, particularly in young children and in the dry season, related to exposure to untreated wastewater;
- partial treatment of the wastewater (to 10^5 thermotolerant coliforms per 100 ml) reduces the effect in adults but not in children;
- treatment may need to be below 10^4 thermotolerant coliforms per 100 ml in circumstances where children have high amounts of contact, or, if this is not possible, effective measures to reduce contact of children with wastewater may need to be introduced.

The better-quality studies of sprinkler irrigation of treated wastewater indicate that there may be an increased risk of infection when the quality of the wastewater is 10^6 thermotolerant coliforms per 100 ml, but no increased risk of infection when the water quality is 10^4–10^5 thermotolerant coliforms per 100 ml or less.

3.3 Quantitative microbial risk analysis

Since the publication of the second edition of these Guidelines in 1989, the development of QMRA has enabled increasingly sophisticated analysis of health risks associated with wastewater use in agriculture. The data generated in these assessments are a useful complement to those available from epidemiological studies. QMRA can estimate risks from a variety of different exposures and/or pathogens that would be difficult to measure through epidemiological investigations due to the high cost and necessity of studying large populations. QMRA has been applied to risks associated with bacteria, protozoa and viruses, but few QMRAs have been conducted on the transmission of helminth infections from wastewater or excreta use activities.

Asano et al. (1992) estimated the risk of infection with three enteric viruses (poliovirus 1 and 3 and echovirus 12) related to use of chlorinated tertiary effluents and unchlorinated secondary effluents given tertiary treatment. Four scenarios of exposure to wastewater were used: (i) irrigation of market garden produce; (ii) irrigation of golf courses; (iii) recreational use of water; and (iv) groundwater recharge. The dose–response model used was the β-Poisson model (Haas, 1983) (see Box 3.1). Asano et al. (1992) used estimates of the amount of water ingested via the various scenarios — for example, 1 ml per day for two days per week throughout the year by golfers handling and cleaning golf balls, and 10 ml per day for consumers of food crops. Allowance was made for viral reduction in the environment — for example, through stopping crop irrigation two weeks before harvest.

The risk of infection related to consuming irrigated "market garden produce" was calculated to be 10^{-6}–10^{-9} per person per year when the effluent contained one viral unit per 100 litres and 10^{-4}–10^{-7} per person per year when the concentration was 111 viral units per 100 litres. The corresponding infection risk estimates were 10^{-11}–10^{-14} per person per year and 10^{-9}–10^{-11} per person per year when unchlorinated secondary effluents with 500 viral units per 100 litres and 73 400 viral units per 100 litres, respectively, were given tertiary treatment (a 5 log unit viral removal). Thus, for all the tertiary effluents investigated, the infection risks were below the accepted infection risk of 10^{-4} per person per year in the United States of America (Rose & Gerba, 1991), and sometimes below this level by many orders of magnitude.

Even when unchlorinated secondary effluents were investigated using viral removal data from wastewater treatment plants in California, USA, QMRA showed that for food crop irrigation and groundwater recharge, the risk of viral infection was less than 10^{-4} per person per year (Tanaka et al., 1998). This study used the same dose–response model as Asano et al. (1992), but used cumulative distribution functions of virus concentrations (instead of point estimates) and 500-trial Monte Carlo simulations. The annual infection risk to consumers from crop irrigation (daily consumption) was calculated for three types of treatment and several treatment plants. The estimates were as follows: 10^{-3}–10^{-5} per person per year for unchlorinated secondary effluent; 10^{-7}–10^{-9} per person per year for direct chlorination of secondary effluent (a 3.9 log unit removal); and 10^{-8}–10^{-10} for full treatment (a 5.2 log unit removal). For golf courses, the annual risks were 10^{-4}–10^{-6} per person per year when

Box 3.1 QMRA: dose–response models

The dose–response models used were the β-Poisson model for rotavirus and *Campylobacter* infections and the exponential model for *Cryptosporidium* infection (Haas et al., 1999). The equations are:

(a) β-Poisson dose–response model (for *Campylobacter* and rotavirus):

$$P_I(d) = 1 - [1 + (d/ID_{50})(2^{1/\alpha} - 1)]^{-\alpha}$$

(b) Exponential dose–response model (for *Cryptosporidium*):

$$P_I(d) = 1 - \exp(-rd)$$

(c) Annual risk of infection:

$$P_{I(A)}(d) = 1 - [1 - P_I(d)]^n$$

where $P_I(d)$ is the risk of infection in an individual exposed to (via ingestion, in this case) a single pathogen dose d; $P_{I(A)}(d)$ is the annual risk of infection in an individual from n exposures per year to the single pathogen dose d; ID_{50} is the median infective dose; and α and r are pathogen "infectivity constants." For rotavirus, ID_{50} = 6.17 and α = 0.253; for *Campylobacter*, ID_{50} = 896 and α = 0.145; and for *Cryptosporidium*, r = 0.0042 (Haas et al., 1999). $P_{I(A)}(d)$ can also be interpreted as the risk over a shorter (or longer) period — for example, an *m*-month risk, with *n* now equal to the number of exposures during *m* months.

The value of $P_{I(A)}(d)$ is in the range 0–1. If $P_{I(A)}(d)$ = 1, infection is certain. However, QMRA cannot determine whether an individual becomes infected more than once per year. Such information can be found only by epidemiological studies.

chlorinated secondary effluent (a 3.9 log unit removal) was used, but 10^{-1}–10^{-2} per person per year when it was not chlorinated. The estimated risks were higher when treated wastewater was used in recreational impoundments used for swimming.

These studies suggest that (i) using wastewater for crop irrigation may not be as "risky" as using it for the irrigation of golf courses or for recreational impoundments, mainly due to viral reduction in the environment between application and exposure; and (ii) it may be possible to use secondary effluents, especially when they are chlorinated, and still be below the acceptable level of risk to crop consumers.

Shuval, Lampert & Fattal (1997) used QMRA to perform a comparative risk analysis of the USEPA & USAID (1992) guidelines and of the second edition of the WHO Guidelines (WHO, 1989). The risk assessment model developed for studying microorganisms in drinking-water (Haas et al., 1993) was used, combined with laboratory data on the degree of viral contamination of vegetables irrigated with wastewaters of various qualities. They compared estimates of disease risk from the consumption of lettuce (100 g per person on alternate days) that had been irrigated with untreated wastewater and treated wastewater with 10^3 thermotolerant coliforms per 100 ml. The risk of clinical cases of hepatitis A infection from eating lettuce that had been irrigated with untreated wastewater was 10^{-2}–10^{-4} per person per year. However, when the lettuces were irrigated with treated wastewaters containing 10^3 thermotolerant coliforms per 100 ml, the risk was 10^{-6}–10^{-8} per person per year, and the corresponding risk for rotavirus disease was 10^{-5}–10^{-6} per person per year. Fattal, Lampert & Shuval (2004) confirmed these results by a more detailed analysis: the hepatitis A disease risks were 4.4×10^{-2} per person per year when lettuce was irrigated with untreated wastewater and 4.7×10^{-6} per person per year when irrigated with wastewater treated to 10^3 faecal coliforms per 100 ml. The corresponding rotavirus disease risks were 10^{-1} and 10^{-5} per person per year, respectively.

More recently, these pioneering studies by Shuval and colleagues have been extended by D.D. Mara and colleagues (unpublished data, 2005) to provide further information as a basis to evaluate the infection risks. These studies explored exposure through direct contact with wastewater (through restricted irrigation), as well as exposure through crop consumption (through unrestricted irrigation). A combination of standard QMRA techniques (Haas et al., 1999) and 10 000-trial Monte Carlo simulations (Sleigh & Mara, 2003) was used. The risk estimates were determined by using the β-Poisson dose–response model for bacterial and viral infections and the exponential dose–response model for protozoan infections.

The model exposure scenario used for restricted irrigation was the involuntary ingestion of soil particles by those working, or by young children playing, in wastewater-irrigated fields. The quantity of soil involuntarily ingested in this way was up to approximately 100 mg per person per day of exposure (Haas et al., 1999; WHO, 2001b). Two "sub-scenarios" were considered:

- highly mechanized agriculture;
- labour-intensive agriculture.

The first scenario represents exposure in industrialized countries where farm workers typically plough, sow and harvest using tractors and associated equipment and could be expected to wear gloves when working in wastewater-irrigated fields. The second scenario is representative of farming practices in developing countries in situations where tractors are not (or only rarely) used and gloves not commonly worn.

Two exposure scenarios were used for unrestricted irrigation:

- an extended version of the scenario of wastewater-irrigated lettuce consumption used by Shuval, Lampert & Fattal (1997);
- the consumption of uncooked wastewater-irrigated onions, based on the epidemiological study in Mexico detailed by Blumenthal et al. (2003) (section 3.2.1).

These two scenarios were chosen as they cover both root and non-root crops eaten uncooked. The onion consumption scenario permitted a comparison between disease incidences determined epidemiologically and infection risks estimated by QMRA.

For restricted irrigation, D.D. Mara et al. (unpublished data, 2005) estimated the median risks per person per year for rotavirus, *Campylobacter* and *Cryptosporidium* infections resulting from the ingestion of 1−10 mg of wastewater-contaminated soil per person per day for 100 days per year for highly mechanized agriculture and 10−100 mg per person per day for 300 days per year for labour-intensive agriculture. Exposure for 300 days per year was chosen to represent a landless labourer working for two days per week for each of three employers; this exposure represents a "worst-case" scenario, as irrigation does not commonly extend over a full year, although in some cases (e.g. coastal desert areas in South America) it does. The risks were estimated for seven single-log ranges (10−100 to 10^7−10^8) of *E. coli* numbers per 100 ml of wastewater. These log ranges were chosen to estimate the risks associated with different levels of treatment from untreated wastewater through to high-level treatment (e.g. as practised in the State of California, USA) (≤23 total coliforms per 100 ml for restricted irrigation; State of California, 2001), while allowing for any value to be exceeded by up to one order of magnitude.

The estimated infection risks for highly mechanized agriculture, shown in Table 3.14, are close to 10^{-3} per person per year for rotavirus infection when the water quality is approximately 10^5 *E. coli* per 100 g of soil. For labour-intensive agriculture with exposure for 300 days per year (Table 3.15), the estimated infection risks are close to 10^{-3} per person per year when the water quality is 10^3–10^4 *E. coli* per 100 g of soil. In both scenarios, the risks for *Campylobacter* and *Cryptosporidium* infections were much lower than 10^{-3} per person per year. Table 3.15 also shows that the infection risks resulting from the use of untreated wastewater (10^7–10^8 *E. coli* per 100 g) were substantial: 0.99 per person per year for rotavirus and 0.50 per person per year for *Campylobacter*. When the exposure was for 150 days per year (Table 3.16), the risks were halved.

For unrestricted irrigation, D.D. Mara et al. (unpublished data, 2005) estimated the median risks per person per year for rotavirus, *Campylobacter* and *Cryptosporidium* infections resulting from the consumption of 100 g of wastewater-irrigated lettuce on alternate days. The parameter values used in the models were modified slightly compared with those used by Shuval, Lampert & Fattal (1997) — for example, by extending the die-off of 10^{-3} downwards by one order of magnitude to 10^{-2} and allowing for ±25% of the values of the β-Poisson "infectivity constants" (ID_{50} and α) given in Box 3.1. The risks were estimated for eight single-log ranges (1–10 to 10^7–10^8) of *E. coli* numbers per 100 ml of wastewater. The estimated infection risks, given in Table 3.17, are 10^{-3} per person per year for rotavirus and approximately 10^{-5} per person per year for *Campylobacter* and *Cryptosporidium* for a wastewater quality of 10^3–10^4 *E. coli* per 100 ml (Table 3.17).

D.D. Mara et al. (unpublished data, 2005) also estimated the median risks per person per year for rotavirus, *Campylobacter* and *Cryptosporidium* infections resulting from the consumption of 100 g of raw onions per person per week for five months; these rates of consumption were based on those found in the dry season in the Mezquital Valley in Mexico, where Blumenthal et al. (2003) studied the weekly prevalence of symptomatic diarrhoeal disease. The parameter values used in the models were modified to reflect the field conditions by using different ranges of parameter values, to allow for (a) the greater number of microorganisms expected to be on the surface of onions than on lettuce (Geldreich & Bordner [1971] found root vegetables irrigated with wastewater containing 5.8×10^4 faecal coliforms per 100 ml to have an order-of-magnitude higher count of faecal bacteria than leafy vegetables); (b) the lower die-off of faecal organisms in soil than on exposed crop surfaces (Strauss, 1985); and (c) a lower volume of wastewater remaining on onions than on lettuce.

The simulated rotavirus infection risk of 0.39 per person per five months for a wastewater quality of 10^3–10^5 *E. coli* per 100 ml (Table 3.18) shows very close agreement with the measured incidence of diarrhoeal disease of 0.38 per person per five months (calculated by converting prevalence values obtained in the epidemiological study to estimates of the rate of infection, using a number of assumptions). The risks calculated for *Campylobacter* and *Cryptosporidium* were lower by one and three orders of magnitude, respectively. Thus, provided that the parameter values used in the QMRA equations are carefully chosen to reflect

Table 3.14 Restricted irrigation: highly mechanized agriculture — median infection risks from ingestion of wastewater-contaminated soil estimated by 10 000-trial Monte Carlo simulations[a]

Soil quality (*E. coli* per 100 g)	Median infection risk (per person per year)		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	0.50	2.1×10^{-2}	4.7×10^{-4}
10^6–10^7	6.8×10^{-2}	1.9×10^{-3}	4.7×10^{-5}
10^5–10^6	6.7×10^{-3}	1.9×10^{-4}	4.6×10^{-6}
10^4–10^5	6.5×10^{-4}	2.3×10^{-5}	4.6×10^{-7}
10^3–10^4	6.8×10^{-5}	2.4×10^{-6}	5.0×10^{-8}
100–1000	6.3×10^{-6}	2.2×10^{-7}	$\leq 1 \times 10^{-8}$
10–100	6.9×10^{-7}	2.2×10^{-8}	–

[a] 1–10 mg soil ingested per person per day for 100 days per year; 0.1–1 rotavirus and *Campylobacter* and 0.01–0.1 *Cryptosporidium* oocyst per 10^5 *E. coli*; $ID_{50} = 6.17 \pm 25\%$ and $\alpha = 0.253 \pm 25\%$ for rotavirus; $ID_{50} = 896 \pm 25\%$ and $\alpha = 0.145 \pm 25\%$ for *Campylobacter*; $r = 0.0042 \pm 25\%$ for *Cryptosporidium*.

Table 3.15 Restricted irrigation: labour-intensive agriculture with exposure for 300 days per year — median infection risks from ingestion of wastewater-contaminated soil estimated by 10 000-trial Monte Carlo simulations[a]

Soil quality (*E. coli* per 100 g)	Median infection risk (per person per year)		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	0.99	0.50	1.4×10^{-2}
10^6–10^7	0.88	6.7×10^{-2}	1.4×10^{-3}
10^5–10^6	0.19	7.3×10^{-3}	1.4×10^{-4}
10^4–10^5	2.0×10^{-2}	7.0×10^{-4}	1.3×10^{-5}
10^3–10^4	1.8×10^{-3}	6.1×10^{-5}	1.4×10^{-6}
100–1000	1.9×10^{-4}	5.6×10^{-6}	1.4×10^{-7}
10–100	2.0×10^{-5}	5.6×10^{-7}	1.4×10^{-8}

[a] 10–100 mg soil ingested per person per day for 300 days per year; 0.1–1 rotavirus and *Campylobacter* and 0.01–0.1 *Cryptosporidium* oocyst per 10^5 *E. coli*; $ID_{50} = 6.17 \pm 25\%$ and $\alpha = 0.253 \pm 25\%$ for rotavirus; $ID_{50} = 896 \pm 25\%$ and $\alpha = 0.145 \pm 25\%$ for *Campylobacter*; $r = 0.0042 \pm 25\%$ for *Cryptosporidium*.

conditions in the field, there can be agreement between QMRA-estimated infection risks and disease incidences determined from epidemiological field studies (this was also found to be the case for restricted wastewater irrigation).

In the approaches discussed above, risks of infection for given wastewater qualities were determined. An alternative approach is to determine wastewater quality, and thus the required level of pathogen reduction in $\log_{10}$ units (or percentage removal),[1] for given levels of tolerable infection risks (Table 3.19). This approach is more useful for establishing operational health-based targets (see section 4.2). It has been used in the drafting of Australian guidelines for wastewater use in agriculture (NRMMC & EPHCA, 2005). The starting point of this approach was to set the

[1] In these Guidelines, $\log_{10}$ unit reductions are generally referred to as log unit reductions. A 1 log unit reduction = 90% reduction; a 2 log unit reduction = 99% reduction; a 3 log unit reduction = 99.9% reduction; and so on.

Table 3.16 Restricted irrigation: labour-intensive agriculture with exposure for 150 days per year — median infection risks from ingestion of wastewater-contaminated soil estimated by 10 000-trial Monte Carlo simulations[a]

Soil quality (*E. coli* per 100 g)	Median infection risk (per person per year)		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	0.99	0.29	6.6×10^{-3}
10^6–10^7	0.65	3.1×10^{-2}	6.8×10^{-4}
10^5–10^6	9.9×10^{-2}	3.2×10^{-3}	7.2×10^{-5}
10^4–10^5	9.6×10^{-3}	3.5×10^{-4}	6.8×10^{-6}
10^3–10^4	9.6×10^{-4}	2.9×10^{-5}	7.0×10^{-7}
100–1000	1.1×10^{-4}	3.0×10^{-6}	7.0×10^{-8}
10–100	1.0×10^{-5}	2.9×10^{-7}	7.0×10^{-9}

[a] 10–100 mg soil ingested per person per day for 150 days per year; 0.1–1 rotavirus and *Campylobacter* and 0.01–0.1 *Cryptosporidium* oocyst per 10^5 *E. coli*; ID_{50} = 6.17 ± 25% and α = 0.253 ± 25% for rotavirus; ID_{50} = 896 ± 25% and α = 0.145 ± 25% for *Campylobacter*; *r* = 0.0042 ± 25% for *Cryptosporidium*.

Table 3.17 Unrestricted irrigation: median infection risks from the consumption of wastewater-irrigated lettuce estimated by 10 000-trial Monte Carlo simulations[a]

Wastewater quality (*E. coli* per 100 ml)	Median infection risk (per person per year)		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	0.99	0.28	0.50
10^6–10^7	0.65	6.3×10^{-2}	6.3×10^{-2}
10^5–10^6	9.7×10^{-2}	2.4×10^{-3}	6.3×10^{-3}
10^4–10^5	9.6×10^{-3}	2.6×10^{-4}	6.8×10^{-4}
10^3–10^4	1.0×10^{-3}	2.6×10^{-5}	3.1×10^{-5}
100–1000	8.6×10^{-5}	3.1×10^{-6}	6.4×10^{-6}
10–100	8.0×10^{-6}	3.1×10^{-7}	6.7×10^{-7}
1–10	1.0×10^{-6}	3.0×10^{-8}	7.0×10^{-8}

[a] 100 g lettuce eaten per person per two days; 10–15 ml wastewater remaining on 100 g lettuce after irrigation; 0.1–1 rotavirus and *Campylobacter* and 0.01–0.1 *Cryptosporidium* oocyst per 10^5 *E. coli*; 10^{-2}–10^{-3} rotavirus and *Campylobacter* die-off and 0–0.1 *Cryptosporidium* oocyst die-off between harvest and consumption; ID_{50} = 6.17 ± 25% and α = 0.253 ± 25% for rotavirus; ID_{50} = 896 ± 25% and α = 0.145 ± 25% for *Campylobacter*; *r* = 0.0042 ± 25% for *Cryptosporidium*.

tolerable risk at 10^{-6} DALY per person per year and derive the related disease risks for rotavirus, *Campylobacter* and *Cryptosporidium*. These were 2×10^{-3}, 1.3×10^{-4} and 8.7×10^{-4} per person per year, respectively, for an exposure scenario of the irrigation of lettuce consumption, assuming 70 exposure events a year in the Australian context. QMRA was then undertaken to calculate the log unit reduction required to achieve these levels of risk, after inputting data on (i) pathogen concentrations in wastewater, (ii) dose–response data, (iii) exposure per event, (iv) disease/infection ratios, (v) DALYs per case of disease and (vi) susceptibility fractions to account for the proportion of the population who are not immune. The required pathogen reductions were calculated as 5.5 log units for rotavirus, 5 for *Campylobacter* and 4.5 for *Cryptosporidium*. The limitations of this approach included the use of a non–Monte Carlo QMRA model, resulting in the calculation of single point estimates, such that variability and uncertainty were not addressed. The estimates were based on conservative values.

Table 3.18 Unrestricted irrigation: median infection risks from the consumption of wastewater-irrigated onions estimated by 10 000-trial Monte Carlo simulations[a]

Wastewater quality (*E. coli* per 100 ml)	Median infection risk (per person per year)		
	Rotavirus	*Campylobacter*	*Cryptosporidium*
10^7–10^8	1.00	0.99	3.6×10^{-2}
10^6–10^7	0.99	0.81	3.9×10^{-3}
10^5–10^6	0.99	0.17	3.2×10^{-4}
10^4–10^5	0.43	1.6×10^{-2}	3.7×10^{-5}
10^3–10^5	0.39	1.7×10^{-2}	2.8×10^{-4}
3×10^4	0.29	1.1×10^{-2}	2.3×10^{-4}
10^3–10^4	4.5×10^{-2}	2.6×10^{-5}	3.7×10^{-6}
100–1000	5.6×10^{-3}	1.0×10^{-4}	3.8×10^{-7}
10–100	4.4×10^{-4}	1.1×10^{-5}	3.0×10^{-8}
1–10	5.7×10^{-5}	1.8×10^{-6}	$<10^{-8}$

[a] 100 g of onions consumed per person once per week for five months; 1–5 ml wastewater remaining on 100 g onions after irrigation; 1–10 rotavirus and *Campylobacter* and 0.1–1 *Cryptosporidium* oocyst per 10^5 *E. coli*; 0.1–1 rotavirus and *Campylobacter* die-off and 0.01–0.1 *Cryptosporidium* oocyst die-off between harvest and consumption; ID_{50} = 6.17 ± 25% and α = 0.253 ± 25% for rotavirus; ID_{50} = 896 ± 25% and α = 0.145 ± 25% for *Campylobacter*; r = 0.0042 ± 25% for *Cryptosporidium*.

3.4 Emerging issues: infectious diseases

One study has demonstrated that *E. coli* O157:H7 could be taken into lettuce plants and seedlings from contaminated irrigation water and manure slurries systemically through the roots, resulting in contamination of the edible parts of the plant (Solomon, Yaron & Matthews, 2002). If more evidence for this type of pathogen uptake is discovered, this would have important implications for the use of manure slurries (and, to a lesser extent, wastewater) for the production of vegetables that are consumed raw. *E. coli* O157:H7 is of particular concern because of its ability to survive in the environment (Wang, Zhao & Doyle, 1996), its relatively low infectious dose ($<10^3$ bacteria) (Ackers et al., 1998) and its potential for causing severe health outcomes in susceptible populations (e.g. children, the elderly and the immunocompromised). Studies from the United States of America detected *E. coli* O157:H7 in one of six samples (approximately 17%) of raw wastewater (Grant et al., 1996). In South Africa, similar results were found in a larger set of wastewater samples (16/91 samples; 17.6%) (Müller, Grabow & Ehlers, 2003). More research is needed to find out how widespread this phenomenon is and its public health significance.

3.5 Chemicals

Toxic chemicals are a growing concern in some regions. The number of toxic chemicals used in households and industry is large and growing. This section examines the health issues associated with toxic chemicals that have been found in wastewater. In general, industrial wastewater discharges into sanitary sewers or drains are the source of many chemicals, although households may also contribute. By limiting toxic chemical discharges into municipal wastewater, the hazard to public health and the environment can be reduced. A risk analysis was carried out to determine which chemicals potentially pose the greatest risks to human health. Section 4.6 gives health-based maximum soil concentrations for certain chemicals to prevent their entrance into the food-chain.

Table 3.19 Unrestricted irrigation: required pathogen reductions for various levels of tolerable risk of infection from the consumption of wastewater-irrigated lettuce and onions estimated by 10 000-trial Monte Carlo simulations[a]

Tolerable level of infection risk (per person per year)	Corresponding required level of reduction (log units)	
	Lettuce	Onions
Rotavirus		
10^{-2}	5	6
10^{-3}	6	7
10^{-4}	7	8
Campylobacter		
10^{-2}	4	4
10^{-3}	5	5
10^{-4}	6	6
Cryptosporidium		
10^{-2}	4	2
10^{-3}	5	3
10^{-4}	6	4

[a] 100 g lettuce and onions eaten per person per two days; 10−15 ml and 1−5 ml wastewater remaining after irrigation on 100 g lettuce and 100 g onions, respectively; 0.1−1 and 1−5 rotavirus and *Campylobacter* and 0.1−1 *Cryptosporidium* oocyst per 10^5 *E. coli* for lettuce and onions, respectively; $ID_{50} = 6.17 \pm 25\%$ and $\alpha = 0.253 \pm 25\%$ for rotavirus; $ID_{50} = 896 \pm 25\%$ and $\alpha = 0.145 \pm 25\%$ for *Campylobacter*; $r = 0.0042 \pm 25\%$ for *Cryptosporidium*.

Industrial and, to a lesser extent, municipal wastewaters are sources of chemical pollutants that may affect human health. Tens of thousands of chemicals are used routinely in manufacturing, agricultural production and household products. A fraction of these potentially toxic chemicals may find their way into wastewater collection systems. Chemical contaminants of potential health concern that have been found in wastewater are shown in Table 4.7 in chapter 4.

The health risks associated with chemicals found in wastewater may need to be given more attention, particularly in developing countries where the pace of industrialization is accelerating and where industrial discharges and municipal wastewater are frequently mixed together.

3.5.1 Health impacts

Direct health impacts

Evidence for direct health impacts from chemical exposures associated with the use of wastewater in agriculture is very limited. This is probably due to the nature of chemical toxicity. For most chemicals, their concentrations in wastewater or wastewater-irrigated products will almost never be high enough to result in acute health effects. Chronic health effects that may be associated with exposure to chemicals in wastewater (e.g. cancer) usually occur only after many years of exposure and may also result from a variety of other exposures not related to the agricultural use of wastewater.

Nevertheless, health effects associated with the use of water heavily contaminated with industrial discharges have been reported. In Japan, Itai-itai disease, a bone and kidney disorder associated with chronic cadmium poisoning, occurred in areas where rice paddies were irrigated with water from the contaminated Jinzu River (WHO, 1992). In some parts of China, the use of industrial wastewater for irrigation was associated with a 36% increase in hepatomegaly (enlarged liver) and a 100% increase in both cancer and congenital malformation rates (Yuan, 1993).

Indirect health impacts

Poor irrigation practices with untreated or partially treated wastewater also impact the quality and safety of groundwater in shallow aquifers and surface waters that may supply drinking-water. Wastewater-related nitrate contamination of aquifers has been extensively documented in both developed and developing countries. High concentrations of nitrate in drinking-water are associated with methaemoglobinaemia ("blue baby" syndrome). Some cases of methaemoglobinaemia associated with nitrate exposure in bottle-fed infants have been reported in Eastern Europe and the United States of America, including several infant deaths (Knobeloch et al., 2000; WHO, 2004a).

Excessive nutrients, primarily nitrogen and phosphorus, in wastewater may contaminate surface waters and can cause eutrophication (nutrient enrichment). Eutrophication of fresh water and salt water may create environmental conditions that favour the growth of toxin-producing cyanobacteria and algae. The resulting toxins can cause gastroenteritis, liver damage, nervous system impairment and skin irritation. Health problems associated with cyanotoxins have been documented in several countries, including Australia, Brazil, Canada, China, the United Kingdom, the United States of America and Zimbabwe. In some cases, liver cancer in humans is thought to be associated with exposure to cyanobacterial toxins (microcystins) through drinking-water (Ling, 2000). Exposure to these toxins has usually been through contaminated drinking-water or recreational water contact (Chorus & Bartram, 1999).

3.5.2 Assessing the risks from chemical contaminants

The use of wastewater may introduce potentially toxic pollutants into soils. Through food-chain transfer, toxic pollutants may affect the health and well-being of consumers, as plants absorb the chemicals from the soils. Pollutants accumulated in the soil as the result of wastewater irrigation may subsequently contaminate surface water and groundwater, resulting in additional exposures.

Based on surveys conducted in many parts of the world, certain chemical constituents, such as heavy metals, appear to be ubiquitous and can be found in almost any municipal wastewater stream; others, especially organic chemicals, are present only in some wastewaters or are present only sometimes (WHO, 1975; USEPA, 1990). The presence of a chemical in one wastewater stream is no indicator for its presence or absence in another wastewater stream.

Based on a review of the literature, Chang et al. (2002) identified several inorganic elements and organic compounds that might pose health risks through the use of wastewater (and sludge) in agriculture (see Table 4.7 in chapter 4). These chemicals were identified as having the following properties:

- They are known to be toxic to humans or animals.
- They have been found in wastewaters and/or sewage sludge.
- They may be readily absorbed from soils by plants.

Inorganic elements

Plant uptake of heavy metals is highly dependent on soil conditions, including pH, the presence of other heavy metals, organic matter content, the application of chemical fertilizers, liming, ploughing and water management (Chen, 1992). These factors greatly influence the bioavailability of specific heavy metals. Alloway & Morgan (1986) found that nickel applied to soil in organic substrates (e.g. sewage sludge) was taken up more readily by plants than when the nickel was introduced in an inorganic substrate. Plants absorb more cadmium and lead from acidic soils than from neutral soils (Chen, Lee & Liu, 1997). In some cases, the presence or absence of other divalent metals in the soil can influence the uptake of heavy metals; for example, calcium, zinc and manganese are thought to compete with cadmium for uptake by plants (Cox, 2000).

All of the inorganic elements in Table 4.7 (in chapter 4) occur naturally in soils. Many of them are biologically beneficial in small quantities and will become harmful only at high levels of exposure. For some inorganic elements (e.g. cobalt and copper), no toxicological threshold has been established; for others (e.g. boron, fluorine and zinc), the thresholds are relatively high. Cobalt, copper and zinc are not likely to be absorbed by plants in sufficient quantities to be harmful to consumers. A toxicological threshold has been established for chromate ion (Cr^{6+}). Chromate is rapidly reduced to Cr^{3+}, however, which forms a less soluble solid phase in wastewater or soils. For these reasons, cobalt, copper, zinc and chromium may be ignored (and are not included in Table 4.7).

The inclusion of molybdenum and especially boron in this list is debatable, because boric acid is a commonly used household chemical and has not been associated with human toxicity (it is, however, toxic to some plants; see Annex 1). Molybdenum is considered to be an essential element. Studies on its toxicity to humans through drinking-water exposures have indicated a no-observed-adverse-effect level (NOAEL) of 0.2 mg/l (WHO, 2004a); however, it is unclear if this finding could be extrapolated to food products. The tolerable daily intake (TDI) for boron is estimated to be 0.16 mg/kg of body weight (WHO, 2004a). The oral reference doses established for these chemicals were derived from limited animal bioassay data (WHO, 2004a). Boron, molybdenum and fluorine form anions in soils and, under appropriate circumstances, may be readily absorbed by plants and thus enter the human food-chain.

Organic chemicals

Many of the organic chemicals in Table 4.7 are industrial solvents and are expected to be removed or degraded during wastewater treatment or sludge digestion. Results of the national sewage sludge survey conducted by the USEPA (1990) indicated that the frequency of detection for the majority of these organic chemicals was less than 10%. When they were found in sewage sludge, their concentrations were low. They probably do not need to be considered in wastewater use in agriculture. However, since raw and poorly treated wastewaters are frequently used for crop irrigation in some regions of the world, these chemicals should be included in the assessment. The potential impact of these chemicals on human health needs to be quantified in any toxicity assessment.

3.5.3 Emerging issues: chemicals

Chemicals that mimic hormones or have antihormonal activity, and so interfere with the functioning of endocrine systems in various species, have been identified in municipal wastewaters. Endocrine disruptors, as they are known, derive from many sources, including pesticides, persistent organic pollutants, non-ionic detergents and human and veterinary pharmaceutical residues. Many of these substances are resistant to conventional wastewater treatment and may persist in the environment for some time (National Research Council, 1998). Human health effects potentially linked to exposure to these chemicals include breast, prostate and testicular cancers, diminished semen quantity and quality and impaired behavioural/mental, immune and thyroid functions in children. Although direct evidence of adverse health effects in humans is lacking, reproductive abnormalities, altered immune function and population disruption potentially linked to exposure to these substances have been observed in amphibians, birds, fish, invertebrates, reptiles and mammals (IPCS, 2002).

Many of the organic compounds identified through the hazard identification process and included in Table 4.7 exhibit endocrine-disrupting characteristics. They are the halogenated organic chemicals (aldrin and dieldrin), plasticizers (phthalates), polycyclic aromatic hydrocarbons (PAHs; e.g. benzo[*a*]pyrene and pyrene), polychlorinated biphenyls (PCBs) and dioxins. Further studies are needed on these substances to assess the potential health and environmental risks they pose during the use of wastewater for crop irrigation.

Pharmaceutically active chemical substances are ubiquitous in municipal wastewater and its treatment by-products. They are released to the terrestrial environment when the wastewater and sewage sludge are applied on cropland or discharged into a receiving water body (Barnes et al., 2002). It appears, from the limited data in the literature, that the compounds are strongly adsorbed by soil organic matter, and they are therefore unlikely to accumulate in the harvested plants (see chapter 7) to levels that, when consumed, would constitute a health risk. No adverse health effects in humans from exposure to these chemicals resulting from wastewater use in agriculture have been documented.

4
HEALTH-BASED TARGETS

This chapter describes the derivation of health-based targets based on a reference or tolerable level of health risk, as described in section 2.4. To achieve the health-based targets, microbial reduction targets are developed. These are described for different irrigation scenarios (i.e. unrestricted, restricted and localized). Parameters to be monitored for verification of microbial reduction targets and other health protection measures are also presented. Countries will be able to use the information in this chapter to develop their own standards. In some cases, the development of different standards for food for export and for food for local consumption will be warranted. Issues surrounding standards for food exports and local consumption are described in sections 4.4 and 4.5. Section 4.6 presents health-based targets that have been derived for selected toxic chemicals.

4.1 Tolerable burden of disease and health-based targets

The most appropriate metric for expressing the burden of a disease is the DALY (Murray & Acharya, 1997) (see Box 2.1 in chapter 2). WHO (2004a) has adopted, in the third edition of the *Guidelines for drinking-water quality*, a tolerable burden of waterborne disease from consuming drinking-water of $\leq 10^{-6}$ DALY per person per year. This value corresponds to a tolerable excess lifetime risk of fatal cancer of 10^{-5} per person (i.e. an individual has a 1 in 100 000 lifetime chance of developing fatal cancer) from consuming drinking-water containing a carcinogen at its guideline value concentration in drinking-water (WHO, 2004a). This level of disease burden can be compared with a mild but more frequent illness such as self-limiting diarrhoea caused by a microbial pathogen. The estimated disease burden associated with mild diarrhoea (e.g. with a case fatality rate of approximately 1×10^{-5}) at an annual disease risk of 1 in 1000 (10^{-3}) (approximately 1 in 10 lifetime risk) is also about 1×10^{-6} DALY (1 µDALY) per person per year (WHO, 2004a). Such a high level of health protection is required for drinking-water, since it is expected to be "safe" by those who drink it. Since food crops irrigated with treated wastewater, especially those eaten uncooked, are also expected to be as safe as drinking-water by those who eat them, the same high health protection level of $\leq 10^{-6}$ DALY per person per year is used for wastewater use in agriculture (see Table 4.1).

Thus, the health-based target adopted in this edition of these Guidelines is a tolerable additional disease burden of $\leq 10^{-6}$ DALY per person per year. For operational purposes, it is also necessary to calculate the corresponding degree of pathogen reduction that achieves this level of health protection and to define appropriate verification measures. This can be done by following the step-by-step approach outlined below.

4.1.1 Step 1: Tolerable risk of infection

"Translate" the tolerable additional annual burden of disease into the equivalent tolerable annual risks of infection and disease due to the pathogen of concern (e.g. *Campylobacter*, *Cryptosporidium*, rotavirus), as follows (where pppy = per person per year):

$$\text{Tolerable disease risk pppy} = \frac{\text{Tolerable DALYs pppy}}{\text{DALYs per case of disease}}$$

Table 4.2 gives the population-based estimates for the DALYs per case of rotavirus disease, campylobacteriosis and cryptosporidiosis (including mortality and, for campylobacteriosis, morbidity due to reactive arthritis and Guillain-Barré syndrome) and the calculated tolerable disease risks.

Table 4.1 Health-based targets for treated wastewater use in agriculture

Exposure scenario	Health-based target (DALY per person per year)	Log_{10} pathogen reduction needed[a]	Number of helminth eggs per litre
Unrestricted irrigation	$\leq 10^{-6}$ [a]		
Lettuce		6	≤ 1 [b,c]
Onion		7	≤ 1 [b,c]
Restricted irrigation	$\leq 10^{-6}$ [a]		
Highly mechanized		3	≤ 1 [b,c]
Labour intensive		4	≤ 1 [b,c]
Localized (drip) irrigation	$\leq 10^{-6}$ [a]		
High-growing crops		2	No recommendation[d,e]
Low-growing crops		4	≤ 1 [c,d]

[a] Rotavirus reduction. The health-based target can be achieved, for unrestricted and localized irrigation, by a 6–7 log unit pathogen reduction (obtained by a combination of wastewater treatment and other health protection measures, including an estimated 3–4 log unit pathogen reduction as a result of the natural die-off rate of pathogens under field conditions and the removal of pathogens from irrigated crops by normal domestic washing and rinsing; see section 4.2.1 for further details); for restricted irrigation, it is achieved by a 2–3 log unit pathogen reduction (section 4.2.2).

[b] When children under 15 are exposed, additional health protection measures should be used (e.g. treatment to ≤0.1 egg per litre, protective equipment such as gloves or shoes/boots or chemotherapy; see sections 4.2.1 and 4.2.2 for details).

[c] An arithmetic mean should be determined throughout the irrigation season. The mean value of ≤1 egg per litre should be obtained for at least 90% of samples in order to allow for the occasional high-value sample (i.e. with >10 eggs per litre). With some wastewater treatment processes (e.g. waste stabilization ponds), the hydraulic retention time can be used as a surrogate to assure compliance with ≤1 egg per litre, as explained in section 5.6.1 and Box 5.2.

[d] See section 4.2.3.

[e] No crops to be picked up from the soil.

The tolerable disease risks are in the range 10^{-3}–10^{-4} per person per year and are conservative values, given that the current global incidence of diarrhoeal disease in the age group 5−80+ is in the range 0.1−1 per person per year (see Table 2.4 in chapter 2).

If there are reliable epidemiological data available that show that these risks of disease are not exceeded by a given combination of health-based protection measures (see Table 4.3 below), it is not necessary to undertake steps 2−4 below, and all that remains to be done in such cases is to establish the treatment verification monitoring level (step 5).

The tolerable disease risks are now converted into a tolerable infection risk per person per year by knowing (or making a reasonable assumption about) the proportion of those infected who become ill — the disease/infection ratio. Table 4.2 gives the values for the disease/infection ratios and the resulting tolerable infection risks for these three diseases. Thus, a "design" value of the tolerable infection risk for rotavirus of 10^{-3} per person per year is adopted (see section 4.2).

Table 4.2 DALYs, disease risks, disease/infection ratios and tolerable infection risks for rotavirus, *Campylobacter* and *Cryptosporidium*

Pathogen	DALYs per case of disease[a]	Disease risk pppy equivalent to 10^{-6} DALY pppy	Disease/ infection ratio	Tolerable infection risk pppy[b]
Rotavirus:				
(1) IC	1.4×10^{-2}	7.1×10^{-5}	0.05[c]	1.4×10^{-3}
(2) DC	2.6×10^{-2} [c]	3.8×10^{-5}	0.05[c]	7.7×10^{-4}
Campylobacter	4.6×10^{-3}	2.2×10^{-4}	0.7	3.1×10^{-4}
Cryptosporidium	1.5×10^{-3}	6.7×10^{-4}	0.3	2.2×10^{-3}

IC, industrialized countries; DC, developing countries; pppy, per person per year
[a] Values from Havelaar & Melse (2003).
[b] Tolerable infection risk = disease risk ÷ disease/infection ratio.
[c] For developing counties, the DALYs per rotavirus death have been reduced by 95%, as approximately 95% of these deaths occur in children under the age of two who are not exposed to wastewater-irrigated foods. The disease/infection ratio for rotavirus is low, as immunity is mostly developed by the age of three.

4.1.2 Step 2: QMRA

Determine, by QMRA, the corresponding pathogen reduction that needs to be achieved. The first step is to determine the maximum number of pathogens ingested per exposure event (e.g. for unrestricted irrigation, the maximum tolerable number of pathogens remaining on the surface of the crop, usually a salad crop [such as lettuce] or a vegetable that may be eaten uncooked [such as cabbage, carrots], at the time of consumption).

4.1.3 Step 3: Required pathogen reduction

Knowing (or estimating) the volume of treated wastewater remaining on the crop following final irrigation (ml of wastewater per 100 g crop), determine the required degree of pathogen reduction to achieve the tolerable additional disease burden of $\leq 10^{-6}$ DALY per person per year. This step requires the numbers of pathogens present in the untreated wastewater to be known or estimated (e.g. in the QMRA calculations in section 3.3 it was assumed that there were 0.01–1 rotavirus and *Campylobacter* and 0.01–0.1 *Cryptosporidium* oocysts per 10^5 *E. coli*).

4.1.4 Step 4: Health-based protection measures to achieve required pathogen reduction

Specify how this pathogen reduction is to be achieved. It can be achieved by wastewater treatment alone or, more commonly, by wastewater treatment in conjunction with other health protection measures, as explained in Table 4.3 and section 4.2 below.

4.1.5 Step 5: Verification monitoring

For viral and bacterial infections, establish the treatment verification monitoring level in terms of *E. coli* (or thermotolerant coliforms) numbers in the final effluent of the wastewater treatment plant, as shown in Table 4.5 below. For helminth infections, establish the treatment verification monitoring level in terms of number of helminth eggs per litre, as shown in Table 4.4 below.

4.1.6 Example derivation of microbial performance targets

Box 4.1 illustrates how this process can be used to derive microbial performance targets for unrestricted irrigation.

Box 4.1 Derivation of microbial performance targets for unrestricted irrigation

This example illustrates how the five-step procedure developed in section 4.1 may be used to derive a health-based operational target for unrestricted crop irrigation with treated wastewater. The parameter values used in steps 2–4 have been chosen solely for the purpose of illustrating this procedure.

Step 1: Tolerable risk of infection
As explained in section 4.1, the "design" risk of rotavirus infection is 10^{-3} per person per year.

Step 2: QMRA
Consumer exposure to pathogens is calculated by using the following illustrative parameter values in the QMRA:

- 5000 rotaviruses per litre of untreated wastewater;
- 10 ml of treated wastewater remaining on 100 g lettuce after irrigation;
- 100 g lettuce consumed per person every second day throughout the year.

The rotavirus dose per exposure (*d*) is the number of rotaviruses on 100 g lettuce at the time of consumption. The dose is determined by QMRA, for which the equations are (Haas et al., 1999):

(a) Conversion of the tolerable infection risk of 10^{-3} per person per year to the risk of infection per person per exposure event (i.e. per consumption of 100 g lettuce, which takes place every two days throughout the year) [$P_I(d)$]:

$$P_I(d) = 1 - (1 - 10^{-3})^{[1/(365/2)]} = 5.5 \times 10^{-6}$$

(b) Calculation of the dose per exposure event from the β-Poisson dose–response equation:

$$P_I(d) = 1 - [1 + (d/N_{50})(2^{1/\alpha} - 1)]^{-\alpha}$$

i.e.:

$$d = \{[1 - P_I(d)]^{-1/\alpha} - 1\}/\{N_{50}/(2^{1/\alpha} - 1)\}$$

where the values of the dimensionless "infectivity constants" for rotavirus are $N_{50} = 6.17$ and $\alpha = 0.253$.

Thus:

$$d = \{[1 - (5.5 \times 10^{-6})]^{-1/0.253} - 1\}/\{6.17/(2^{1/0.253} - 1)\} = 5 \times 10^{-5} \text{ per exposure event}$$

Step 3: Required pathogen reduction
This dose of 5×10^{-5} rotavirus is contained in the 10 ml remaining on the lettuce at the time of consumption — i.e. a rotavirus concentration of 5×10^{-3} per litre. The number of rotaviruses in the raw wastewater is 5000 per litre, and therefore the required pathogen reduction in $\log_{10}$ units is:

$$\log_{10}(5000) - \log_{10}(5 \times 10^{-3}) = 3.7 - (-2.3) = 6$$

Box 4.1 (continued)

Step 4: Health-based protection measures to achieve required pathogen reduction
The required rotavirus reduction is 6 log units. In this example, it is assumed that there is a 2 log unit pathogen reduction between last irrigation and consumption (due to a combination of, for example, 1 log unit due to pathogen die-off and 1 log unit due to produce washing; see Table 4.3 below). Taking this 2 log unit reduction into account, the wastewater treatment plant has to achieve a 4 log unit pathogen reduction — i.e. a reduction of rotavirus numbers from 5000 per litre in the raw wastewater to 0.5 per litre in the treated wastewater.

Step 5: Verification monitoring
This 4 log unit pathogen reduction by treatment is verified not by measuring pathogen numbers in samples of raw wastewater and treatment plant effluent, but by the reduction in numbers of a pathogen indicator organism. *Escherichia coli* is recommended for this purpose, although thermotolerant coliforms may be used instead. Table 4.5 below gives *E. coli* verification numbers per 100 ml for various required reductions of viral, bacterial and protozoan pathogens (Table 4.4 below gives helminth egg verification numbers per litre for various required reductions of helminth eggs). In this example, an *E. coli* verification level of $\leq 10^3$ would be adopted for monitoring purposes.

4.2 Microbial reduction targets

The approach adopted in these Guidelines focuses on risks from the consumption of food crops eaten uncooked and risks to fieldworkers from direct contact with treated wastewater, for unrestricted and restricted wastewater irrigation, respectively. Data on the health effects of using wastewater in agriculture, including data from epidemiological, microbiological and QMRA studies, were used to assess the infectious disease risks from the use of treated and partially treated wastewater in agriculture. Analysis of the risks resulting from exposure to wastewaters of different qualities was performed. Data developed through Monte Carlo–based QMRA and epidemiological studies (with verification of the Monte Carlo–QMRA models) supported the process of deriving health-based targets directly from these data. Monte Carlo–QMRA was used to generate estimates of infection over a wider range of wastewater qualities, as described in section 3.3. The analyses took account of consumption of crops eaten raw and of risks from direct contact with wastewater (involving involuntary soil ingestion), so that performance targets could be derived for restricted irrigation (where the exposure of farm workers and their children is the exposure of concern), as well as for unrestricted irrigation. The results of these analyses were then checked against the results obtained from relevant epidemiological studies.

4.2.1 Unrestricted irrigation

Microbial reduction targets for viral, bacterial and protozoan pathogens

The Monte Carlo–QMRA results for unrestricted irrigation, based on the exposure scenario of lettuce consumption (section 3.3), together with the relevant epidemiological evidence (section 3.2), show that, in order to achieve $\leq 10^{-6}$ DALY per person per year for rotavirus, a total pathogen reduction of 6 log units for the consumption of leaf crops (lettuce) and 7 log units for the consumption of root crops (onions) is required (see Table 3.19 in chapter 3). In these Guidelines, a pathogen reduction of 6−7 log units is used as the performance target for unrestricted irrigation to achieve the tolerable additional disease burden of $\leq 10^{-6}$ DALY per person per year. Because the risks associated with exposure to rotavirus are estimated to be the highest, this level of pathogen reduction will provide sufficient protection against bacterial and protozoal infections.

A 6–7 log unit pathogen reduction may be achieved by the application of appropriate health protection measures, each of which has its own associated log unit reduction or range of reductions (Table 4.3). A combination of these measures is used such that, for all combinations, the sum of the individual log unit reductions for each health protection measure adopted is equal to the required overall reduction of 6–7 log units.

Table 4.3 Pathogen reductions achievable by various health protection measures

Control measure[a]	Pathogen reduction (log units)	Notes
Wastewater treatment	1–6	The required pathogen reduction to be achieved by wastewater treatment depends on the combination of health protection measures selected (as illustrated in Figure 4.1; pathogen reductions for different wastewater treatment options are presented in chapter 5).
Localized (drip) irrigation (low-growing crops)	2	Root crops and crops such as lettuce that grow just above, but partially in contact with, the soil
Localized (drip) irrigation (high-growing crops)	4	Crops, such as tomatoes, the harvested parts of which are not in contact with the soil
Spray drift control (spray irrigation)	1	Use of micro-sprinklers, anemometer-controlled direction-switching sprinklers, inward-throwing sprinklers, etc.
Spray buffer zone (spray irrigation)	1	Protection of residents near spray or sprinkler irrigation. The buffer zone should be 50–100 m.
Pathogen die-off	0.5–2 per day	Die-off on crop surfaces that occurs between last irrigation and consumption. The log unit reduction achieved depends on climate (temperature, sunlight intensity, humidity), time, crop type, etc.
Produce washing with water	1	Washing salad crops, vegetables and fruit with clean water
Produce disinfection	2	Washing salad crops, vegetables and fruit with a weak disinfectant solution and rinsing with clean water
Produce peeling	2	Fruits, root crops
Produce cooking	6–7	Immersion in boiling or close-to-boiling water until the food is cooked ensures pathogen destruction.

Sources: Beuchat (1998); Petterson & Ashbolt (2003); NRMMC & EPHCA (2005).

[a] These are described in detail in chapter 5.

Figure 4.1 shows pathogen reductions achieved by several options for combining wastewater treatment and other health protection measures to achieve $\leq 10^{-6}$ DALY per person per year. The options in Figure 4.1 represent examples of combinations of health protection measures that can achieve the health-based target in practice. Other combinations are also possible. Planners and designers of wastewater use schemes may wish to explore and/or use a variety of health protection measure combinations that are locally feasible to implement. New treatment technologies may also offer the opportunity of developing new options.

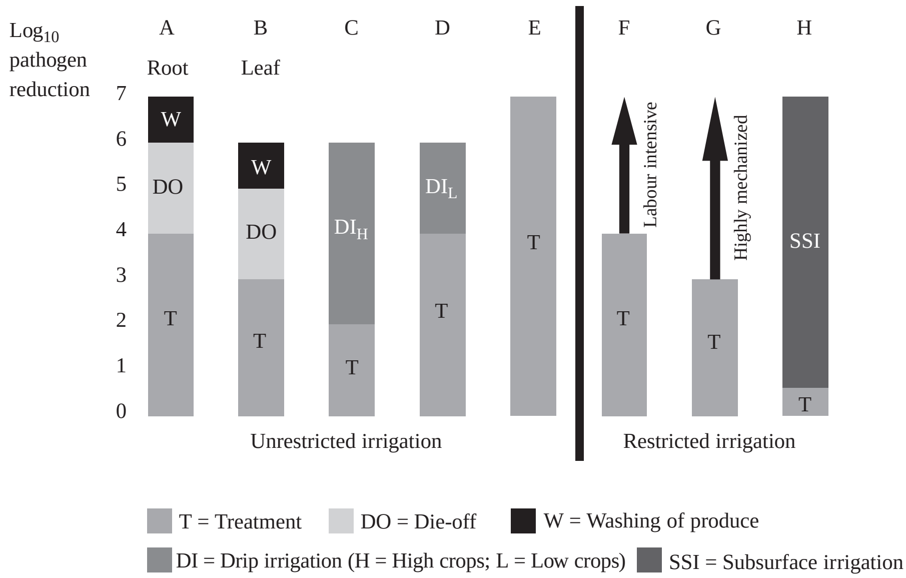

Figure 4.1
Examples of options for the reduction of viral, bacterial and protozoan pathogens by different combinations of health protection measures that achieve the health-based target of ≤10^{-6} DALY per person per year

Option A in Figure 4.1 shows that the required pathogen reduction is achieved by the combination of (a) wastewater treatment, which provides a 4 log unit pathogen reduction, (b) pathogen die-off between the last irrigation and consumption (a 2 log unit reduction) and (c) washing the salad crops or vegetables with water prior to consumption (a 1 log unit reduction). This option, which provides a 7 log unit pathogen reduction, is suitable when root crops that may be eaten uncooked are irrigated with treated wastewater. This is similar to a recommended required effluent quality of 1000 thermotolerant coli/100 ml in the second edition of these guidelines (WHO, 1989).

Option B has a lower degree of wastewater treatment than Option A (3 log units, rather than 4) combined with two post-treatment health protection measures: a 2 log unit reduction due to die-off and a 1 log unit reduction due to washing the salad crops or vegetables with water prior to consumption. This option, which provides a 6 log unit pathogen reduction, is suitable for the irrigation of non-root salad crops and vegetables eaten uncooked. This provides a sufficient level of health protection because salad crops often have less contamination than root crops and thus consuming them poses less health risk (see Tables 3.17 and 3.18 in chapter 3). This is similar to the recommended required effluent quality of 10,000 thermotolerant coli/100 ml in the second edition of these guidelines (WHO,1989).

Option C combines an even lower degree of treatment (2 log units) but with drip irrigation of high-growing crops (such as tomatoes), which achieves the required remaining 4 log unit pathogen reduction.

Option D incorporates the drip irrigation of low-growing non-root crops (a 2 log unit reduction), so a greater degree of treatment (4 log units) is provided (a valid alternative would be, for example, a 2 log unit reduction by treatment followed by a 1 log unit reduction due to die-off and a 1 log unit reduction due to produce washing).

Option E relies solely on wastewater treatment to achieve the required 6–7 log unit reduction. A typical sequence of wastewater treatment processes to achieve this would comprise conventional wastewater treatment (e.g. primary sedimentation, activated sludge, including secondary sedimentation) followed by chemical coagulation, flocculation, sedimentation and disinfection (chlorination or ultraviolet irradiation). Such a sequence is used, for example, in California, USA, to ensure compliance with the state water recycling criteria for unrestricted irrigation (≤2.2 total coliforms per 100 ml and a turbidity of ≤2 nephelometric turbidity units) (State of California, 2001). This option does not take into account pathogen reduction due to (a) natural die-off between final irrigation and consumption and (b) specific food preparation practices at the household level, such as washing, disinfection, peeling and/or cooking, and overall health protection is therefore greater than even 10^{-6} DALY per person per year. The very high costs and operational complexity of the wastewater treatment processes required for this option will generally preclude its application in many countries. Even in countries where this option is affordable, it should be subject to a robust cost-effectiveness analysis.

Options F, G and H in Figure 4.1 relate to restricted irrigation and are discussed in section 4.2.2. The in-depth risk analyses carried out by scientific communitity working on safe use of wastewater provide the basis for these recommended options. They take into account ecology, epidemiology, human behaviour and cost-effectiveness.

Microbial reduction targets for helminth eggs

Microbial reduction targets for protection against helminth infections are based on the results of epidemiological and microbiological studies. QMRA was not used to derive these performance targets, as there are no credible data on the infection risks and DALYs per person per year resulting from wastewater-related exposures or the infectivity constants for relevant helminths, such as *Ascaris*, for use in QMRA calculations. Furthermore, it is the intensity of the infection, rather than simply infection, that is associated with disability resulting from helminth infections.

Epidemiological studies of *Ascaris* infection among consumers (section 3.2.1) have indicated that wastewater treatment reduces the risk of *Ascaris* infection to adult consumers of crops irrigated with raw wastewater. The value of ≤1 helminth egg per litre is supported by microbiological evidence from field studies in Brazil (section 3.1.1) that, when facultative pond effluent with <0.5 egg per litre was used for irrigation, no eggs were detected on the crops. Therefore, a performance target of ≤1 helminth egg per litre of treated wastewater is recommended for unrestricted irrigation.

Epidemiological studies in Central Mexico (section 3.2.1) indicate that the achievement of ≤1 egg per litre may not be sufficiently protective in situations where conditions favour egg survival (e.g. warm, moist soil conditions), thus allowing for accumulation of eggs on the soil or on the crops, especially where children under the age of 15 consume uncooked food crops brought home from the field by their fieldworker parents. Thus, when children under 15 are exposed by eating uncooked field vegetables (as opposed to commercial food crops) that have been irrigated with treated wastewaters containing ≤1 egg per litre, additional health protection measures are required to safeguard the exposed children. These may include (i) anthelminthic treatment through mass chemotherapy campaigns or school-based chemotherapy programmes for helminthiasis control (see also section 4.2.2 on restricted irrigation), where health data indicate that helminth infections are prevalent; and/or (ii) the promotion of washing field vegetables in a weak detergent solution before consumption (see below). Alternatively, wastewater could be treated to the level of $\leq$0.1 egg per litre (see Box 5.2 in chapter 5).

An effective health protection measure for removing helminth eggs from the surface of crops eaten uncooked is washing the crop in a weak detergent solution and rinsing thoroughly with safe drinking-water. Helminth eggs are very "sticky," so they easily adhere to crop surfaces; the detergent solution releases them into the aqueous phase. This control measure reduces the number of eggs on the crop surface by 1–2 log units (B. Jiménez-Cisneros, personal communication, 2005). There is no specification for washing in a detergent and rinsing to obtain a 1–2 log reduction in the scientific literature, however, and in many cultures, the use of a detergent would rarely be complied with for certain crops such as lettuce or parsley (H. Shuval, personal communication, 2005).

The required helminth egg reduction to achieve the target of $\leq$1 egg per litre depends on the number of eggs in the raw wastewater. For example, if there are 10^3 eggs per litre in the raw wastewater, the required reduction is 3 log units; if there are 10^2, the required reduction is 2 log units; and if there are 10, the required reduction is 1 log unit (Table 4.4). Wastewater treatment processes to achieve, or partially achieve, these log unit reductions are described in chapter 5. If the number of helminth eggs in untreated wastewater is $\leq$1 per litre, then no additional health protection measures are required, as the target value is automatically achieved (this is the typical situation in most industrialized countries).

Table 4.4 shows examples of options for the reduction of helminth ova by two health protection measures and their associated verification requirements.

4.2.2 Restricted irrigation

Microbial reduction targets for viral, bacterial and protozoan pathogens

The Monte Carlo–QMRA results for labour-intensive restricted crop irrigation, based on the exposure scenario of involuntary soil ingestion, together with the relevant epidemiological evidence (chapter 3), show that in order to achieve the health-based target of $\leq 10^{-6}$ DALY per person per year for rotavirus, wastewater treatment is needed to achieve a reduction of the *E. coli* count by 4 log units (from 10^7–10^8 to 10^3–10^4 per 100 ml) (see Table 3.15 in chapter 3). Thus, for labour-intensive restricted irrigation, the health-based target is achieved by a 4 log unit pathogen reduction. This is illustrated by Option F in Figure 4.1. For highly mechanized agriculture, wastewater treatment to 10^5–10^6 *E. coli* per 100 ml is required (Table 3.14), i.e. a pathogen reduction of 3 log units, illustrated by Option G in Figure 4.1.

Option H in Figure 4.1 illustrates a typical single-household or institutional situation: minimal treatment in a septic tank (0.5 log unit pathogen reduction) followed by subsurface irrigation via the soil absorption system for the septic tank effluent. There is no contact between the crop and the pathogens in the septic tank effluent, so the subsurface irrigation system is credited with the remaining 6.5 log unit pathogen reduction required for root crops.

Table 4.4 Options for the reduction of helminth eggs by health protection measures for different helminth egg numbers in untreated wastewater and associated verification requirements

Health protection measure	Number of helminth eggs per litre of untreated wastewater	Required helminth egg reduction by treatment (log units)	Verification monitoring level (helminth eggs per litre of treated wastewater)[a]	Notes
Treatment	10^3	3	≤1	Treatment should be shown to achieve this egg quality reliably (see also Box 5.2).
	10^2	2	≤1	
	10	1	≤1	
	≤1	0	N/A	The target of ≤1 egg per litre is automatically achieved.
Treatment and produce washing	10^3	2	≤10	The reduction achieved by treatment is followed by a 1 log unit reduction by produce washing in a weak detergent solution and rinsing with clean water.[b]
	10^2	1	≤10	As above
	10	0	N/A	The required 1 log unit reduction is achieved by produce washing in a weak detergent solution and rinsing with clean water.[b]
	≤1	0	N/A	The target of ≤1 egg per litre is automatically achieved.

N/A, not applicable

[a] With waste stabilization ponds, the pond retention times can be used as a verification tool, as explained in Box 5.2. (Currently, there are no generally valid surrogate verification tools for other treatment processes, although it may be possible to develop them locally.)

[b] Valid only where this practice is common or where it can be successfully promoted and verified (see Table 4.3).

Microbial reduction targets for helminth eggs

The epidemiological evidence presented in chapter 3 provides the basis for developing a performance target for helminth eggs in restricted irrigation. The performance target for restricted irrigation is ≤1 helminth egg per litre of treated wastewater.

Epidemiological evidence from Mexico on *Ascaris* infection (section 3.2.2) shows that ≤1 egg per litre does not sufficiently protect children under the age of 15 who have exposure to wastewater-irrigated fields through either play or farming activities, although it does protect adult fieldworkers. Thus, when children under 15 are exposed by working or playing in wastewater-irrigated fields, additional health protection measures are required. In these circumstances, and where helminth infections are prevalent, anthelminthic treatment should be used as an additional risk management strategy. This may be delivered through school-based chemotherapy programmes for helminthiasis control (Montresor et al., 2002, 2005) or by periodic special treatment campaigns delivered by local health services in high-risk areas (especially where such children may not be attending schools). Where possible, such campaigns should also include a health promotion component to reduce exposure, for example, by emphasizing prevention of hand–soil contact through the use of gloves and appropriate tools and by hand washing with soap after contact with wastewater.

4.2.3 Localized irrigation

When localized irrigation (drip, trickle or bubbler irrigation) is used as a wastewater application technique, the log unit reductions for viral, bacterial and protozoan pathogens given in Table 4.3 should be used. In addition, when it is used to irrigate low-growing crops (i.e. those in partial contact with the soil), the microbial reduction target of ≤1 helminth egg per litre of treated wastewater should also be applied. However, when localized irrigation is used to irrigate high-growing crops (i.e. those with their harvested parts not in contact with the soil), specified performance targets for helminth egg concentrations are not necessary.

4.3 Verification monitoring

To ensure that health-based targets are being met, it is important to develop performance targets that can be monitored. There are three types of monitoring:

- Validation is the initial testing to prove that a system as a whole and its individual components are capable of meeting the performance targets and, thus, the health-based targets.
- Operational monitoring is the routine monitoring of parameters that can be measured rapidly (i.e. through tests that can be performed quickly, parameters measured online, or through visual inspection) to inform management decisions to prevent hazardous conditions from arising.
- Verification monitoring is done periodically to show that the system is working as intended. This type of monitoring usually requires more complicated or time-consuming tests that look at parameters such as bacterial indicators (*E. coli*) or helminth eggs.

Monitoring is further discussed in chapter 6. Verification monitoring requirements for unrestricted, restricted and localized irrigation are discussed below.

4.3.1 Wastewater treatment

As pathogen numbers in raw and treated wastewaters are not measured routinely (if at all), the performance of the wastewater treatment processes used to partially or wholly ensure $\leq 10^{-6}$ DALY per person per year cannot be determined on the basis of pathogen removal efficiency in the wastewater treatment plant. Therefore, monitoring to verify the microbiological performance of the treatment plant is done by determining the effluent numbers of a pathogen indicator bacterium such as *E. coli*. Table 4.5 lists for all the options in Figure 4.1 the numbers of *E. coli* in the treatment plant effluent that may be used as a verification tool to determine whether or not the required pathogen removal in the treatment plant is being achieved.

When advanced wastewater treatment is used as the sole health protection control measure (Option E in Figure 4.1), treatment plant performance may be verified using a selection of operational performance parameters, as shown in the footnote to Table 4.5 (State of California, 2001).

Table 4.5 Verification monitoring of wastewater treatment (*E. coli* numbers per 100 ml of treated wastewater) for the various levels of wastewater treatment in Options A−G in Figure 4.1

Type of irrigation	Option (Figure 4.1)	Required pathogen reduction by treatment (log units)	Verification monitoring level (*E. coli* per 100 ml)	Notes
Unrestricted	A	4	$\leq 10^3$	Root crops
	B	3	$\leq 10^4$	Leaf crops
	C	2	$\leq 10^5$	Drip irrigation of high-growing crops
	D	4	$\leq 10^3$	Drip irrigation of low-growing crops
	E	6 or 7	$\leq 10^1$ or $\leq 10^0$	Verification level depends on the requirements of the local regulatory agency[a]
Restricted	F	4	$\leq 10^4$	Labour-intensive agriculture (protective of adults and children under 15)
	G	3	$\leq 10^5$	Highly mechanized agriculture
	H	0.5	$\leq 10^6$	Pathogen removal in a septic tank

[a] For example, for secondary treatment, filtration and disinfection: five-day biochemical oxygen demand, <10 mg/l; turbidity, <2 nephelometric turbidity units; chlorine residual, 1 mg/l; pH, 6−9; and faecal coliforms, not detectable in 100 ml.

4.3.2 Other health protection measures

The health protection measures listed in Table 4.3, other than wastewater treatment (see section 4.3.1 above), also need to be monitored to ensure that they are in place and working as expected. Some of the health protection measures can be monitored by simple visual inspection (e.g. the types of crops being grown in wastewater irrigation areas, the type of wastewater application techniques being used, the use of protective clothing, the presence or absence of emergent vegetation in waste stabilization ponds or wastewater treatment and storage reservoirs); others will be more difficult to monitor (e.g. produce washing, disinfection, peeling and/or cooking at the household level). Verification of crop contamination levels at the point of harvest or at the point of sale will require laboratory analysis. As these health protection measures and their associated log unit pathogen reductions are central to health protection when wastewater treatment alone is not used to achieve the required total pathogen reduction of 6−7 log units, it is important to verify that they are in fact being used. Table 4.6 lists these minimum monitoring requirements.

4.4 Food exports

The rules that govern international trade in food were agreed during the Uruguay Round of Multilateral Trade Negotiations and apply to all members of the World Trade Organization (WTO). With regard to food safety, rules are set out in the Agreement on the Application of Sanitary and Phytosanitary Measures. According to this agreement, WTO members have the right to take legitimate measures to protect the life and health of their populations from hazards in food, provided that the measures are not unjustifiably restrictive of trade (WHO, 1999). The import of

Table 4.6 Minimum verification monitoring frequencies for health protection control measures

Health protection measures	Minimum verification monitoring frequency
Wastewater treatment	(a) Urban areas: one sample per fortnight for *E. coli* and one sample per month for helminth eggs (b) Rural areas: 1 sample every 3–6 months for helminth eggs Five-litre composite samples required for helminth eggs prepared from grab samples taken six times per day (further details given in Volume 5 of these Guidelines)
Localized (drip) irrigation with low and high rate-growing crops	Annual surveys to verify the irrigation method used and the types of crops grown
Spray irrigation (spray drift control and buffer zone)	Annual surveys to verify the spray drift control methods used and the extent of the buffer zone
Pathogen die-off	Annual local surveys to determine microbial quality of wastewater-irrigated crops at harvest and at selected points of retail sale
Produce washing, disinfection, peeling and cooking with water	Annual local surveys to verify occurrence at household level of these food preparation control measures and to assess the impact of food hygiene education programmes

contaminated vegetables has led to disease outbreaks in recipient countries. Moreover, pathogens can be (re)introduced into communities that have no natural immunity to them, resulting in large disease outbreaks (Frost et al., 1995; Kapperud et al., 1995). Guidelines for the international trade of wastewater-irrigated food products should be based on sound scientific risk management principles.

WHO Guidelines for the safe use of wastewater in agriculture are based on a risk analysis approach that is recognized as the fundamental methodology underlying the development of food safety standards that both provide adequate health protection and facilitate trade in food. Adherence to the recommended WHO Guidelines for exports of wastewater-irrigated food products will help to ensure the international trade of safe food products. EUREPGAP, a private sector European organization for sustainable agriculture and the certification of food imports into Europe, prohibits the use of untreated wastewater for crop irrigation but accepts the use of wastewater treated to the guideline values specified in the second edition of these Guidelines (EUREPGAP, 2004).

4.5 National standards: variations from $\leq 10^{-6}$ DALY per person per year

The performance targets developed for unrestricted and restricted irrigation in section 4.2 provide "full" health protection (i.e. they achieve the health-based target of $\leq 10^{-6}$ DALY per person per year). However, it is realized that some countries may wish to set different standards based on local circumstances. For example, some developing countries may not be able to afford the cost of wastewater treatment, even for restricted irrigation. Wastewater treatment may be considered to be of a low priority if the local incidence of diarrhoeal disease is high and other water supply, sanitation and hygiene promotion interventions are more cost-effective in controlling transmission. In such circumstances, it is recommended that, initially, a national standard is established for a locally appropriate level of tolerable additional burden of disease based on the local incidence of diarrhoeal diseases — for example, $\leq 10^{-5}$ or $\leq 10^{-4}$ DALY per person per year.

This initial standard should then be made progressively more stringent so that it eventually reaches the health-based target of $\leq 10^{-6}$ DALY per person per year (see Anderson et al., 2001; von Sperling & Fattal, 2001). It may also need to be accompanied by an enforced legal prohibition on children working in fields irrigated by raw or inadequately treated wastewater (initially, this might refer to children under, for example, 10 years of age; over time, this could be extended to children under 15). The health basis of such a prohibition should be clearly explained to those affected by it, in particular subsistence farmers with children under the age of 10 or 15. Additional health protection measures for reducing the adverse health impacts of the currently widespread practice of crop irrigation with raw wastewater are described in chapter 5.

Some countries may wish to focus on preventing the transmission of bacterial infections through wastewater irrigation, where immunity to viral infections develops at a young age and other transmission routes are more important. For example, the main risk factors for rotavirus infection are person-to-person contact, absence of breastfeeding and hygiene related to use of babies' bottles, and immunity is developed by the age of five in most people (although infections do occur in adults). The risk of infection for *Campylobacter* is 10^{-4} per person per year (Table 4.2). However, QMRA has indicated that the water quality associated with a *Campylobacter* infection risk of 1×10^{-4} per person per year is 1 log unit less than that for a rotavirus infection risk of 1×10^{-3}. Thus, in the case of unrestricted irrigation, the required wastewater quality would be 10^4–10^5 *E. coli* per 100 ml, rather than 10^3–10^4 *E. coli* per 100 ml (see Table 3.19 in chapter 3). In such circumstances, the verification monitoring level would also change by 1 log unit, making the level for unrestricted irrigation of leafy crops $\leq 10^5$ *E. coli* per 100 ml. The values for restricted irrigation would change in a similar way (see Tables 3.14–3.16).

Some developing countries may also wish to set an initially less stringent performance target for helminth eggs if their local prevalence of helminthiases is high and other control interventions are likely to be more cost-effective in the short term. For example, the initial target might be ≤ 10 or ≤ 5 eggs per litre of treated wastewater.

Similarly, an industrialized country that already has a more stringent national health-based target (e.g. equivalent to $\leq 10^{-7}$ DALY per person per year) or other objectives (e.g. environmental regulations) may wish to keep them — for example, where a lower tolerable risk of infection or disease is already used and where adequate wastewater treatment plants already exist and their reliable operation is assured.

4.6 Chemicals

4.6.1 Health-based targets

To derive the numerical limits for the maximum tolerable pollutant concentration in wastewater-irrigated soils, the process starts with establishing the acceptable daily human intake (ADI) for a pollutant. It then quantitatively backtracks the pollutant transport through various environmental exposure routes to arrive at a tolerable pollutant concentration in the soil. Human exposure to pollutants applied to soils through wastewater irrigation may take place through eight pathways (USEPA, 1992), as follows:

1. wastewater → soil → plant → human;
2. wastewater → soil → human;
3. wastewater → soil → plant → animal → human;
4. wastewater → soil → animal → human;
5. wastewater → soil → airborne particulate → human;
6. wastewater → soil → surface runoff → surface water → human;
7. wastewater → soil → vadose zone → groundwater → human;
8. wastewater → soil → atmosphere → human.

To obtain preliminary numerical limits in wastewater-irrigated soils, a simplified approach was adopted. Instead of assessing all of the exposure routes, WHO considered only (a) the food-chain transfer of pollutants via the wastewater → soil → plant → human route and (b) the pollutant intake from the consumption of grain, vegetable, root/tuber crops and fruit. Food-chain transfer is the primary route of human exposure to environmental pollutants. Based on the global diet, the daily intake of grains/cereals, vegetables, root/tuber crops and fruit accounts for approximately 75% of daily adult food consumption (Gleick, 2000). The exposure scenario assumed that most exposed individuals were the adult residents (60 kg of body weight) of a land application area whose entire consumption of grain, vegetables, root/tuber crops and fruit was produced from wastewater-irrigated soils and that their daily intake of pollutants from this consumption accounted for 50% of the ADI. The remaining 50% of the ADI was credited to other exposure routes (e.g. drinking-water, cigarettes, etc.).

Based on the assumption that food-chain transfer is the primary route of exposure to potentially hazardous pollutants in the wastewater, WHO derived numerical limits defining the maximum permissible pollutant concentrations in soils for a set of organic and inorganic pollutants. These maximum permissible health-related pollutant concentrations in the receiving soils are summarized in Table 4.7. They define safe concentrations in the soil above which the transfer of pollutants to people via the food-chain may occur. For inorganic elements, their concentrations in wastewater-irrigated soils will slowly rise with each successive wastewater application. However, for many of the organic pollutants, the likelihood is small that they will accumulate in the soil to their computed threshold concentrations because their typical concentrations in wastewaters are very low.

Table 4.7 Maximum tolerable soil concentrations of various toxic chemicals based on human health protection

Chemical	Soil concentration (mg/kg)
Element	
Antimony	36
Arsenic	8
Barium[a]	302
Beryllium[a]	0.2
Boron[a]	1.7
Cadmium	4
Fluorine	635
Lead	84
Mercury	7

Table 4.7 (continued)

Chemical	Soil concentration (mg/kg)
Molybdenum[a]	0.6
Nickel	107
Selenium	6
Silver	3
Thallium[a]	0.3
Vanadium[a]	47
Organic compound	
Aldrin	0.48
Benzene	0.14
Chlordane	3
Chlorobenzene	211
Chloroform	0.47
2,4-D	0.25
DDT	1.54
Dichlorobenzene	15
Dieldrin	0.17
Dioxins	0.000 12
Heptachlor	0.18
Hexachlorobenzene	1.40
Lindane	12
Methoxychlor	4.27
PAHs (as benzo[*a*]pyrene)	16
PCBs	0.89
Pentachlorophenol	14
Phthalate	13 733
Pyrene	41
Styrene	0.68
2,4,5-T	3.82
Tetrachloroethane	1.25
Tetrachloroethylene	0.54
Toluene	12
Toxaphene	0.0013
Trichloroethane	0.68

[a] The computed numerical limits for these elements are within the ranges that are typical for soils.

4.6.2 Physicochemical quality of treated wastewaters for plant growth requirements

To accommodate plant growth requirements, the physicochemical quality of treated wastewaters used for crop irrigation should comply with the guideline values set by the FAO (Ayers & Westcot, 1985; Tanji & Kielen, 2002). This information is summarized in Annex 1.

5
HEALTH PROTECTION MEASURES

As described in chapter 4, the health-based target of a tolerable additional burden of disease of $\leq 10^{-6}$ DALY per person per year can be achieved when treated wastewater is used for crop irrigation, by a combination of health protection measures that produces an overall pathogen reduction of 6−7 log units (Figure 4.1; Table 4.3). These control measures include:

- crop restriction;
- wastewater application technique;
- pathogen die-off between last irrigation and consumption;
- food preparation measures (washing, disinfecting, peeling, cooking);
- human exposure control;
- wastewater treatment.

The selection of health protection measures by planners and designers of wastewater use schemes can be based on several factors, including the current wastewater treatment infrastructure and the products that will be grown. For new schemes, planning for crop restriction might be a desirable option, as the target of $\leq 10^{-6}$ DALY per person per year is achieved by a pathogen reduction of only 2−3 log units compared with the 6–7 log unit reduction required for unrestricted irrigation (Figure 4.1); it is therefore a lower-cost option.

The feasibility and efficacy of any combination of these health protection measures will depend on several factors, which must be carefully considered before any combination of them is put into practice. These factors include:

- availability of resources (labour, funds, land, water);
- existing social and agricultural practices;
- market demand for wastewater-irrigated food and non-food crops;
- existing patterns of excreta-related disease;
- institutional capacity and jurisdiction to ensure the efficacy of selected health protection measures (e.g. ability to (a) ensure that wastewater treatment is effective in reducing pathogens to the extent required; and (b) promote effectively washing or disinfection of wastewater-irrigated produce).

These health protection measures are effective against the pathogens and some chemicals present in the wastewater that are the primary health hazards associated with the agricultural use of wastewater. There are, however, secondary risks that may arise from the creation of habitats that facilitate the survival and breeding of vectors and a subsequent increase in the transmission of vector-borne diseases in wastewater-irrigated areas. Conducting an analysis of any existing or proposed wastewater irrigation system will identify the key risk points, and this is an important step in identifying which health protection measures are likely to be appropriate (see chapter 6). Health impact assessment (Annex 3) will also help to identify health hazards and risk factors that may arise due to wastewater use in agriculture; this will provide a context for the formulation of a public health action plan.

The health protection measures listed above are discussed in detail in sections 5.1−5.6. Their application when untreated wastewater is used for crop irrigation is presented in section 5.7.

5.1 Crop restriction

Restricted irrigation produces many useful and profitable crops, including (a) non-food crops (e.g. cotton and "biodiesel" crops such as jojoba, jatropha and rapeseed); (b) food crops that are processed before consumption (wheat); and (c) food crops that have to be cooked (potatoes, rice). The vulnerable group includes those who work in wastewater-irrigated fields (and also, if spray or sprinkler irrigation is used, nearby residents; see section 5.2). Crop consumers are protected because they either do not eat the foods or eat them only after extensive processing and/or cooking, which inactivate the pathogens. As shown in Figure 4.1 and section 4.2.2, the health-based target of $\leq 10^{-6}$ DALY per fieldworker per year can be met with a 2 or 3 log unit pathogen reduction (depending on whether children under the age of 15 are exposed or not), compared with the 6–7 log unit reduction required for unrestricted irrigation.

Crop restriction requires, of course, that farmers use only wastewater that has been treated to the quality required for unrestricted irrigation to irrigate food crops that are eaten uncooked. Thus, restricted irrigation is feasible where:

- a law-abiding society and/or strong law enforcement exists;
- a public body controls allocation of the wastes and has the legal authority to require that crop restrictions be adhered to;
- an irrigation project has strong central management;
- there is adequate demand for the crops allowed under crop restriction, and where they produce a reasonable profit;
- there is little market pressure in favour of excluded crops.

It is important that planners and designers of restricted irrigation schemes engage with local farmers early in the planning process to consult them and determine what "restricted crops" can be grown at a reasonable profit. They must clearly understand the difference between restricted and unrestricted irrigation (including the different wastewater qualities used for each), and they must be aware of the health consequences that will occur if they irrigate food crops that are eaten uncooked with wastewater treated only to the level for restricted irrigation.

Examples of successful crop restriction schemes are found in India, Mexico, Peru and Chile (Blumenthal et al., 2000b; Buechler & Devi, 2003). In Chile, the use of crop restriction, when implemented with a general hygiene education programme, reduced the transmission of cholera from the consumption of raw wastewater–irrigated vegetables by 90% (Monreal, 1993). Experience from Hyderabad, India, indicates that restricted irrigation is not synonymous with restricted farmer income: two of the most profitable wastewater-irrigated crops are para grass (used to feed water buffalo) and jasmine flowers (used for flavouring tea) (Buechler & Devi, 2003).

5.2 Wastewater application techniques

The choice of wastewater application method can impact the health status of farm workers, consumers and nearby communities (Table 5.1).

5.2.1 Flood and furrow irrigation

Fieldworkers and their families are at the highest risk when furrow or flood irrigation techniques are used. This is especially true when protective clothing (i.e. boots, shoes, gloves) is not worn and earth is moved by hand (Blumenthal et al., 2000b). However, wastewater treatment to achieve a pathogen reduction of 2−3 log units protects fieldworkers (sections 4.2.3 and 5.6).

Table 5.1 Selection of wastewater application techniques based on health protection

Irrigation technique	Factors affecting choice	Special measures for wastewater
Flood	Lowest cost Exact levelling not required	Thorough protection for fieldworkers, crop handlers and consumers
Furrow	Low cost Levelling may be needed	Protection for fieldworkers, possibly for crop handlers and consumers
Spray and sprinkler	Medium water use efficiency Levelling not required Advanced sprinklers that reduce crop contamination and potential contamination of local communities have been developed that can reduce exposure to pathogens by 1 log unit	Some crops, especially tree fruits, are prone to more contamination Minimum distance of 50–100 m from houses and roads Anaerobic wastewaters should not be used because of odour nuisance New technologies reduce spray drift and may be able to reduce crop contamination by better targeting
Subsurface and localized (drip, trickle and bubbler)	High cost High water use efficiency Higher yields Potential for significant reduction of crop contamination Localized irrigation systems and subsurface irrigation can substantially reduce exposure to pathogens by 2–6 log units	Localized irrigation: selection of non-clogging emitters; filtration to prevent clogging of emitters

5.2.2 Spray and sprinkler irrigation

Spray and sprinkler irrigation have the highest potential to spread contamination onto crop surfaces and affect nearby communities. Bacteria and viruses (but not usually helminth eggs or protozoan (oo)cysts) can be transmitted through aerosols to nearby communities. Where spray or sprinkler irrigation is used with wastewater, it may be necessary to set up a buffer zone (e.g. 50–100 m from houses and roads) to prevent adverse health impacts on local communities. Setting up an adequate buffer zone is equivalent to a 1 log unit pathogen reduction (see Table 4.3 in chapter 4) (NRMMC & EPHCA, 2005). Spray drift away from the site of application can be reduced by using techniques such as low-throw sprinklers, micro-sprinklers, part-circle sprinklers (180 degrees inward throw), tree/shrub screens planted at field borders and anemometer switching systems (NRMMC & EPHCA, 2005).

5.2.3 Localized irrigation

Localized irrigation techniques (e.g. bubbler, drip, trickle) offer farm workers the most health protection because the wastewater is applied directly to the plants. Although these techniques are generally the most expensive to implement, low-cost drip irrigation systems have recently been adopted by some farmers in Cape Verde and India (Kay, 2001; Postel, 2001; FAO, 2002). The benefits of these systems in terms of reduced (waste)water usage and higher crop yields convinced many private farmers in Cape Verde to drip-irrigate their crops. Further research on viable approaches using suitable local materials (e.g. bamboo) may facilitate greater uptake of this technology in various low-resource settings.

Localized irrigation is estimated to provide an additional pathogen reduction of 2–4 log units, depending on whether or not the harvested part of the crop is in contact with the ground (see Table 4.3) (NRMMC & EPHCA, 2005).

The emitters used in drip irrigation can block if the suspended solids content of the wastewater is high. Emitter blockage also occurs as a result of soil-based algae migrating to the emitters, as this is where the wastewater nutrients are released. Algae from waste stabilization ponds do not usually block emitters, although care is required to choose an emitter that does not block easily (Taylor et al., 1995; Capra & Scicolone, 2004).

5.2.4 Cessation of irrigation

Vaz da Costa Vargas, Bastos & Mara (1996) showed that cessation of irrigation with wastewater for one to two weeks prior to harvest can be effective in reducing crop contamination by providing time for pathogen die-off (section 5.3). Enforcing withholding periods is likely to be difficult, however, in unregulated circumstances, because many vegetables (especially lettuce and other leafy vegetables) need watering nearly until harvest to increase their market value. However, it may be possible with some fodder crops that do not have to be harvested at the peak of their freshness (Blumenthal et al., 2000b). Alternatively, crops could be irrigated from non-contaminated water sources (where available) after the cessation of wastewater use until harvest.

5.3 Pathogen die-off before consumption

The interval between final irrigation and consumption reduces pathogens (bacteria, protozoa and viruses) by approximately 1 log unit per day (Petterson & Ashbolt, 2003). The precise value depends on climatic conditions, with more rapid pathogen die-off (approximately 2 log units per day) in hot, dry weather and less in cool or wet weather without much direct sunlight (approximately 0.5 log unit per day). This reduction is extremely reliable and should be taken into account when selecting the combination of wastewater treatment and other health protection measures (see Figure 4.1 in chapter 4). Helminth eggs can remain viable on crop surfaces for up to two months, although few survive beyond approximately 30 days (Strauss, 1996) (see also section 3.1.1).

5.4 Food preparation measures

Vigorous washing of rough-surfaced salad crops (e.g. lettuce, parsley) and vegetables eaten uncooked in tap water reduces bacteria by at least 1 log unit; for smooth-surfaced salad crops (e.g. cucumbers, tomatoes), the reduction is approximately 2 log units (Brackett, 1987; Beuchat, 1998; Lang et al., 2004). Washing in a disinfectant solution (commonly a hypochlorite solution) and rinsing in tap water can reduce pathogens by 1–2 log units. Washing in a detergent (e.g. washing-up liquid) solution and rinsing in tap water can reduce helminth egg numbers by 1–2 log units (B. Jiménez-Cisneros, personal communication, 2005).

Peeling fruits and root vegetables reduces pathogens by at least 2 log units. Cooking vegetables achieves an essentially complete reduction (5–6 log units) of pathogens.

These reductions are extremely reliable and should always be taken into account when selecting the combination of wastewater treatment and other health-based control measures (see Figure 4.1). Effective hygiene education and promotion programmes will be required to inform local food handlers (in markets, in the home and in restaurants and food kiosks) how and why they should wash wastewater-irrigated produce effectively with water or disinfectant and/or detergent solutions.

5.5 Human exposure control

5.5.1 Fieldworkers

Agricultural fieldworkers are at high potential, and often actual, risk of parasitic infections. However, a recent case–control study in Viet Nam of wastewater-irrigated "wet" rice culture shows that farmers engaged in wastewater-fed rice culture have no higher risk of helminth infections than farmers using river water for irrigation (Trang et al., in press). Such risks can be reduced, even eliminated, by the use of less-contaminating irrigation methods (section 5.2) and by the use of appropriate protective clothing (i.e. shoes or boots for fieldworkers and gloves for crop handlers). These health protection measures have not been quantified in terms of pathogen exposure reduction but are expected to have an important positive effect. This is especially true for wearing shoes or boots where there is a risk of hookworm or schistosomiasis transmission. Fieldworkers should be provided with access to sanitation facilities and adequate water for drinking and hygienic purposes in order to avoid the consumption of, and any contact with, wastewater. Similarly, safe water should be provided at markets for washing and "freshening" produce. A study conducted in Peru indicated that wastewater-irrigated crops with acceptable levels of bacteria at the farm were frequently recontaminated in the market (Castro de Esparza & Vargas, 1990, cited in Peasey et al., 2000).

Effective hygiene promotion programmes are almost always needed (Blumenthal et al., 2000b). These should target fieldworkers, produce handlers, vendors and consumers. Hand washing with soap should be emphasized. It may be possible to link hygiene promotion to agricultural extension activities or other health programmes (e.g. immunization programmes).

The risk of cattle ingesting helminth eggs from the soil is high, because grazing cattle may ingest 1–18% of their dry matter intake as soil and sheep as much as 30%, depending on the management and supply of grass (Cabaret et al., 2002). Although *Taenia* eggs have been known to survive for several months on grazing land, the risk of bovine cysticercosis is greatly reduced by ceasing wastewater application at least two weeks before cattle are allowed to graze (Feachem et al., 1983). Tapeworm transmission can be controlled by good meat inspection, provided that animals are slaughtered only in recognized abattoirs where all carcasses are inspected and all infected carcasses rejected.

Precautions against schistosomiasis transmission in endemic areas should also be taken. For example, fieldworkers should be given boots to wear when working in irrigation canals. On large commercial wastewater irrigation schemes, molluscicides may be added to the treated wastewater as it leaves the treatment works.

5.5.2 Consumers

The food preparation measures detailed in section 5.4 protect consumers, but not those preparing the food, who are best protected by exposure control techniques such as rigorous personal and domestic hygiene, frequent hand washing with soap, the use of separate areas for food preparation and the subsequent handling of washed, disinfected and cooked food. Effective hygiene education and promotion are required.

5.5.3 Chemotherapy and immunization

Immunization against helminth infections and most diarrhoeal diseases is currently not feasible. However, for highly exposed groups, immunization against typhoid may be worth considering. Tourists visiting areas where wastewater is used frequently to irrigate crops should be vaccinated against typhoid and hepatitis A virus to give them more protection against these diseases.

Additional protection may be provided by the availability of adequate medical facilities to treat diarrhoeal disease and by regular chemotherapy. This might include chemotherapeutic control of intense helminth infections in children and control of anaemia in both children and adults, especially women and post-menarche girls. Chemotherapy must be reapplied at regular intervals to be effective. The frequency required to keep worm burdens at a low level (e.g. as low as in the rest of the population) depends on the intensity of the transmission, but chemotherapy may be required 2−3 times a year for children living in endemic areas (Montresor et al., 2002). Albonico et al. (1995) found that reinfection with helminths could return to pretreatment levels within six months of a mass chemotherapy campaign if the prevailing conditions did not change.

Chemotherapy and immunization cannot normally be considered as adequate strategies to protect fieldworkers and their families exposed to raw wastewater (section 5.7). However, where such workers are organized within structured situations, such as government or company farms, chemotherapy and immunization could be beneficial as palliative measures, pending improvement in the quality of the wastewater used or the adoption of other health-based control measures (e.g. protective clothing).

For schistosomiasis, a chemotherapy programme targeted at the highest-risk populations is recommended. In high-prevalence situations, WHO suggests that school-age children be treated once per year. Community-directed treatment for other high-risk groups (e.g. agricultural fieldworkers) should be made available. Where the prevalence of schistosomiasis is moderate, school-age children should be treated once every two years. In communities where schistosomiasis prevalence is low, school-age children should be treated twice during primary schooling (once at the beginning and again on leaving) (WHO, 2002).

5.6 Wastewater treatment

Wastewater treatment processes are described in this section primarily with respect to their ability to remove excreted pathogens, rather than to describe their design and operation, which are detailed in some recent texts (e.g. Metcalf & Eddy, Inc., 2003; Mara, 2004; Ludwig et al., 2005; von Sperling & Chernicharo, 2005). Validation, operational and verification monitoring of wastewater treatment processes are described in chapter 6. A comprehensive review of pathogen reduction in the environment, including removal during wastewater treatment, is given in Asano (1998) and Feachem et al. (1983). Typical ranges of pathogen removals in various wastewater treatment processes are given in Table 5.2.

A rigorous costing methodology for comparing and selecting wastewater treatment processes, which includes the cost of the land area required, is given by Arthur (1983). The advantages and disadvantages of various wastewater treatment processes are listed in Table 5.3.

Table 5.2 Log unit reduction or inactivation of excreted pathogens achieved by selected wastewater treatment processes

Treatment process	Log unit pathogen removals[a]			
	Viruses	Bacteria	Protozoan (oo)cysts	Helminth eggs
Low-rate biological processes				
Waste stabilization ponds	1–4	1–6	1–4	1–3[b]
Wastewater storage and treatment reservoirs	1–4	1–6	1–4	1–3[b]
Constructed wetlands	1–2	0.5–3	0.5–2	1–3[b]
High-rate processes				
Primary treatment				
Primary sedimentation	0–1	0–1	0–1	0–<1[b]
Chemically enhanced primary treatment	1–2	1–2	1–2	1–3[b]
Anaerobic upflow sludge blanket reactors	0–1	0.5–1.5	0–1	0.5–1[b]
Secondary treatment				
Activated sludge + secondary sedimentation	0–2	1–2	0–1	1–<2[b]
Trickling filters + secondary sedimentation	0–2	1–2	0–1	1–2[c]
Aerated lagoon + settling pond	1–2	1–2	0–1	1–3[c]
Tertiary treatment				
Coagulation/flocculation	1–3	0–1	1–3	2[b]
High-rate granular or slow-rate sand filtration	1–3	0–3	0–3	1–3[b]
Dual-media filtration	1–3	0–1	1–3	2–3[b,d]
Membranes	2.5–>6	3.5–>6	>6	>3[b,d]
Disinfection				
Chlorination (free chlorine)	1–3	2–6	0–1.5	0–<1[b]
Ozonation	3–6	2–6	1–2	0–2[e]
Ultraviolet radiation	1–>3	2–>4	>3	0[c]

Sources: Feachem et al. (1983); Schwartzbrod et al. (1989); Sobsey (1989); El-Gohary et al. (1993); Rivera et al. (1995); Rose et al. (1996, 1997); Strauss (1996); Landa, Capella & Jiménez (1997); Clancy et al. (1998); National Research Council (1998); Yates & Gerba (1998); Karimi, Vickers & Harasick (1999); Lazarova et al. (2000); Jiménez et al. (2001); Jiménez & Chávez (2002); Jiménez (2003, 2005); von Sperling et al. (2003); Mara (2004); Rojas-Valencia et al. (2004); WHO (2004a); NRMMC & EPHCA (2005).

[a] The log unit reductions are $\log_{10}$ unit reductions defined as $\log_{10}$ (initial pathogen concentration/final pathogen concentration). Thus, a 1 log unit reduction = 90% reduction; a 2 log unit reduction = 99% reduction; a 3 log unit reduction = 99.9% reduction; and so on.

[b] Data from full-scale plants.

[c] Theoretical efficiency based on removal mechanisms.

[d] Data from tests with up to 2 log units initial content; removal may be greater than that reported.

[e] Data from laboratory tests.

Table 5.3 Advantages and disadvantages of different wastewater treatment processes

Treatment	Advantages	Disadvantages[a]
Low-rate biological systems		
Waste stabilization ponds, wastewater storage and treatment reservoirs	Effective at reducing pathogen concentrations (all types of pathogens) Low costs of construction, operation and maintenance Simplicity of operation and maintenance Produce little sludge with low helminth ova content Work well in warm climates with medium to low evaporation No use of electrical energy for operation Help to reconcile wastewater production with water irrigation demand because they can store water for use at peak demand times	Hydraulic short-circuiting may reduce pathogen removal efficiency Algae in effluents may interfere with irrigation application Require large amounts of land (especially in temperate environments) Can facilitate vector breeding if not properly maintained High evaporation in arid climates leads to loss of water resources and increased effluent salinity
Constructed wetlands	Effective in reducing pathogen concentrations — medium bacterial and viral removal efficiency Low cost, low complexity Relatively simple operation and maintenance requirements Require no electricity May improve environment for other species (e.g. birds)	Pathogen removal variable, depending upon a variety of factors Different designs/plants needed in different settings High evapotranspiration in arid climates leads to loss of water resources and increased effluent salinity May facilitate vector breeding Wildlife excreta may cause deterioration of effluent quality
High-rate processes		
Primary sedimentation	Low cost Simple technology	Low pathogen removal
Chemically enhanced primary treatment	Improves primary sedimentation at low cost Low area requirement High helminth egg removal efficiency Produces effluents suitable for agricultural needs	Produces more sludge than normal primary sedimentation Need to treat the sludge produced to inactivate pathogens Need to use chemicals
Activated sludge or trickling filters + secondary sedimentation + disinfection	Technology widely available and well understood Performance can be optimized for good pathogen removal	High cost and complexity Need trained staff Require electricity Produce large volumes of sludge, which need to be handled, treated and disposed of Need to treat the sludge produced to inactivate pathogens Sludge bulking may increase helminth egg numbers in the effluent

Table 5.3 (continued)

Treatment	Advantages	Disadvantages[a]
Upflow anaerobic sludge blanket reactor	Low cost Medium helminth egg removal efficiency	Effluent can cause odour problems Needs trained staff Sludge needs digestion and/or treatment to inactivate pathogens
Aerated lagoon + settling pond	Technology widely available and well understood Performance can be optimized for good pathogen removal No need for primary sedimentation	Require electricity Require larger land area than other high-rate processes Less expensive and complex than other high-rate processes Sludge needs to be treated to inactivate pathogens
Coagulation, flocculation and sedimentation	Improve virus and other pathogen removal/inactivation efficiency Low additional cost	Increase sludge production Sludge needs to be treated to inactivate pathogens
High-rate granular or slow-rate sand filtration	Improves pathogen removal Well understood technology Low additional cost	Needs careful management to optimize performance Slow-rate filters require more space Sludge needs to be treated to inactivate pathogens
Dual-media filtration	When used after primary treatment, efficiently removes protozoan (oo)cysts and helminth eggs When used after secondary treatment, improves pathogen removal Well understood technology Low additional cost	Low efficiency of bacterial and viral removals Needs careful management to optimize performance
Chlorination (free chlorine)	Lowest-cost disinfection method Well understood technology Effective inactivation of bacteria and viruses	Needs pretreatment to be efficient Low efficiency of protozoan and helminth inactivation Creates disinfection by-products Hazardous chemical
Ozone disinfection	Effective inactivation of bacteria, viruses and some protozoa	Effective where organic matter is low Higher cost and complexity than chlorination Low efficiency of protozoan and helminth inactivation Needs to be generated on site Production of hazardous by-products
Ultraviolet disinfection	Effective in inactivating bacteria, viruses and some protozoa Low cost No toxic chemicals used or produced	Effective only in effluents with low suspended solids content and high transmittance Does not inactivate helminth eggs Performance can be reduced by particulate matter and biofilm formation Needs good maintenance of lamps

Table 5.3 (continued)

Treatment	Advantages	Disadvantages[a]
Primary sedimentation + membrane bioreactors	Remove all pathogens	Complex Expensive Sludge needs to be treated to inactivate pathogens Membrane fouling

Sources: Feachem et al. (1983); Schwartzbrod et al. (1989); Sobsey (1989); Rivera et al. (1995); Rose et al. (1996, 1997); Strauss (1996); Landa, Capella & Jiménez (1997); Asano & Levine (1998); Clancy et al. (1998); National Research Council (1998); Yates & Gerba (1998); Karimi, Vickers & Harasick (1999); Lazarova et al. (2000); Jiménez et al. (2001); Jiménez & Chávez (2002); Jiménez (2003, 2005); Metcalf & Eddy, Inc. (2003); von Sperling et al. (2003); Mara (2004); Rojas-Valencia et al. (2004); WHO (2004a); NRMMC & EPHCA (2005); von Sperling & Chernicharo (2005).

[a] Many of these disadvantages can be minimized by careful engineering design and good operation and maintenance.

Two types of treatment systems are described in this section:

- low-rate biological systems: mostly pond-based systems with long retention times;
- high-rate processes: mostly engineered structures with short retention times (i.e. high flow rates).

5.6.1 Low-rate biological systems

Waste stabilization ponds

Waste stabilization ponds are shallow basins that use natural factors such as sunlight, temperature, sedimentation, biodegradation, etc., to treat wastewater (Jiménez, 2003; Mara, 2004). Water treatment systems made up of stabilization ponds usually consist of anaerobic, facultative and maturation ponds linked in series. For optimal performance, the ponds should be designed in such a way as to minimize or eliminate hydraulic short-circuiting. In tropical environments (20–30 °C), well designed and properly operated and maintained waste stabilization pond systems can achieve a 2–4 log unit removal of viruses, a 3–6 log unit removal of bacterial pathogens, a 1–2 log unit removal of protozoan (oo)cysts and a 3 log unit removal of helminth eggs; the precise values depend on the number of ponds in series and their retention times (Mara & Silva, 1986; Oragui et al., 1987; Grimason et al., 1993; see Mara, 2004, for further details on waste stabilization pond design for pathogen removal).

Protozoan (oo)cysts and helminth eggs are removed by sedimentation (and thus remain in the pond sludge). Viruses are removed by adsorption onto solids, including algae (if these solids settle, the adsorbed viruses also remain in the pond sludge). Bacteria are removed or inactivated by several mechanisms, including temperature, pH values above 9.4 (induced by rapid algal photosynthesis) and a combination of high light intensity (>450 nm wavelength) and high dissolved oxygen concentrations (Curtis, Mara & Silva, 1992).

The design of waste stabilization ponds for helminth egg and *E. coli* removal is outlined in Box 5.1; both procedures are very reliable, and, as explained in the box, measured values of the mean hydraulic retention times in waste stabilization ponds can be used as a simple surrogate estimation of the number of helminth eggs in the final effluent (i.e. to check compliance with the microbial reduction target for helminths of ≤1 egg per litre). Evaporation should always be taken into account in waste stabilization pond design (Mara, 2004).

Box 5.1 Design of waste stabilization ponds for helminth egg and *E. coli* reduction

Helminth eggs

The design equation of Ayres et al. (1992b) is used:

$$R = 100[1 - 0.41\exp(-0.49\theta + 0.0085\theta^2)]$$

where R is the percent egg reduction in an anaerobic, facultative or maturation pond; and θ is the retention time in the pond (in days). Thus, for a series of ponds:

$$E_e = E_i(1 - r_a)(1 - r_f)(1 - r_m)^n$$

where E_e and E_i are the numbers of helminth eggs per litre of the final effluent and the raw wastewater, respectively; $r = R/100$; the subscripts a, f and m refer to the anaerobic, facultative and maturation ponds; and n is the number of equally sized maturation ponds.

The retention time in a pond defines the helminth egg reduction in it. Thus, if the flow (Q, m^3/day) into a pond is measured regularly during the irrigation season, and since its retention time (θ, days) is then known (= V/Q, where V is the pond volume, m^3), R can be calculated. If this is done for every pond in the series, and provided E_i is determined on every occasion the flow is measured, E_e can be determined.

An alternative approach is to calculate the total egg reduction in the waste stabilization pond series (R_T), as follows:

$$R_T = 100[1 - (1 - r_a)(1 - r_f)(1 - r_m)^n]$$

As E_e should be ≤ 1 egg per litre (Table 4.4), then the maximum number of eggs in the raw wastewater ($E_{i(max)}$) consistent with $E_e = 1$ is given by:

$$E_{i(max)} = E_e(1 - r_T)^{-1} = (1 - r_T)^{-1}$$

where $r_T = R_T/100$. If this calculated value of $E_{i(max)}$ is more than the known value of E_i, then the waste stabilization pond system can be safely assumed to be producing a final effluent with ≤ 1 helminth egg per litre. Thus, routine monitoring for helminth eggs is not required; it would be sufficient to determine E_i on a few occasions at the start of every irrigation season.

E. coli

The equations of Marais (1966) are used. For a single pond:

$$N_e = \frac{N_i}{1 + k_{B(T)}\theta}$$

$$k_{B(T)} = 2.6(1.19)^{T-20}$$

where N_e and N_i are the numbers of *E. coli* per 100 ml of the pond effluent and influent, respectively; $k_{B(T)}$ is the first-order rate constant for *E. coli* reduction at T °C in a completely mixed reactor (/day); θ is the mean hydraulic retention time in the pond (days); and T is the design temperature (°C).

For a series of anaerobic, facultative and maturation ponds, the first equation above becomes (since the effluent of one pond is the influent to the next):

Box 5.1 (continued)

$$N_e = \frac{N_i}{(1 + k_{B(T)}\theta_a)(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_m)^n}$$

where N_e and N_i are now the *E. coli* numbers per 100 ml of the final effluent and the raw wastewater, respectively; the subscripts a, f and m refer to the anaerobic, facultative and maturation ponds; and n is the number of equally sized maturation ponds. For use in design, this equation is rewritten as:

$$\theta_m = \{[N_i/N_e(1 + k_{B(T)}\theta_a)(1 + k_{B(T)}\theta_f)(1 + k_{B(T)}\theta_m)]^{1/n} - 1\}/k_{B(T)}$$

This form of the equation enables the waste stabilization pond series to be easily designed for the required number of *E. coli* per 100 ml of final effluent (N_e) (Figure 4.1; Table 4.5). It is solved first for $n = 1$, then for $n = 2$ and so on, until the calculated value of θ_m is <3 days (the minimum permissible retention time in a maturation pond). The designer then selects the most appropriate combination of n and θ_m (i.e. the one that has the least overall retention time and therefore the least land area requirement).

Waste stabilization ponds are most effective in warm climates. In colder climates, they can still be effective, but they require a longer retention time and thus a greater land area. In hot, arid climates, substantial water loss due to evaporation may occur in the dry season (e.g. approximately 25% of incoming volume in waste stabilization ponds in parts of Mexico [Jiménez, 2003] and Jordan [Duqqah, 2002]), and this will increase salinity of the effluent.

Waste stabilization ponds are most commonly the lowest-cost treatment option in tropical environments where inexpensive land is available (Arthur, 1983). They are relatively easy to operate and maintain, do not require skilled labour to operate and do not require electricity. However, the growth of vegetation in or near ponds must be controlled to prevent the creation of vector and snail intermediate host breeding habitats.

Wastewater storage and treatment reservoirs

Wastewater storage and treatment reservoirs (also called effluent storage reservoirs) have been used in several arid and semi-arid countries. They offer the advantage of storing wastewater until it can be used in the irrigation season, thus allowing the whole year's wastewater to be used for irrigation; a larger area of land is irrigated, and more crops are produced. The wastewater has to be pretreated (e.g. in an anaerobic pond) before it is added to the wastewater storage and treatment reservoir.

Procedures for designing waste storage and treatment reservoirs are detailed in Juanicó & Dor (1999) and Mara (2004). In general, if waste storage and treatment reservoirs are properly designed, operated and maintained, pathogen removals are very similar to those reported in waste stabilization ponds — i.e. a 2–4 log unit removal of viruses, a 3–6 log unit removal of bacterial pathogens, a 1–2 log unit removal of protozoan (oo)cysts and a 3 log unit removal of helminth eggs (if the waste storage and treatment reservoirs are operated as batch systems, helminth egg removal is 100%; Juanicó & Milstein, 2004).

Waste storage and treatment reservoirs also reduce evaporative losses and subsequent increases in salinity because of their greater depth (5−15 m) and smaller surface area. Whereas, as noted above, Jiménez (2003) found that a waste stabilization pond in an arid area of Mexico lost 25% of its inflow volume due to the high local rate of evaporation, Mara et al. (1997) reported that a waste storage and treatment reservoir in Brazil lost only 14% of its inflow volume during a four-month rest period during the hottest part of the year.

Constructed wetlands

Constructed wetlands are beds of aquatic macrophytes that grow in soil or, more commonly, sand or gravel. There are three main types: surface-flow, horizontal-flow subsurface and vertical-flow systems. Although, in principle, any aquatic macrophyte can be grown in constructed wetlands, the majority are planted with reeds and/or rushes; high-value ornamental flowers have also been grown successfully in constructed wetlands (Belmont et al., 2004). Constructed wetlands are secondary or tertiary treatment units; they are generally preceded by septic tanks, anaerobic ponds or conventional wastewater treatment plants. They are designed for biochemical oxygen demand (BOD), solids and nutrient removal, and not specifically for pathogen reduction. Nevertheless, some pathogen reduction does occur, although it may not be consistent. Reductions are <1–2 log units for viruses, <1–3 log units for bacteria, <1–3 log units for protozoan (oo)cysts and up to 3 log units for helminth eggs. Further details are given in Rivera et al. (1995) and IWA Specialist Group (2000).

Constructed wetlands can be important sources of nuisance mosquitoes as well as, in some cases, mosquitoes of public health importance. Reports, among others, from the eastern seaboard of the United States of America, from southern Sweden and from Australia describe the phenomenon and present possible environmental management solutions (Schaefer et al., 2004; Victorian Government Department of Sustainability and Environment, 2004). Clearly, siting constructed wetlands at safe distances from human settlements is a measure of critical importance.

5.6.2 High-rate processes

High-rate processes are usually engineered systems built around complex infrastructure that have high flow rates and low hydraulic retention times. They usually include a primary treatment step to settle solids followed by a secondary treatment step to biodegrade organic substances, and they may include tertiary or advanced processes for the removal of specific contaminants.

These systems are often expensive, especially when tertiary treatment processes are required to meet microbial reduction targets. Additionally, most high-rate processes remove nitrogen, phosphorus and organic matter, which are all useful in irrigated agriculture.

In many (if not most) situations in developing countries, low-rate biological systems are more appropriate in terms of costs, pathogen reduction efficiency and simplicity of operation and maintenance.

Primary treatment

Primary treatment is achieved in sedimentation tanks with a retention time of approximately 2–6 h. Pathogen reduction is minimal, generally <1 log unit. However, where wastewaters have high numbers of helminth eggs, primary treatment can remove substantial numbers of eggs, even though the reduction is <1 log unit.

Chemically enhanced primary treatment

The pathogen reduction efficiency of primary treatment can be increased by incorporating coagulation/flocculation upstream and/or by using filtration downstream of gravity sedimentation (Metcalf & Eddy, Inc., 2003). Chemically enhanced primary treatment, also called advanced primary treatment, uses specific chemicals (e.g. lime or ferric chloride, often with a high-molecular-mass anionic polymer) to facilitate particle coagulation and flocculation. Improving these processes increases the removal of suspended solids, including helminth eggs (Gambrill, 1990; Morrissey & Harleman, 1992; Jiménez & Chávez, 1998, 2002; Harleman & Murcott, 2001). Studies in Mexico City showed that advanced primary treatment was capable of producing effluents with 2−5 eggs per litre. When advanced primary treatment effluents were filtered through polishing sand filters, effluents with <1 egg per litre were produced at one third of the cost of a secondary treatment system (activated sludge), including sludge treatment and disposal 30 km away (Landa, Capella & Jiménez, 1997; Harleman & Murcott, 2001). Additionally, many virus particles are associated with particulate matter (suspended solids), and advanced primary treatment increases suspended solids removal from approximately 30% to 70−80% (Jiménez, 2003). Another advantage is that nitrogen, organic matter and phosphorus are only partially removed (Jimenez & Chavez, 1998, 2002).

Upflow anaerobic sludge blanket reactors

Upflow anaerobic sludge blanket reactors are high-rate anaerobic units used for the primary treatment of domestic wastewater. They have a hydraulic retention time of the order of 6−12 h (Mara, 2004). Wastewater is treated during its passage through a sludge layer (the sludge "blanket") by anaerobic bacteria. The treatment process is designed primarily for the removal of organic matter (BOD). However, upflow anaerobic sludge blanket reactors remove helminth eggs by 1−2 log units; upflow anaerobic sludge blanket reactor effluents in Brazil contain 3−10 eggs per litre (von Sperling et al., 2003; von Sperling, Bastos & Kato, 2004).

Secondary treatment

Secondary treatment systems, which follow primary treatment, are biological treatment processes coupled with solid/liquid separation. The biological processes are engineered to provide effective bio-oxidation of organic substrates dissolved or suspended in the wastewater. Secondary treatment processes comprise an aerobic microbial reactor followed by secondary sedimentation tanks to remove and concentrate the biomass produced from the conversion of wastewater organic constituents. The aerobic reactors use either suspended-growth processes (e.g. activated sludge, aerated lagoons, oxidation ditches) or fixed-film processes (trickling filters, rotating biological contactors). Although secondary treatment systems are designed primarily for the removal of BOD, suspended solids and often nutrients (nitrogen and phosphorus), they can, with optimized performance, reduce bacterial and viral pathogens by approximately 2 log units, protozoan (oo)cysts by 0−1 log unit and helminth eggs by approximately 2 log units, depending on the suspended solids concentration.

Tertiary treatment

Tertiary treatment refers to treatment processes downstream of secondary treatment, such as (a) additional solids removal by flocculation, coagulation and sedimentation and/or granular medium filtration; and (b) disinfection. When tertiary treatment processes are used, the overall sequence of wastewater treatment processes is generally described as "advanced wastewater treatment."

Coagulation, flocculation and sedimentation further reduce pathogens. Chemicals (e.g. ferric chloride, ferrous chloride, aluminium trisulfate, calcium oxide) are added to secondary effluents, which cause very small particles to combine or aggregate.

Larger aggregated particles then settle out of the liquid. Because viruses and bacteria are often associated with particulate matter, increasing its removal also increases their removal — for example, viruses can be reduced by 2–3 log units under optimal conditions (Jiménez, 2003); reductions for other pathogens are given in Table 5.2.

Filtration is also an effective additional step for removing pathogens. It can be used after primary treatment to improve helminth removal (e.g. after a coagulation/flocculation step in advanced primary treatment) or, more commonly, after secondary treatment. In filtration, pathogens and other particulate matter are removed by passing the effluents through sand or other porous media. There are several types of filtration, including high-rate granular filtration, slow sand filtration and dual-media filtration. Dual-media filtration uses two types of media with different properties to maximize the removal of particles with different properties. The effectiveness of filtration techniques for removing pathogens depends on the operating conditions. For example, high-rate and dual-media filtration are usually preceded by coagulation. By optimizing the coagulation process with dual-media filtration, bacterial reduction can increase from <1 log unit to 2–3 log units (WHO, 2004a). Efficient slow sand filtration requires optimum ripening, cleaning and refilling without short-circuiting (WHO, 2004a). Pathogen reductions achieved by filtration processes are given in Table 5.2.

The effectiveness of *disinfection* depends on several factors, including the type of disinfectant, contact time, temperature, pH, effluent quality and type of pathogen (WEF, 1996). Chlorine (free chlorine), ozone and ultraviolet irradiation are the principal disinfectants used to treat wastewater; chloramines may be used for advanced primary treatment effluents. Disinfection should be optimized for each type of disinfectant. In general, bacteria are the most susceptible to all three disinfectants. Helminth eggs and protozoan cysts/oocysts are the most resistant to chlorine and ozone, and certain viruses (e.g. adenoviruses) are the most resistant to ultraviolet disinfection (Rojas-Valencia et al., 2004). Although there are no data for helminth eggs, they are also expected to be resistant to ultraviolet irradiation. Pathogen reductions achieved by these disinfection processes are given in Table 5.2.

Effluents from activated sludge aeration tanks may be further treated by passage through *membranes*. The membranes have a very small pore size (20–500 nm), so they operate in the ultrafiltration and microfiltration range. They are thus able to achieve essentially complete reduction (i.e. >6 log units) of all pathogens, including viruses. However, membranes are very complex and expensive to operate (membrane fouling is a particular concern), although costs have been decreasing as the technology improves. A full description is given by Stephenson et al. (2000). Membranes provide an extremely efficient (but correspondingly expensive) combination of secondary and tertiary treatment.

5.7 Raw wastewater use

Globally, most wastewater used for crop irrigation is untreated, and often no other health promotion measures are in place to minimize the resulting adverse health impacts. As discussed in chapter 3, raw wastewater use in agriculture leads to a variety of health problems, especially helminth infections and diarrhoeal disease in both children and adults. A combination of the different health protection measures described in this chapter can be implemented to help make this practice safer. This section examines some practical steps that can be taken in the short and medium terms to reduce the adverse health impacts when raw wastewater is used for crop irrigation.

Crop restriction is the most suitable control measure when untreated wastewater is used for crop irrigation. Farmer education about the need for crop restriction is essential, especially concerning (a) the health risks to consumers if untreated wastewater were to be used for unrestricted irrigation and (b) which local "restricted" crops can be profitably grown. Local environmental health officers should regularly inspect the wastewater-irrigated fields to ensure that no unrestricted irrigation occurs.

Low-cost drip irrigation systems have been developed, and their use by farmers should be encouraged. They provide increased health protection and higher crop yields and use less water. Details are given by Polak et al. (1997), Kay (2001), Postel (2001), FAO (2002), Intermediate Technology Consultants (2003), von Westarp, Chieng & Schreier (2004) and International Development Enterprises (2005) (see also Table 4.3 and section 5.2). Simple wastewater pretreatment is required (section 5.6).

If untreated wastewater is used for unrestricted irrigation, then the 1–2 log unit pathogen reduction per day that occurs between the last irrigation and consumption is very important.

The simple food preparation measures detailed in section 5.4 should be actively promoted among local food handlers (in markets, in the home and in restaurants and food kiosks). A successful example of this is given by Faruqui, Niang & Redwood (2004), who reported results of a survey of produce consumers in Dakar, Senegal: this showed that approximately 70% were aware of the health risks from eating raw wastewater–irrigated vegetables, and they therefore either disinfected them or ate them only after cooking.

A survey of farmers who used raw wastewater for irrigation in Dakar, Senegal, revealed that less than half were aware of the health risks posed by the use of raw wastewater for irrigation purposes, and very few took precautions to reduce their exposure (e.g. by wearing gloves or shoes) (Faruqui, Niang & Redwood, 2004). Therefore, increasing awareness of the health risks may help to change behaviours.

Hygiene education and promotion are thus key public health interventions. Specific programmes and messages can be targeted at farmers, communities and produce consumers exposed either directly or indirectly to raw wastewater. Hygiene promotion can be conducted by local health assistants, on radio and television and through primary and secondary schools.

Other exposure control methods could include erecting low-cost fences around irrigation canals that transport raw wastewater and/or covering open sewers.

Immunization and chemotherapy are effective for preventing and reducing illness. Areas that rely on raw wastewater for irrigation should be targeted for immunization campaigns (especially typhoid, polio and hepatitis A). Regular mass chemotherapy campaigns against helminths in high-prevalence areas are also very effective (especially for 5- to 15-year-old children) and could be linked to hygiene promotion programmes for farmers and exposed communities. However, immunization and chemotherapy should not be seen as alternatives to wastewater treatment and other health protection measures. They are meant to be complementary health protection measures.

Untreated wastewater is commonly used for crop irrigation simply because the municipality has not constructed, or is unable to afford the construction of, a wastewater treatment plant. The health benefits of at least minimal wastewater treatment are potentially very large, however, especially if untreated wastewater is used for unrestricted irrigation. Crop restriction should be the first control measure applied (section 5.1). Simple wastewater treatment in anaerobic and facultative ponds (section 5.6.1) or advanced primary treatment with high-rate granular filtration (section 5.6.2) will usually achieve the health-based targets for restricted irrigation (Tables 4.1, 4.3 and 4.4). Helminth egg reduction is very important; if ≤1 egg per litre cannot be achieved, a reduction to ≤10 or ≤5 eggs per litre is a good initial step. Helminth eggs decrease in number in untreated wastewater over time, as even minimal wastewater treatment does much to decrease the prevalence of helminth infections by reducing the opportunity for reinfection, especially when regular mass chemotherapy campaigns are in force.

6 MONITORING AND SYSTEM ASSESSMENT

Monitoring has three different purposes: validation, or proving that the system is capable of meeting its design requirements; operational monitoring, which provides information regarding the functioning of individual components of the health protection measures; and verification, which usually takes place at the end of the process (e.g. treated wastewater, crop contamination) to ensure that the system is achieving its specified targets.

The most effective means of consistently ensuring the safety of wastewater use in agriculture is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in the process, from the generation and use of wastewater to the consumption of the product. This approach is captured in the Stockholm Framework. System assessment and its components are discussed in section 6.2.

The combination of health protection measures adopted in a particular wastewater use scheme requires regular monitoring to ensure that the system continues to function effectively. Monitoring, however, in the sense of observing, inspecting and collecting samples for analysis, is not sufficient on its own. Institutional arrangements must be established for the information collected in this way to provide feedback to those who implement the health protection measures. The responsibility for the monitoring of health protection measures should be clearly defined in the relevant legislation (see chapter 10).

6.1 Monitoring functions

The three functions of monitoring are each used for different purposes at different times. See Table 6.1 for a brief description of each type of monitoring. Validation is performed at the beginning when a new system is developed or when new processes are added and is used to test or prove that the system is capable of meeting the specified targets. Operational monitoring is used on a routine basis to indicate that processes are working as expected. Monitoring of this type relies on simple measurements (e.g. pH, turbidity) that can be read quickly so that decisions can be made in time to remedy a problem. Verification is used to show that the end product (e.g. treated wastewater, crop contamination) meets treatment targets (e.g. microbial quality specifications). Information from verification monitoring is collected periodically and thus would arrive too late to allow managers to make decisions to prevent a hazard break-through. However, verification monitoring can indicate trends over time (e.g. if the efficiency of a specific process was improving or decreasing). The validation and verification targets for effluents presented in the current guidelines are basically similar to what was referred to as recommended effluent standards or guidelines in the previous edition.

6.2 System assessment

The first step in developing a risk management system is to form a multidisciplinary team of experts with a thorough understanding of wastewater use in agriculture. Typically, such a team would include agriculture experts, engineers, water quality specialists, environmental health specialists, public health authorities and food safety experts. In most settings, the team would include members from several institutions, and there should be members from independent institutions, such as from universities.

Effective management of the wastewater use system requires a comprehensive understanding of the system, the range and magnitude of hazards that may be present and the magnitude of related risk levels, and the ability of existing processes and

Table 6.1 Definitions of monitoring functions

Function	Definition
Validation	Testing the system and its individual components to obtain evidence that it is capable of meeting the specified targets (i.e. microbial reduction targets). Should take place when a new system is developed or new processes are added.
Operational monitoring	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. turbidity following wastewater treatment). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.
Verification	The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

infrastructure to manage actual or potential risks. It also requires an assessment of capabilities to meet targets. When a new system or an upgrade of an existing system is being planned, the first step in developing a risk management plan is the collection and evaluation of all available relevant information and consideration of what risks may arise during the entire production process. Figure 6.1 illustrates the development of a risk management plan.

The assessment and evaluation of a wastewater use system are enhanced through the development of a flow diagram. Such diagrams provide an overview description of the system, including the identification of sources of hazards, determining factors of associated risks and health protection measures. It is important that the representation of the wastewater use system be conceptually accurate. If the flow diagram is not correct, it is possible to overlook potential hazards that may be significant. To ensure accuracy, the flow diagram should be validated by visually checking it against features observed on the ground.

Data on the occurrence of hazards in the system combined with information concerning the effectiveness of existing controls enable an assessment of whether health-based targets can be achieved with the existing health protection measures. They also assist in identifying health protection measures that would reasonably be expected to achieve those targets if improvements are required.

To ensure accuracy of the assessment, it is essential that all elements of the wastewater use system are considered concurrently and that interactions and influences between elements and their overall effect are taken into consideration.

6.3 Validation

Validation is concerned with obtaining evidence on the performance of control measures, both individually and collectively. It should ensure that the system is capable of meeting the specified microbial reduction targets. Validation is used to test or prove design criteria. It should be conducted before a new risk management process is put into place (e.g. for wastewater treatment, wastewater application, produce washing/disinfection, etc.), when equipment is upgraded (e.g. new filter) or when new equipment or processes (e.g. addition of new coagulants) are added. It can also be used to test different combinations of processes to maximize process efficiency. Validation can be conducted at the facility scale or on a test scale. In a waste stabilization pond validation, for example, dye testing would be able to confirm that the design retention time was being achieved in practice.

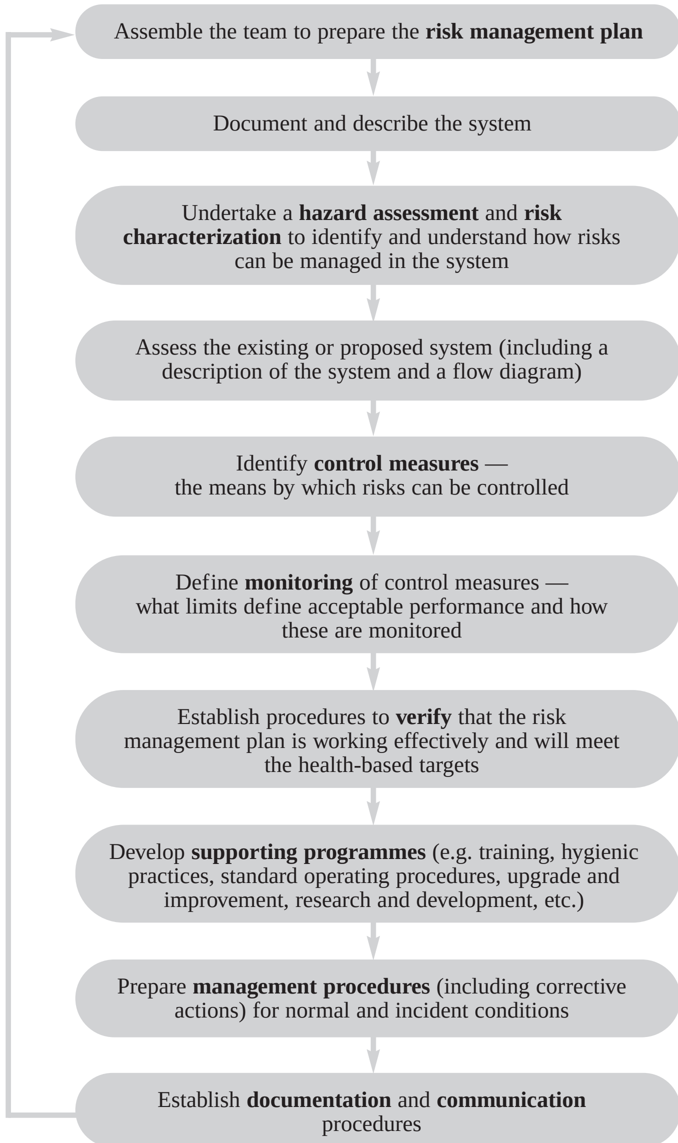

Figure 6.1
Development of a risk management plan (WHO, 2004a)

The first stage of validation is to consider data that already exist. These will include data from the scientific literature, trade associations, regulation and legislation departments and professional bodies, historical data and supplier knowledge. These data will inform the testing requirements. The second stage of validation is to conduct laboratory or pilot-level evaluations of the components and overall system under conditions that approximate those found at the actual site. A system should be validated for the different types of situations that occur (e.g. hot season vs cold season; dry season vs wet season; winter, spring, summer and autumn). Validation is not used for day-to-day management of wastewater treatment and use; as a result, parameters that may be inappropriate for operational monitoring can be used, and the lag time for return of results and additional costs from measurements can often be tolerated (WHO, 2004a).

6.4 Operational monitoring

Control measures are actions implemented in the system that prevent, reduce or eliminate contamination and are identified in system assessment. They include, for example, wastewater treatment and storage facilities, waste application techniques, use of protective clothing and sanitary conditions in the market or where the food is being prepared and consumed. If collectively operating properly, they would ensure that health-based targets are met.

Operational monitoring is the execution of planned observations or measurements to assess whether the control measures in a wastewater use system are operating properly. It is possible to set limits for control measures, monitor those limits and take corrective action in response to a detected deviation before the contamination passes through the system. Examples of limits are total suspended solids to indicate the level of particulate matter that might be associated with pathogens, turbidity, pH and flow rates. The presence or absence of plants in wastewater irrigation canals is an important indicator, since these may provide suitable habitats for disease vectors or snail intermediate hosts of schistosomes. Operational monitoring should take place around system parameters that indicate the potential for increased risk of hazard break-through. It is facilitated by simple measurements that can be taken quickly. For example, turbidity can be monitored quickly (often in real time) to indicate if a filter is malfunctioning or if a membrane is broken. Operational monitoring parameters are different for high-rate wastewater treatment and low-rate biological treatment systems. Examples of parameters that can be monitored are presented in Table 6.2.

The frequency of operational monitoring varies with the nature of the control measure; for example, checking physical infrastructure integrity (e.g. vegetation on the banks of wastewater treatment ponds) may occur monthly or less frequently, whereas monitoring turbidity in an activated sludge plant may be conducted in real time. If monitoring shows that a limit does not meet specifications, then there is the potential for a hazard break-through. The amount of time needed to correct an action should determine the rate of operational monitoring. For example, with waste stabilization pond systems, operational monitoring for various parameters (see Table 6.2) could take place at regular intervals of several weeks or longer, because the retention time is often long (e.g. 12–20 days). With wastewater treatment systems that have much shorter retention times (e.g. activated sludge), operational monitoring of parameters such as turbidity can take place online in real time.

A variety of physicochemical parameters should be monitored at regular intervals to verify the performance of a wastewater treatment system. Five-day BOD, chemical oxygen demand, total suspended solids, total dissolved solids, pH, temperature, exposure time and total nitrogen and phosphorus are examples of chemical parameters that are monitored for verification. Most of these parameters are monitored to prevent environmental impacts of wastewater discharge and to meet regulatory requirements for quality of wastes to be discharged. However, some may also be used as proxies for hazardous substances. For example, Jiménez & Chávez (1998) found a direct correlation between total suspended solids and intestinal helminth concentrations. It is easier to measure total suspended solids than to directly determine the concentration of helminth eggs, which requires a trained parasitology technician and suitable laboratory facilities.

In most cases, operational monitoring will be based on simple and rapid observations or tests, such as turbidity or structural integrity, rather than complex microbial or chemical tests. The complex tests are generally applied as part of validation and verification activities rather than as part of operational monitoring.

Monitoring needs to be conducted in such a way that it provides statistically meaningful information (e.g. sample duplicates), is directed at controlling the most important hazards and can inform changes to health protection measures. A monitoring programme should be designed in such a way that it can be performed within the technical and financial resources of any given situation. The objective is timely monitoring of control measures with a logically based sampling plan, to minimize negative public health impacts (WHO, 2004a).

6.5 Verification monitoring

Verification is the use of methods, procedures or tests in addition to those used in operational monitoring to determine if the performance of the wastewater/excreta use system is in compliance with the stated objectives outlined by the health-based targets and/or whether the system needs modification and revalidation.

For microbial reduction targets, verification is likely to include microbial analysis. In most cases, it will involve the analysis of faecal indicator microorganisms; in some circumstances, it may also include assessment of specific pathogen densities (e.g. helminth ova). Verification of the microbial quality of wastewater may be undertaken by local public health agencies.

Approaches to verification include testing of wastewater after treatment or wastewater at the point of application or use. Verification of the microbial quality of the wastes often includes testing for *E. coli* or thermotolerant coliforms. While *E. coli* is a useful indicator, it has limitations; the absence of *E. coli* will not necessarily indicate the absence of other pathogens. Under certain circumstances, it may be desirable to include more resistant microorganisms, such as *Ascaris* or bacteriophages (viruses that infect bacteria), as indicators for other microbial groups.

If wastewater is suspected to contain sizable industrial discharges, then periodic monitoring of the wastewater for heavy metals and chlorinated hydrocarbons may be warranted. Also, if crops with particular sensitivities (e.g. boron sensitivity) are being grown, then it will be important to monitor those chemicals that could have an impact on agricultural productivity (see Annex 2).

Table 6.2 Validation, operational monitoring and verification monitoring parameters for different control measures

Control measure	Validation requirements	Operational monitoring parameters	Verification monitoring parameters
Wastewater treatment	Effectiveness of treatment processes at inactivating/ removing pathogens and indicator organisms (*E. coli*, helminth eggs) System design (e.g. retention time, short-circuiting in waste stabilization pond by conducting dye testing) Analytical procedures for detecting indicators and/or pathogens (including measuring viability) Effectiveness of treatment in removing locally important toxic chemicals Analytical procedures and capabilities for detecting chemicals in wastewater, excreta or pond water	*Low-rate biological systems:* Flow rates BOD (loading rates may need to vary during colder periods) Algal concentrations and species types Dissolved oxygen at different pond depths (facultative and maturation ponds) *High-rate processes:* BOD Turbidity pH Organic carbon Particle counts Membrane integrity (pressure testing) Chlorine residual	*E. coli* Helminth eggs (including *Schistosome* spp., where appropriate) Locally important toxic chemicals
Health and hygiene promotion	Testing of promotional materials with relevant stakeholder groups	Local programmes in operation Promotional materials available Promotion included in school curriculum	Increased awareness of health and hygiene issues in key stakeholder groups Improved practices
Chemotherapy and immunization[a]	Effectiveness of different vaccines/drugs in preventing or treating locally important infections	Numbers of people vaccinated/treated Villages/schools targeted near wastewater use areas Frequency of campaigns	Reduced prevalence and intensity of infections Fewer disease outbreaks in targeted areas
Product restriction	Survey of product consumers to identify species always eaten after thorough cooking Analysis of marketability of different species/crops Economic viability of growing products not for human consumption	Types of crops grown in wastewater use areas	Water quality testing of wastewater to ensure that water used for unrestricted irrigation meets WHO microbial reduction targets

Table 6.2 (continued)

Control measure	Validation requirements	Operational monitoring parameters	Verification monitoring parameters
Waste application/ timing	Test the amount of time needed for pathogen die-off under different climatic conditions and for different pathogens/indicators between waste application and crop harvest to ensure minimal contamination	Monitor waste application timing and time to harvest	Analyse plant contamination
Produce washing, disinfection, cooking foods	Research on which methods are most effective in reducing contamination, pathogen inactivation Testing of educational materials among relevant stakeholders	Inspection by food safety authorities to ensure that proper procedures are being used at markets or restaurants where products are prepared	Periodic microbial testing of the hygiene of food preparation spaces in markets and restaurants, product testing to investigate where contamination occurs Inspection of markets to assess availability of safe drinking-water for product washing/freshening
Access control, use of personal protective equipment	Testing access control measures for effectiveness in preventing public exposures to wastewater Identifying which personal protective equipment is available at low cost that workers will wear Testing the effectiveness of the personal protective equipment in preventing exposure to hazards	Visual inspection of wastewater use areas for warning signs, fences, etc. Visual inspection of workers to ensure that they are wearing the appropriate personal protective clothing	Public health surveillance of workers to document reductions in skin diseases, schistosomiasis (where relevant) and hookworm
Intermediate host and vector control	Test system to evaluate its effect on insect vector breeding and/or survival and growth of relevant snail species Test control measures such as the reduction of emergent vegetation and its impact on the breeding of disease vectors or snail intermediate hosts Check for obstructed drains, seepage and a rise in groundwater levels that can result in pools of standing water	Visual inspection of facilities to observe vegetative growth in irrigation canals or treatment ponds Inspection of waters for relevant insect larvae or snail intermediate hosts	Public health surveillance to document vector-borne diseases or schistosomiasis in workers and local communities

[a] Chemotherapy and immunization are considered to be supplementary health protection measures and should not be used instead of other health protection measures such as wastewater treatment.

6.6 Small systems

Validation, operational monitoring and verification monitoring are important steps to identify and eventually mitigate public health issues that might be associated with wastewater use in agriculture. However, in some situations, the use of wastewater in agriculture can be difficult to monitor (e.g. in urban areas or in informal small-scale operations). Additionally, much of the wastewater use in agriculture that is practised is indirect and informal (e.g. irrigation with faecally contaminated surface waters) and thus harder to plan and control. Countries and local authorities may have limited budgets for validation and monitoring and thus will need to develop validation and monitoring programmes based on the most important local public health issues, the availability of professional staff and access to laboratory facilities.

When many small-scale wastewater irrigation operations exist, the national health or food safety authority may choose to validate health protection measures at a central research site and then disseminate information to relevant stakeholders (e.g. through the development of guidelines, through public health outreach workers, through agriculture extension workers or through local stakeholder workshops).

Operational monitoring should focus on visual inspections and safety audits without requiring difficult or expensive laboratory testing. For example, visual inspection of a facility will indicate the types of crops being grown or if workers are using boots and gloves. Similarly, food markets can be quickly inspected visually to detect unhygienic conditions or lack of safe water for product washing/freshening.

Verification monitoring may be easier to conduct at a central point (e.g. a wastewater discharge point or a market). Data from public health surveillance for faecal–oral diseases, schistosomiasis, intestinal helminth infections and other locally important diseases should be used to adjust health protection measures as necessary.

6.7 Other types of monitoring

6.7.1 Food inspection

Periodically, the microbial and chemical contamination of wastewater-irrigated crops should be tested. Products should be tested for *E. coli* or thermotolerant coliforms and helminth eggs where they are a hazard. The concentrations of heavy metals that may pose a health risk (e.g. cadmium, lead) should also be tested to ensure that they are within the safety limits specified by the Codex Alimentarius Commission.

6.7.2 Public health surveillance

Direct measurement of specific health outcomes (e.g. intestinal helminth infections, schistosomiasis and vector-borne diseases, such as filariasis) is possible and should be conducted periodically in exposed populations. This is discussed in the context of the Stockholm Framework in chapter 2.

7
SOCIOCULTURAL ASPECTS

Human behavioural patterns are a key determining factor in the transmission of excreta-related diseases. The social feasibility of changing certain behavioural patterns in order to introduce wastewater use schemes or to reduce disease transmission in existing schemes needs to be assessed on an individual project basis. Cultural beliefs vary so widely in different parts of the world that it is not possible to assume that any of the practices that have evolved in relation to wastewater use can be readily transferred elsewhere (Cross, 1985). However, there does appear to be a positive correlation between the occurrence of traditional waste use in societies and their population density, which has been called the "nutritional imperative." Societies that use excreta and wastewater or have used it in the recent past in agriculture or aquaculture are the most densely populated: Europe, India, China, Viet Nam and parts of Indonesia (Edwards, 1992).

Closely associated with cultural beliefs is the public perception of wastewater use. Even when projects are technically well planned and all of the relevant health protection measures have been included, the project can fail without adequately accounting for public perception. This chapter describes both of these aspects and how they relate to the use of wastewater in agriculture.

7.1 Cultural and religious beliefs

Untreated wastewater is currently used for agriculture in many parts of the world. Although there does not appear to be any significant sociocultural revulsion at this practice because of economic necessity, treated wastewater is much less objectionable in appearance than untreated wastewater and, from a socioaesthetic (as well as a health) perspective, is more suitable for agricultural use. Public fears may be allayed by suitably designed information programmes (see Box 7.1).

Box 7.1 Sociocultural acceptance of wastewater use in Nablus, West Bank and Gaza Strip, Palestinian Self-Rule Areas

During the development of a wastewater treatment and use demonstration plant in the town of Nablus, West Bank and Gaza Strip, Palestinian Self-Rule Areas, surveys of different stakeholders (i.e. general public, farmers and pilot project site visitors) were conducted. The majority of Palestinians are Muslims, and the surveys focused on sociocultural aspects of wastewater use. Conclusions from the survey were as follows:

- Villagers surveyed believed that the use of wastewater is acceptable in Islam providing that the effluent quality is safe and does not harm the health of the users.
- Drought and water shortage justified the use of wastewater in irrigation to conserve fresh water for other, more important purposes.
- Most of the people surveyed had never seen wastewater treatment plants.
- Most of the people surveyed thought that the use of raw wastewater was dangerous, whereas treated wastewater was an important resource.
- Survey respondents were willing to consume products grown with treated wastewater.
- Public perception and acceptance could be increased by exposing people to wastewater treatment demonstration plants and increasing public outreach efforts.

Source: Al Khateeb (2001).

In Islamic countries, it has been judged that wastewater can be used for irrigation provided that the impurities (*najassa*) present in raw wastewater are removed. According to Farooq & Ansari (1983), there are three ways in which impure water may be transformed into pure water:

1) self-purification of the water (e.g. removal of the impurities by sedimentation);
2) addition of pure water in sufficient quantity to dilute the impurities;
3) removal of the impurities by the passage of time or physical effects (e.g. sunlight and wind).

It is notable that the first and third of these transformations are essentially similar to those achieved by wastewater treatment processes.

In 1978, the Council of Leading Islamic Scholars of Saudi Arabia issued a fatwa (legal ruling on an issue of religious importance) concerning the use of wastewater in Islamic societies. The fatwa stated: "Impure wastewater can be considered as pure water and similar to the original pure water, if its treatment using advanced technical procedures is capable of removing its impurities with regard to taste, colour and smell, as witnessed by honest, specialized and knowledgeable experts. Then it can be used to remove body impurities and for purifying, even for drinking. If there are negative impacts from its direct use on the human health, then it is better to avoid its use, not because it is impure but to avoid harming the human beings." The Council of Leading Islamic Scholars prefers to avoid using wastewater for drinking (if possible) "to protect health and not to contradict with human habits" (Faruqui, Biswas & Bino, 2001).

Nevertheless, untreated wastewater is used in some Islamic countries, principally in areas where there is an extreme water shortage and then generally from a local wadi (ephemeral desert stream), but this is clearly a result of economic need and not of cultural preference.

In some Buddhist cultures, the use of wastewater and excreta as fertilizers in agriculture is in agreement with the central philosophy of reincarnation. It is not difficult to extend the philosophical concept of recycling human energy — birth, growth, decay, death and rebirth — to the harmonious concept of recycling earthly resources (Warner, 2000).

7.2 Public perception

The maintenance of good public relations, especially with respect to protection of consumer health, is a very important task. The public must have confidence that the food they are consuming is in no way injurious to their health. In this respect, programmes for the routine monitoring of wastewater and of produce quality are extremely important, as is the demonstrated absence of the transmission of infectious disease.

The public perception of wastewater use in agriculture varies much from one community to another. Where there is water scarcity or where wastewater is seen as a resource upon which people rely for their livelihoods, its use in agriculture is likely to be more acceptable. However, where people see it as a nuisance due to odour, perceived health or environmental impacts and lower property values, then it may be less acceptable.

It is important to recognize that even in situations where advanced wastewater treatment processes will be used to treat the wastewater and actual health risks will be very low, negative public perception can derail even well planned projects.

Bridgeman (2004) outlines several conclusions regarding public perception that arose during the development of various wastewater use projects in California, USA:

- Public perception varies by community; there is no one solution that will work in all communities. Outreach programmes must be based on a comprehensive understanding of the profile of the community that the planned project is to serve. From this, stakeholder-specific action plans should be developed.
- Community and stakeholder participation at the earliest stages of the project are important.
- The strength of public opinion regarding the use of wastewater should not be underestimated.
- A scheme will be approved by a community only following consistent, clear and reliable communication with that community. Key messages should be presented in a manner that is understandable to community members.
- Efforts to inform and involve the community should be proactive and not reactive.
- Successful projects require trust between the project planners and the potential recipients.
- Messages should focus on the positive benefits of the project.
- Education of the recipient communities is essential for projects to succeed.
- Timing of implementation and careful monitoring of public opinion are important. Communities may be more receptive to wastewater use projects when they are faced with a drought.
- Regardless of the economic and scientific basis behind the proposals for schemes, there may be people who, for their own reasons, will never accept the proposals.
- Monitoring programmes are key elements of projects to reassure the public.

7.2.1 Public acceptance of wastewater use schemes

To achieve general acceptance of wastewater use schemes, experience shows that active public involvement from the planning phase to the full implementation process is critical. Public involvement starts with the identification of and early contact with potential users, leading to the formation of an advisory committee and the holding of public hearings on potential use schemes. The exchange of information between authorities and public representatives ensures that the adoption of a specific water reuse programme will address real user needs and generally recognized community goals for health, safety, ecological concerns, programme cost, etc. (Crook et al., 1992; Helmer & Hespanhol, 1997).

Gaining public acceptance is easier once the need to use wastewater is established. If a community is aware of water scarcity and the need to conserve high-quality water sources for domestic purposes, they will be more willing to accept wastewater use. The use of wastewater becomes a solution to a problem instead of a problem in itself (UKWIR, 2005). As Figure 7.1 demonstrates, the public is more likely to accept wastewater use where there is a perception that there will be limited contact with the wastewater. Thus, using wastewater to irrigate fodder crops or crops that are always cooked before consumption is likely to be more acceptable to the public than using it to irrigate crops that will be eaten raw. As uses that increase the probability of coming into contact with the wastewater grow (e.g. using treated wastewater for laundry at the household level, storing treated wastewater in reservoirs used for recreation or as

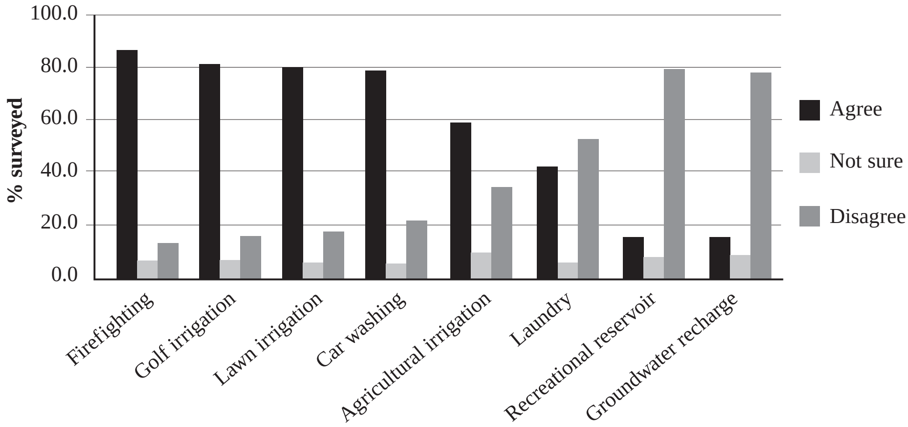

Figure 7.1
Attitudes towards wastewater use options (Robinson, Robinson & Hawkins, 2005)

drinking-water supplies or recharging groundwater used as drinking-water sources), the use of wastewater becomes less acceptable to the public.

Acceptance of wastewater use systems depends on the degree to which the responsible agencies succeed in providing the concerned public with a clear understanding of the complete programme; the knowledge of the quality of the treated wastewater and how it is to be used; confidence in the local management of the public utilities and on the application of locally accepted technology; assurance that the wastewater use application being considered will involve minimal health risks and minimal detrimental effects to the environment; and assurance, particularly for agricultural uses, of the sustainability of supply and suitability of the treated wastewater for the intended crops.

Figure 7.2 provides a flow chart for establishing programmes to involve the concerned community with all phases of wastewater use projects, from the planning phase to full implementation of the project, and Table 7.1 presents communication tools to address, educate and inform the public at different levels of involvement (Helmer & Hespanhol, 1997).

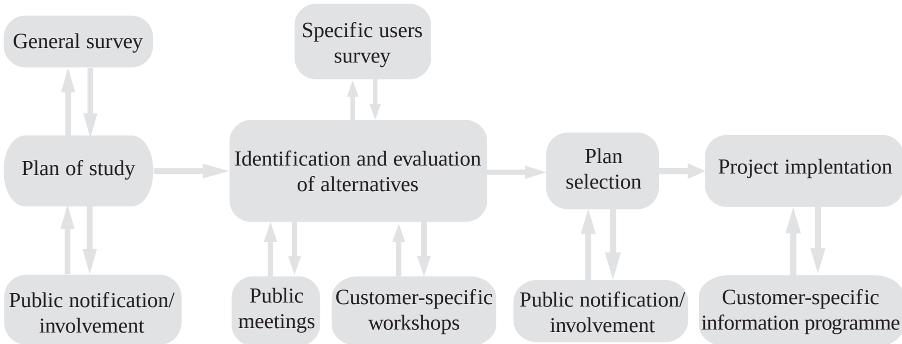

Figure 7.2
Developing a strategy for increasing public participation (adapted from Crook et al., 1992; Helmer & Hespanhol, 1997)

Table 7.1 Tools for increasing public participation in the decision to use wastewater

Purpose	Tools
Education and information	Newspaper articles, radio and television programmes, speeches and presentations, field trips, exhibits, information depositories, school programmes, films, brochures and newsletters, reports, letters, conferences
Review and reaction	Briefings, public meetings, public hearings, surveys and questionnaires, question and answer columns, advertised "hotlines" for telephone inquiries
Interaction dialogue	Workshops, special task forces, interviews, advisory boards, informal contacts, study group discussions, seminars

Source: Adapted from Crook et al. (1992).

8
ENVIRONMENTAL ASPECTS

The use of wastewater in agriculture has the potential for both positive and negative environmental impacts. With careful planning and management, the use of wastewater in agriculture can be beneficial to the environment.

This chapter will present an overview of the beneficial and harmful components of wastewater and the impacts on soils and water bodies (surface water and groundwater). Suggestions for managing environmental impacts are also given.

Wastewater is an important source of water and nutrients for many farmers in arid and semi-arid climates. Sometimes it is the only water source available for agriculture. When wastewater use is well managed, it helps to recycle nutrients and water and therefore diminishes the cost of fertilizers or simply makes them accessible to farmers. This in itself has environmental consequences (e.g. less energy is needed to produce fertilizers [Sala & Serra, 2004], less phosphorus needs to be mined, etc.). Where wastewater treatment services are not provided, the use of wastewater in agriculture actually acts as a low-cost treatment method, taking advantage of the soil's capacity to naturally remove contamination. Therefore, the use of wastewater in irrigation helps to reduce downstream health and environmental impacts that would otherwise result if the wastewater were discharged directly into surface water bodies.

Nevertheless, agricultural wastewater use poses environmental risks. Possible effects and their relevance depend on each specific situation and how the wastewater is used. In many places, wastewater irrigation has arisen spontaneously and without planning — often the wastewater is untreated. In other situations, the use of wastewater in agriculture is strictly controlled. These practices will lead to different environmental impacts. Figure 8.1 shows schematically the generation and use of wastewater and how it interacts with the environment.

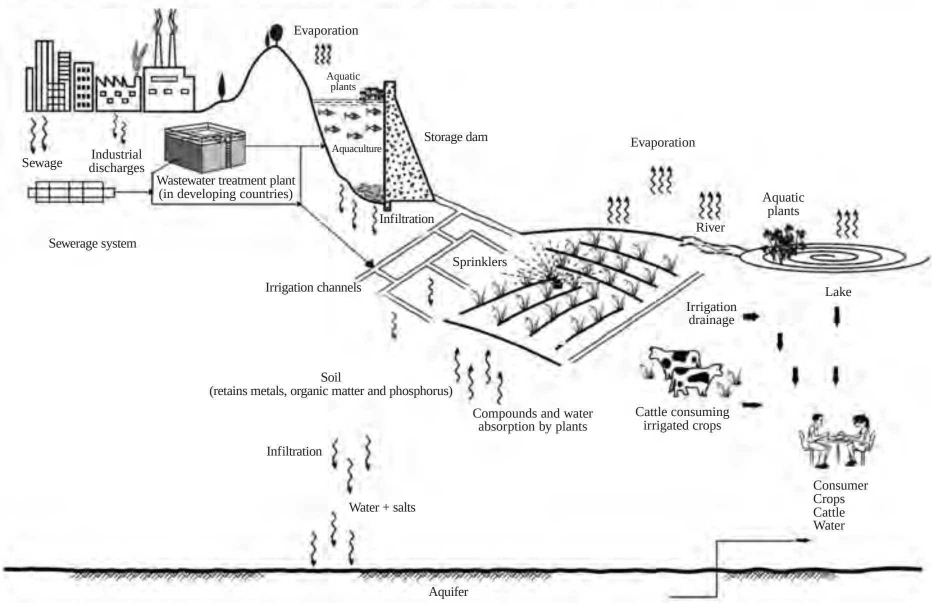

Figure 8.1
Simplified scheme of agricultural wastewater use and effects on the environment

The properties of domestic wastewater and industrial wastewater differ. Generally, the use of domestic wastewater for irrigation poses less risk to the environment than the use of industrial wastewaters, especially where industries use or produce highly toxic chemicals in their processes. Toxic chemicals from industrial processes are discharged into domestic wastewater in many countries, creating more serious environmental problems and endangering the health of the farmers and product consumers (see Box 8.1).

Box 8.1 Impact of industrial effluents on agriculture and aquaculture

The Bau Tram dam, located 10 km northwest of Danang City, Viet Nam, was built in 1961 with 1.2 million cubic metres of storage capacity. Water from the dam is used to irrigate 120 ha of rice paddies and produce fish. Irrigation water from the dam allows farmers to grow three rice crops per year (with a productivity of about 6 t/ha). Initially, the Bau Tram dam received the municipal wastewater of the local population. In 1990, however, the new industrial zone of Hoa Khanh began to divert 436 m^3/day of non-treated or barely treated industrial effluents into the reservoir. In some years, 50% of the agricultural production was lost, and aquaculture had to be stopped. In addition, water supplies were contaminated with heavy metals. Metals in the dam's sediments were transported to the fields during droughts and have contaminated the soils.

Source: Adapted from Raschid-Sally, van der Hoek & Ranawaka (2001).

8.1 Components of wastewater

The quality of wastewater (in terms of its physical and chemical characteristics) partly determines its environmental impacts. In arid and semi-arid areas, chemical concentrations are higher than in humid ones, because less water is used at the point of generation and higher evaporation rates during distribution and treatment reduce the water component. The following components of wastewater may have an impact on the environment:

- pathogens;
- salts;
- metals;
- toxic organic compounds;
- nutrients (nitrogen, phosphorus and potassium);
- organic matter;
- suspended solids;
- acids and bases (pH).

8.1.1 Pathogens

As indicated in chapters 2 and 3, wastewater may contain a variety of pathogens (i.e. bacteria, helminths, protozoa and viruses). These substances can contaminate crops, soil, surface water and groundwater. The survival of different pathogens in different media is described in chapters 2 and 3. From a health perspective, pathogens in the wastewater are generally considered to be the primary hazard, especially when inadequately treated or untreated wastewater is used in irrigation.

All of these types of pathogens can contaminate crops or soils. If wastewater is applied to extremely porous soils or thin or broken soils where groundwater is close to the surface (or is directly under the influence of surface waters), pathogens can contaminate aquifers. In general, the helminths and protozoa, because of their relatively large size, are removed more quickly in the top layers of soil through filtration. However, *Giardia* and *Cryptosporidium* have been detected in groundwater from a variety of different sites (Moulton-Hancock et al., 2000). Viruses and bacteria are smaller than helminths and protozoa and thus may be more mobile in the soil. Some viruses may be transported for long distances in aquifers, both vertically and horizontally (Yates & Gerba, 1998).

8.1.2 Salts

Perhaps the most important negative effect on the environment caused by agricultural wastewater use is the increase in soil salinity, which, if not controlled, can decrease productivity in the long term. Salinity is measured indirectly by a set of parameters such as conductivity, sodium adsorption ratio, sodium and chloride concentrations and dissolved solids. The rate at which soil salinity increases depends on the water quality and other factors, such as soil transmissivity, organic matter content, land drainage, irrigation rate and depth to the groundwater. For all these reasons, it is not easy to predict salinization rates, and it is more efficient to monitor salinity periodically at the site. There are four ways in which salinity affects soil productivity:

- It changes the osmotic pressure at the root zone due to high salt content.
- It provokes specific ion (sodium, boron or chloride) toxicity.
- It may interfere with plant uptake of essential nutrients (e.g. potassium and nitrate) due to antagonism with sodium, chloride and sulfates.
- It may destroy the soil structure by causing soil dispersion and clogging of pore spaces. This is exacerbated by both low-salinity waters and high sodium concentrations in the water in relation to calcium and magnesium concentrations in the soil. This is reflected in the sodium adsorption ratio (see Annex 1 for further discussion of the sodium adsorption ratio).

In the long term, wastewater use will always increase salinity of the soils and groundwater, because it contains more salts than fresh water. For that reason, it is necessary to combine the use of wastewater with practices to control salinization, such as soil washing, appropriate soil drainage and controlling salt inputs into the wastewater from detergents, water softeners, saline water infiltration, etc. (see Box 8.2). Salt content varies widely in municipal wastewaters, depending on the salinity content of the water supply and, to a lesser extent, saline discharges.

8.1.3 Heavy metals

The use of domestic wastewater for agriculture (treated or not) results in the accumulation of heavy metals in the arable soil layer (first soil layers used for cultivation after ploughing) without causing negative effects in crops, even if applied for long periods of time (several decades). The use of wastewater containing industrial discharges with high heavy metal concentrations leads to metal accumulation in soils and crops and has been associated with health problems in crop consumers (see chapter 3) (Chen, 1992; WHO, 1992; Yuan, 1993; Chang et al., 1995). Annex 2 contains a summary of studies on the impact of domestic and industrial wastewater irrigation on the concentrations of heavy metals in soils.

Regardless of the metal content of the wastewater, a metal will not be absorbed by plants unless it first reaches a threshold concentration in the soil (see chapter 4 for metal concentrations that pose a health risk; see Annex 1 for concentrations of heavy

Box 8.2 Salinization prevention in Israel

Israel uses 70% of its municipal wastewater for agricultural irrigation. This practice contributes to increasing salinity in soils and groundwater supplies, since treated wastewater has a higher salt concentration than fresh water. In Israel, salts in the wastewater come from detergents, water softening, hospitals, swimming pools, cleaning processes, meat processing and textile and dairy industries. Preventing the addition of salts to the wastewater at the point of generation is much cheaper than removing the salts once they have been added. An extensive control programme has been developed (see table below). Due to this programme and other measures, chlorides in sewage have dropped from 120 mg/l in 1992 to 60 mg/l in 2002; and boron from 0.6 mg/l in 1999 to 0.3 mg/l in 2002, with 0.2 mg/L predicted by 2008. Wastewater treatment processes that reduce the salt content (e.g. reverse osmosis) of the effluents have been adopted in the most sensitive environments.

Programme to control salt content in sewage

Date	Measure
1991	Requirement to use potassium salts instead of sodium in ion exchangers in certain industries
1993	Request to progressively discharge industrial softening brines to sea
1994	Regulation on quantity of salts used for ion exchanger regeneration
1995	Guidelines for controlling salt discharges from slaughterhouses
1996	Limitations on industrial brine discharges to sewer
1997	Standards on the proper construction and operation of evaporation ponds
1998	Complete prohibition of industrial discharges of brine to sewer
1999	Standard on the formulation of domestic and industrial detergents, progressively limiting the boron content from 8.4 g/kg to 0.5 g/kg in 2008, sodium from no limit to 4 g/kg for 2001 and chlorides from 61 g/kg to 40 g/kg for detergent for washing machines and from 121 to 90 g/kg for detergents for hand washing
2003	Public education on the use of salts in dishwashers and the use of detergents
2004	Limits on the concentration of salts in all industrial effluents: chlorides (430 mg/l), sodium (230 mg/l), fluorides (6 mg/l) and boron (1.5 mg/l)

Source: Adapted from Weber & Juanicó (2004).

metals that have an impact on agricultural productivity) and the metal is in a mobile phase (e.g. not adsorbed to soil particles or dissolved in soil water). Metals are bound to soils with pH above 6.5 and/or with high organic matter content. At pH levels below this value, organic matter is consumed or all feasible soil adsorption sites are saturated; metals become mobile and can be absorbed by crops and contaminate water bodies. Cadmium, copper, molybdenum, nickel and zinc are frequently present in wastewater and can be mobilized easily and absorbed by plants. Cadmium and nickel are more important health hazards than the other metals (see chapters 3 and 4) because of their greater toxicity to humans. Impacts of heavy metals on crops are complex, because there may be antagonistic interactions that affect their uptake by plants (Drakatos et al., 2002).

8.1.4 Toxic organic compounds

In wastewater, a great variety of toxic compounds may be present. Many are difficult to detect due to the lack of analytical techniques and the increasing number of compounds that are being produced and discharged to sewers. Domestic wastewater normally has low contents of toxic organic compounds, but concentrations can increase if it receives industrial discharges, agricultural runoff (i.e. containing pesticides and their residues), leaks from storage tanks or pipes (that contain products such as fuels), leachates from polluted soils, confinement sites and landfills and air pollutants deposited in rain. Among those compounds are industrial compounds (phthalates, biphenyl, *p*-nonylphenol, PCBs and tributyl tin), pesticides (atrazine, simazine, methoxychlor, 2,4-D, DDT, dieldrin, endosulphan and lindane), petroleum components, disinfection by-products or their precursors, hormones (from humans, such as 7-ethinylestradiol, or from plants, such as 17-α-estradiol, estriol) and pharmaceuticals (see below).

These pollutants may have carcinogenic, teratogenic and/or mutagenic effects. Additionally, some of them might interfere with hormone functions (endocrine disrupters) in animals or humans. If wastewater is treated prior to its use in agriculture, the concentration of many of these compounds will be reduced by adsorption, volatilization and biodegradation. Absorption of these substances by plants through roots is not likely to occur due to the large size and high molecular mass of many of these compounds, which reduces their mobility in soil and water (Pahren et al., 1979). It is possible that these chemicals can be transferred to the edible surfaces of crops irrigated with wastewater.

Endocrine disruptors may not degrade quickly in the environment. Mansell, Drewes & Rauch (2004) found that 17-α-estradiol, estriol and testosterone are not sensitive to photodegradation (i.e. less than 10% destruction after 24-h exposure to ultraviolet light). Thus, these compounds could remain on the surface of crops irrigated with wastewater. The concentrations of these compounds are usually extremely low, and to date only effects on animals in direct contact with polluted water have been demonstrated. Effects on humans have not been demonstrated.

USEPA (1981) concluded that, as long as irrigation is not performed continuously and at high rates, compounds such as endrin, methoxychlor, toxaphene, lindane, 2,4-D, 2,4,5-TP, silvex, tetrachloroethylene, *p*-dichlorobenzene and *o*-xylene are removed though soil infiltration. Synthetic organic compounds and organochlorides are adsorbed and biodegraded with time in soil. Cordy et al. (2003) studied the removal of 34 organic compounds that can be found in wastewater (some of them endocrine disruptors) and did not detect any of them after 3 m of infiltration through desert soils with a retention time of 21 days. Removal of endocrine disruptors such as steroidal hormones detected in treated and non-treated wastewater through infiltration in soils has also been demonstrated by Mansell, Drewes & Rauch (2004).

The dominant removal mechanism for these substances is adsorption. Removal efficiencies are greater in soils containing higher contents of silt, clay and organic matter. Additional attenuation, to below the detection limit, occurs by biodegradation, regardless of aerobic or anoxic conditions or the type of organic carbon matrix present (hydrophobic acids, hydrophilic carbon vs colloidal carbon).

A variety of pharmaceutical residues or their metabolic by-products in low concentrations can be detected in wastewater. This is a concern, because some of these chemicals retain their activity and, if they contaminate surface water or groundwater, could lead to human exposures through drinking-water. A number of biologically active pharmaceuticals and their metabolites have been identified in groundwater and drinking-water samples (Heberer, Reddersen & Mechlinski, 2002). The effects of these substances on the ecosystem and other animals are not yet known.

Studies with wastewater have shown that some of these substances may survive secondary and even tertiary treatments. A study of treated wastewater effluents (both secondary and tertiary treated effluents) that underwent further soil aquifer treatment indicated that most pharmaceuticals or their metabolic by-products were effectively removed by passage through the soil and after sufficient retention time in the aquifer. However, two drugs (carbamazepine and primidone) did not show significant reductions, even after six years of passage through the soil aquifer treatment system (Drewes, Heberer & Reddersen, 2002).

More research is needed to determine what chemicals are likely to persist in the environment, which of these may be harmful at the concentrations present in wastewater and what treatment techniques are most effective at removing them. Based on the soil aquifer study, it appears that chemicals with certain properties (e.g. acidic products or metabolites) are removed more easily than others (Drewes, Heberer & Reddersen, 2002).

8.1.5 Nutrients

As described in chapter 1, wastewater contains a variety of plant nutrients. Organic matter in the wastewater also can improve soil structure and fertility. A number of studies have demonstrated the positive impact of wastewater on crop productivity due to its nutrient content and organic matter (Day, Taher & Katterman, 1975; Day & Tucker, 1977; Bole & Bell, 1978; Marten, Larson & Clapp, 1980; Khouri, Kalbermatten & Bartone, 1994; Shahalam, Abuzahra & Jaradat, 1998; Parameswaran, 1999; Scott, Zarazua & Levine, 2000). Nitrogen, phosphorus and potassium are described below.

Nitrogen

Nitrogen is a necessary macronutrient for plants that can be found in wastewater as nitrate, ammonia, organic nitrogen and nitrite. The sum of all these forms is known as total nitrogen. Most plants absorb nitrates only, but normally the other forms are transformed into nitrates in the soil (National Research Council, 1996). Nevertheless, only 50% of the ammonia and 30% of organic nitrogen are assimilated by plants, since the rest is lost during transformation through several mechanisms, such as volatilization (Girovich, 1996). The main problem with nitrogen is that nitrates are very soluble in water, which is why, when irrigating crops, most of it is washed out. Often, this cannot be controlled, because many crops require large quantities of water to grow properly (Pescod, 1992). The quantity of nitrogen washed out depends mainly on the irrigation rate, the soil characteristics and the nitrogen content of the wastewater. Nitrogen needs to be added for each agricultural cycle, and nitrogen removed from the soils can affect other sites (e.g. if it enters groundwater or surface water). The amount of nitrogen that can be applied without leaching important quantities depends on the soil's nitrogen content (0.05–2%) and the crop demand, which oscillates between 50 and 350 kg of nitrogen per hectare, depending on the stage of the cropping cycle (Girovich, 1996). Nitrates are stable in groundwater and can build up to concentrations that might contribute to methaemoglobinaemia in bottle-fed infants if this water is used to prepare infant formulas (see chapter 3) (WHO, 2004a).

Phosphorus

Phosphorus is a plant macronutrient that is often scarce in soils in a form that is bioavailable to plants and almost always needs to be added with fertilizers. Phosphorus is relatively stable in soils and may accumulate in them, especially at or near the soil surface. Wastewater normally contains low amounts of phosphorus, so its use for irrigation is beneficial and does not negatively impact the environment (Girovich, 1996). This is the case even when wastewater effluents with high concentrations of phosphorus (e.g. effluents from dairy factories) are applied over long periods of time (Degens et al., 2000). However, because phosphorus builds up at the soil surface, it can affect surface waters through soil erosion and runoff.

It is predicted that accessible phosphate reserves will run out in 60–130 years (Steen & Agro, 1998). The mining of phosphate causes environmental damage, because it is often removed close to the surface in large open mines, leaving behind scarred land. Approximately 25% of the mined phosphorus ends up in aquatic environments or buried in landfills or other sinks (Tiessen, 1995). This causes eutrophication of water bodies, leading to more environmental damage. Moreover, to reduce eutrophication from phosphorus in wastewater discharged into surface waters, wastewater treatment plants require expensive, complex processes to remove it. Thus, the use of wastewater in agriculture recycles phosphorus, minimizes environmental impacts and reduces the costs of wastewater treatment to meet environmental regulations (EcoSanRes, 2005).

Potassium

Potassium is a macronutrient that is present in high concentrations in soils (3% of the lithosphere) but is not bioavailable, since it is bound to other compounds. Therefore, potassium needs to be added to soils through fertilizers. Approximately 185 kg of potassium per hectare is required. Wastewater contains low potassium concentrations, insufficient to cover the theoretical demand. The use of wastewater in agriculture does not normally cause negative environmental impacts associated with potassium (Mikkelsen & Camberato, 1995).

8.1.6 Organic matter

Wastewater not only adds nutrients to soils, but also enriches the humic content by adding organic matter that increases soil moisture, retains metals (through cationic exchange and the formation of organometallic compounds) and enhances microbial activity. This capacity to improve soils gives wastewater an additional advantage over synthetic fertilizers. The benefits observed depend on the original organic matter content in soils, which varies from <1.2% in poor soils to >5% in rich soils.

Most organic compounds of human, animal or plant origin contained in sewage are rapidly decomposed in soils. This has been extensively studied in soil aquifer treatment systems. Under aerobic conditions, breakdown is generally faster, more complete (into carbon dioxide, minerals and water) and performed with a greater variety of compounds than under anaerobic conditions. Stable, non-toxic organic compounds such as humic and fulvic acids are formed. Wastewater application in controlled conditions (i.e. through controlled irrigation rates and using intermittent flooding) allows the biodegradation of hundreds of kilograms of BOD per hectare per day, with no impact on the environment (Bouwer & Chaney, 1974). In cases where BOD concentrations are extremely high combined with high total dissolved solids levels, soil clogging can occur. However, this usually does not occur unless BOD levels exceed 500 mg/l (Darrell, 2002). In most cases, BOD levels are reduced to essentially zero after a short distance from the soil surface. However, at the end, water still contains some organic carbon, usually a few milligrams per litre due to humic and fulvic acids, but also possibly resulting from the presence of synthetic organic compounds. These recalcitrant compounds are not normally present in significant concentrations in municipal wastewater but can be important when industrial discharges are present. The behaviour of this kind of organic matter is described in section 8.1.4.

8.1.7 Suspended solids

Suspended solids in wastewater can clog the irrigating infrastructure, particularly if sprinklers and drip irrigation are used. In addition, if they are not biodegradable, they can also reduce percolation. Suspended solids from waste stabilization ponds may include algal particles, which add organic material and nutrients to the soil after they biodegrade.

8.1.8 Acids and bases (pH)

The pH of wastewater is usually slightly alkaline. When wastewater is combined with soil of adequate alkalinity, the acid/base soil equilibrium is not affected. Highly acid effluents (e.g. some industrial effluents) applied to soils with low alkalinity for long periods can modify pH. As mentioned in section 8.1.3, low pH values affect the mobility of heavy metals in the soil. Certain crops require specific pH ranges for optimum growth.

8.2 Environmental effects through the agricultural chain

The use of wastewater can affect soil or water resources through the agricultural chain, as shown in Table 8.1. on the following page. Some details concerning these impacts are given following Table 8.1.

8.2.1 Soils

Soil is a complex mixture of mineral and organic substances in concentrations that vary widely in different regions and climates. For this reason, it is very difficult to generalize as to which compounds are pollutants and in what concentrations. Effects depend not only on the physical and chemical properties of soils, but also on the type of crops, climate and quality and quantity of water used for irrigation. Najafi, Mousavi & Feizi (2003) indicate that even the irrigation method has an influence (for instance, metal accumulation is much lower when drip irrigation is used at 30 cm of depth than if it is performed at 15 cm or on the surface). The only relatively accurate methods to determine the effects on soils are:

- to measure the initial soil characteristics and monitor them over time; or
- to compare similar soils irrigated under similar conditions with either wastewater or fresh water.

The main and most common problem that wastewater use can cause in soils is salinization. This problem occurs even with fresh water if appropriate soil washing does not occur and land drainage is inadequate. The use of wastewater can accelerate the process of soil salinization due to its higher salt content. Salinization causes soil structure to collapse, losing pores and interconnections that allow water and air passage, and consequently:

- lateral drainage is increased;
- soils erode more easily;
- oxygenation is limited;
- root development is inhibited;
- plant growth is diminished or stopped.

Table 8.1 Effects on soils, crops and livestock, by type of compound

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Nitrogen	Municipal wastewater with 20–85 mg TN/l	Acidification problems provoked by synthetic fertilizers are not observed	Increases productivity in quantity and quality Depending on soil's content and type of crops, problems can arise above 30 mg $N\text{-}NO_3$/l	No problems reported
	Wastewater with >30 mg/l	No reported effects	Can increase succulence beyond desirable levels, causing lodging in grain crops and reducing sugar content in beets and cane Beyond seasonal needs, may induce more vegetative than fruit growth and also delay ripening	Forage, being the main food for cattle, can cause grass tetany, a disease related to an imbalance of nitrogen, potassium and magnesium in pasture grasses
Phosphorus	Municipal wastewater with 6–20 mg/l	No reported effects	Increases productivity	
	Municipal wastewater with >20 mg/l	No reported effects	Reduce copper, iron and zinc availability in alkaline soils	
Potassium	Normal content in municipal wastewater[a]	No reported effects	Increases productivity	
	Content above normal municipal wastewater values[a]	No reported effects	Increases productivity	

Table 8.1 (continued)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Organic matter	Municipal wastewater with 110–400 mg BOD/l	Improves microbial activity and soil fertility Colloidal and suspended organic matter increase moisture and nutritious content, improving structure Diminishes salinity effects due to a higher water content Retains and binds heavy metals Depending on its composition and soil consumption, can release salts, nitrogen and metals	Increases productivity	No problems reported
	Content in wastewater greater than content in normal sewage[a]	Continuous irrigation and high organic matter contents may clog soil pores and favour an anaerobic population in the root zone Organic matter combined with nitrogen and continuous irrigation can cause important nitrogen losses by denitrification		
Salinity (variable, depending on the water supply content and type of discharges)	Wastewater with: TDS 250–850 mg/l Conductivity <3 dS/m SAR 5–9 Sodium <100 mg/l	No short-term effects observed Long-term salinization occurs at a rate that depends upon the frequency of soil washing and land drainage properties	Problems in sensitive crops with TDS of 450–2000 mg/l and conductivities of 0.7–3 dS/m Conductivities between 5 and 8 dS/m and non-sensitive crops do not display problems If soil is saline, crops absorb more salts, causing the crops' value to diminish in some countries and for some crops, such as vineyards	

Table 8.1 (continued)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Salinity *(continued)*	Wastewater with: TDS >2000 mg/l Conductivity >3 dS/m SAR >8 Sodium >100 mg/l	Loss of soil structure and capacity for water and air transport, and thus to sustain plants Effects depend on conductivity and SAR values, frequency of soil washing and land drainage conditions	Impacts in almost all types of crops Sodium diminishes yields in sensitive crops up to 100 mg/l SAR >3 affects some crops, depending on the water conductivity Productivity diminishes or even stops if salinization is very high	
Boron (very variable in wastewaters, depending on the water supply content and discharges)	Municipal wastewater with 0.7–3 mg/l Municipal wastewater with >3 mg/l	No reported effects	Affects very sensitive (0.5–0.75 mg/l), sensitive (0.75–1 mg/l) and moderately sensitive (2–4 mg/l) crops Affects moderately sensitive (2–4 mg/l), tolerant (4–6 mg/l) and very tolerant (6–15 mg/l) crops	
Chlorides	Wastewater with 30–100 mg/l Wastewater with >140 mg/l	Can cause salinization, depending on other parameters as well as frequency of soil washing and land drainage conditions	Below 140 mg/l, no effects are observed >140 mg/l, crops are affected, with very visible effects at concentrations >350 mg/l Leaves of sensitive plants (crops and woody plants) are burnt when sprinklers are used for irrigation	
Alkalinity (carbonates and bicarbonates)	Wastewater with 50–200 mg $CaCO_3$/l	No reported effects		No problems reported
	Wastewater with >500 mg $CaCO_3$/l	Concentrations above equilibrium conditions in soils precipitate calcium, affecting soil structure	In warm climates, bicarbonates burn leaves	
Metals	Municipal wastewater or industrial effluents without high metal concentrations	Concentration in soil is increased with time in the first soil layers; depending on pH, organic matter content and irrigation time, metals are either bound to the soil particles or mobile	No effects are observed with normal metal contents of sewage	

Table 8.1 (continued)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Metals *(continued)*	Municipal wastewater or industrial discharges with high metals content	See Annex 2	See Annex 2	See Annex 2
	Aluminium and iron	Reduce phosphorus mobility	Can cause phosphorus deficiencies	
	Cadmium		Is toxic, and uptake can increase with time, depending on soil concentrations	May be harmful to animals in doses much lower than visibly affect plants Absorbed cadmium is stored in kidney and liver; remaining meat and milk products unaffected
	Copper			May be harmful to animals at concentrations too low to visibly affect plants Is not a health hazard to monogastric animals, but can be toxic to ruminants (cows and sheep) Tolerance to copper increases as available molybdenum increases
	Zinc and nickel		Cause visible adverse effects in plants before plant concentrations are high enough to be of concern in animals or humans	

Table 8.1 (continued)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
Metals *(continued)*	Molybdenum			May be harmful to animals at concentrations that are too low to visibly affect plants Causes adverse effects in animals consuming forage with 10–20 mg/kg and low copper content Consumption of crops with more than 5 mg/kg is toxic to ruminants Molybdenum toxicity is related to the ingestion of copper and sulfate
Toxic organic compounds		Long term: some may biodegrade in soils Some compounds, such as pesticides, might contain metals and contribute to their accumulation in soils	In general, their large sizes and high molecular mass do not allow them to be absorbed through plants Can contaminate plant products through water contact during irrigation; sewage normally contains concentrations too low to cause problems	
Suspended solids	Municipal wastewater with 100–350 mg/l	Clog soils, depending on concentration, composition and soil porosity; >100 mg/l of mineral solids can cause problems If soil is clogged, water infiltration rate diminishes and irrigation becomes less effective		
pH	Municipal wastewater with pH 7–7.4	No reported effects		

Table 8.1 (continued)

Parameter	Concentration in the irrigating water	Soil	Crops	Livestock
pH *(continued)*	Wastewater with pH out of the 6.5–8.5 range	If soil alkalinity is not sufficient to maintain pH above 6.5, metal solubilization can occur; when pH is maintained below 8.5, aluminium can be solubilized and soil deflocculated, and nitrogen can be lost by volatilization	Effects depend on the solubilized metal (see Annex 2)	

dS/m, deciSiemens per metre; SAR, soil adsorption ratio; TDS, total dissolved solids; TN, total nitrogen

Sources: NAS & NAE (1972); Seabrook (1975); Sidle, Hook & Kardos (1976); Benham-Blair & Affiliates, Inc. & Engineering Enterprises, Inc. (1979); Marten, Larson & Clapp (1980); Bouwer (1991); Metcalf & Eddy, Inc. (1991); Oron et al. (1992); Pescod (1992); National Research Council (1996); Siebe & Fischer (1996); Shahalam, Abuzahra & Jaradat (1998); Siebe (1998); ACTG (1999); Downs et al. (2000); Friedel et al. (2000); Simmons & Pongsakul (2002); AATSE (2004); Jiménez (2004); Jiménez, Siebe & Cifuentes (2004); Lee et al. (2004).

[a] Municipal wastewater content according to Metcalf & Eddy, Inc. (2003).

Salinity effects are, in general, mostly of concern in arid and semi-arid regions where accumulated salts are not flushed from the soil profile by natural precipitation and where the use of wastewater occurs. The risk of salinization, as already mentioned, is measured through a combination of parameters. A useful guideline is that, depending on the type of soils and the washing and drainage conditions, salinity problems can happen with conductivities >3 dS/m, dissolved solids >500 mg/l (being severe if >2000 mg/l) and a sodium adsorption ratio of 3–9 (see Annex 1 for more information) (Ayers & Wescot, 1985).

Sodicity, a specific kind of salinization, is produced by a high sodium ion concentration related to the concentrations of calcium and magnesium ions. This phenomenon can happen even with waters with low dissolved solid content and conductivity. Other compounds that can cause soil deflocculation are carbonates and bicarbonates. The effect is moderate between bicarbonate concentrations of 90 and 500 mg/l; above 500 mg/l, problems can arise. Wastewater is not the only factor that causes salinization; inefficient soil and subsoil drainage, climate and the type of soil also can cause it, even with freshwater irrigation.

Changing the quality of the irrigation water can also affect soils, since a new equilibrium must be reached. For instance, if water with an elevated organic content is replaced by another one with reduced organic content, two effects can be observed (Siebe & Fischer, 1996):

1) salinization problems due to an increase in salt concentrations near the roots as moisture is lost;
2) metal mobilization, since there is no organic matter to bind them.

The greater the differences in the water quality between the original water and the new water source, the more noticeable the effects on the soil.

Soil has a tremendous capacity to adsorb heavy metals (see Annex 1) — so much so that it has been estimated that domestic wastewater of average metal concentration (values can be consulted in Metcalf & Eddy, Inc., 2003) could be applied to the land for several hundred years without fully exhausting the capacity of the soil to adsorb heavy metals (Reed, Thomas & Kowal, 1980). Metals are retained in the upper layers, remaining bound to the organic fraction or precipitated due to pH. Only a small fraction of metals is infiltrated to lower layers, and a still much smaller fraction is absorbed by crops. For instance, around 80–94% of cadmium, copper, nickel and zinc are removed in the first 5–15 cm of soil, 5–15% runs off and 1–8% is absorbed by grasses (Peters, Lee & Bates, 1980).

8.2.2 Groundwater

Table 8.2 describes the impacts some of the substances found in wastewater can have on groundwater and surface water. An indirect consequence of irrigated agriculture with either fresh water or wastewater is aquifer recharge (Table 8.3; Box 8.3). Recharge of aquifers is almost always unplanned and has the advantage of increasing the local availability of water. This should be considered when wastewater irrigation schemes are being planned.

Table 8.2 Impact on groundwater and surface water bodies by different compounds during irrigation with wastewater

Compound	Impact	Relative impact on groundwater or surface water	
		Groundwater	**Surface water**
Nitrogen	May contaminate underground and surface water bodies by infiltration and irrigation runoff. The amount of nitrogen leached depends on crop demand, hydraulic load due to rain and irrigation water, soil permeability and nitrogen content in soils.	High	Medium
Phosphorus	Agricultural runoff containing phosphorus can cause the growth of aquatic plants as a result of eutrophication in surface water bodies (reservoirs and lakes), which can lead to the obstruction of irrigation infrastructure (filters, weirs, pipes and spillways) and clog filters in water treatment plants.	Not significant	Medium
Biodegradable organic matter	If runoff contains high levels of organic matter, the organic matter can consume dissolved oxygen in lakes and rivers.	Not significant	Medium
Salinity	Saline soil leachates contaminate surface and underground water bodies; up to a certain level, it can limit water use. TDS > 500 mg/l causes flavour but not health problems in water supplies. Very high concentrations have laxative effects on consumers and corrode water distribution equipment.	Medium	Low
Boron	Boron from wastewater is not removed by treatment, almost not retained in soils and not absorbed by plants. Although it is an essential element, it easily becomes toxic above the required levels. By leaching, it enters groundwater and, through runoff or from polluted aquifers, surface water bodies. Accumulation in water bodies limits their use, mainly for irrigation. Some crops are sensitive to boron (see Annex 1).	Medium	Low
Heavy metals	By leaching from acid soils, they can reach aquifers and enter surface waters through runoff.	Low	Low
Toxic organic compounds	Mostly removed by soils.	Not significant	Not significant

TDS, total dissolved solids

Table 8.3 Aquifer recharge during wastewater use in agriculture

Effect	References
After 35 years of irrigation with domestic wastewater in Haroonabad, Pakistan, groundwater quality beyond the site has been modified compared with a similar zone irrigated with fresh water as follows: salinity 5.4 ± 2 vs 2.8 ± 0.4 dS/m, *E. coli* 338 vs 20 MPN/100 ml and nitrates 68 vs 47 mg NO_3/l	Matsuno et al. (2004)
In Gabal, the Asfar farm in the Greater Cairo region, untreated or primary-treated wastewater used for irrigation since 1915 has led to reduced salinity of groundwater (the aquifer was saline to begin with) as well as its recharge.	Farid et al. (1993); Rashed et al. (1995)
In Mezquital, Mexico, more than 25 m^3/s of wastewater are infiltrated to the aquifer as a consequence of agricultural irrigation. The irrigating water improves its quality through its storage in reservoirs and passage through channels and soils. The aquifer provides a water supply for more than 300 000 people, even though salinity is increasing.	BGS-CNA (1998); Jiménez, Siebe & Cifuentes (2004)

MPN, most probable number

Water application in excess of plant needs and the soil retention capacity leads to water infiltration, which also occurs during storage and transportation prior to use. Foster et al. (2004) analysed aquifer recharge from wastewater irrigation in Miraflores, the periurban area of Lima, Peru, Wagi Dhuleil, Jordan, Mezquital Valley, Mexico, Leon, Mexico, and Hat Yai, Thailand, and estimated infiltration of at least 1000 mm/year, a value that in many cases exceeds the local pluvial precipitation. Rashed et al. (1995) estimated that infiltration equals 50–70% of the water used for agriculture.

The impact on groundwater quality depends on several factors, such as the irrigation rate, the irrigation water quality, the treatment given to water by soils, the vulnerability of the aquifer, the form in which irrigation is performed, the rate of the artificial recharge compared with the natural rate, the original quality of underground water and its potential use, the time under irrigation and the type of crops (Foster et al., 2004).

Aquifers beneath agricultural fields often display high nitrate concentrations, because both the use of wastewater and artificial fertilizers add nitrogen to soils faster than plants can absorb it, and hence nitrogen is removed by water as any other salt would be. Nitrates are also stable in groundwater and thus can increase in concentration over time.

In the long term, salinity in aquifers generally increases. Based on the original quality, the present and future use and the interconnections between the aquifer and other water bodies, this effect may or may not be important (Farid et al., 1993). If the groundwater depth is less than 1–1.5 m, there are severe risks of increasing soil salinity; thus, it is frequently suggested that the use of wastewater for irrigation should be restricted to areas with groundwater depths greater than 1.5–3 m.

Normally, metals have little impact on aquifers, since domestic wastewater contains low levels. According to Leach, Enfield & Harlin (1980) and USEPA (1981), the metals that are most toxic to humans — cadmium, lead and mercury — were absent in groundwater at five sites in the United States of America after 30–40 years of applying secondary and primary effluents at rates between 0.8 and 8.6 m/year for different crops. The reason given was that soil pH was above 6.5, and metals were bound tightly by soil particles.

Box 8.3 Wastewater irrigation and aquifer recharge in the Mezquital Valley in Tula, Mexico

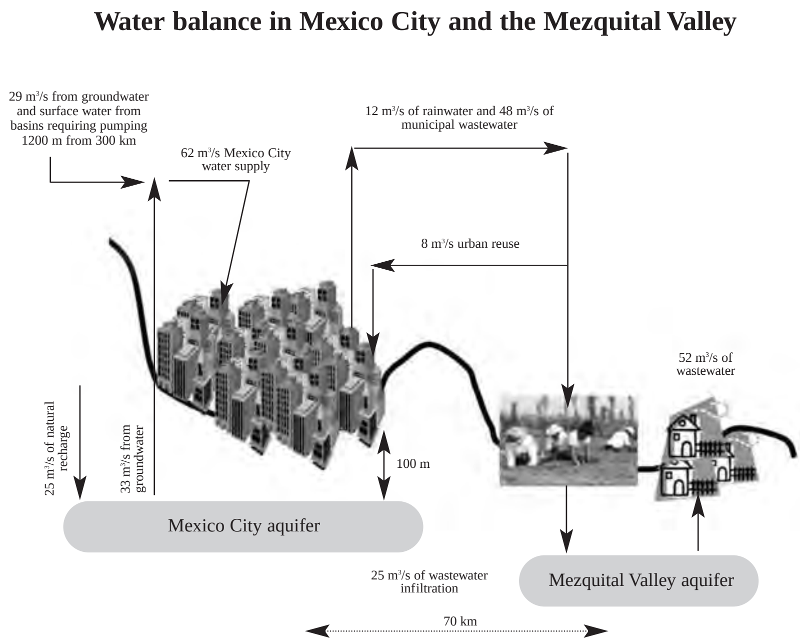

Figure 8.2
Aquifer recharge in the Mezquital Valley resulting from wastewater irrigation

Near Mexico City, in the Mezquital Valley, 85 000 ha are irrigated with mostly untreated wastewater from the city. Wastewater is appreciated by Mezquital farmers, since it allows agricultural development in an area with 550 mm annual precipitation and soils with low organic matter content that require irrigation and fertilizers to be productive. In fact, farmers are against wastewater treatment that could remove "the substance" — that is, the fertilizing materials. Wastewater contributes 2400 kg of organic matter, 195 kg of nitrogen and 81 kg of phosphorus to the soils per hectare each year. After 80 years of irrigation, phosphorus in the soils has increased from 6 to 20 g/m^2, nitrogen from 0.2 to 0.8 kg/m^2 and organic matter from 2% to 5%. Metals in the soils have also increased, from three to six times their original values.

It has been observed that wastewater application increases microbial activity and soil denitrification capacity. However, salinity has increased and has reduced microbial activity in sites with more than 65 years of irrigation. Salinity is becoming a problem in zones with poor soil drainage (vertisol soils) located in the lower parts of the valley (Friedel et al., 2000). Crops grown at sites with more than 80–100 years of irrigation do not show elevated metal concentrations. Metals are fixed to soils by pH and organic matter content. However, salinity in crops has increased (e.g. in alfalfa, from 1.5 to 4 g/kg in sites watered for more than 80 years) (Siebe, 1998).

Due to the high irrigation rate (1.5–2.2 m/year) and to the storage and transport of wastewater in unlined dams and channels, the aquifer is being recharged, and new underground deposits have been formed. In 1998, the British Geological Survey calculated that the water infiltration rate was at least 25 m^3/s. This incidental recharge

Box 8.3 (continued)

has happened in such magnitude and for such a long time that the phreatic level has risen in some places from 50 m deep to the surface. Springs have appeared with flows between 40 and 600 l/s. These springs have become the only water supply for more than 300 000 people. Fortunately, the transport of wastewater in channels and its use in irrigation have improved its quality. By the time the water enters the aquifer, organic matter has been reduced by 95%, metal concentrations by 70–90%, microorganisms by >99.9% and levels of more than 130 organic compounds by >99%. Pollutant removal is different for each compound, depending on its trajectory through the Valley, its passage rate through soil and the type of removal mechanisms involved. Salt concentrations (i.e. dissolved solids, conductivity or nitrates) have increased.

The new water deposits in the Mezquital Valley have created ecological change; from being a semi-arid zone, now the area has several springs and wetlands with a variety of animals and plants (including "acociles," a type of Mexican shrimp that grows only in very clean waters). Owing to the increasing demand for fresh water in Mexico City, where there is a water deficit of 5 m^3/s, the government is considering returning 6–10 m^3/s from the water accumulated in the Mezquital Valley subsoil. This is an attractive option compared with others that require importing water from sites located more than 1000 m lower than Mexico City and 200 km away ("The Mezquital" is only 150 m lower and 100 km away) or from sites closer to Mexico City but whose population does not want its water to be taken away, or treating Mexico City's wastewater to inject it into the aquifer for human consumption, thus seriously decreasing its current use in the Mezquital Valley.

Sources: Jiménez & Chávez (2004); Jiménez, Siebe & Cifuentes (2004).

Organic matter reaching aquifers from percolating treated wastewater varies in concentration between 1 and 5 mg of total organic carbon (TOC) per litre. If untreated wastewater is used, the content can rise to 6–9 mg of TOC per litre (Foster et al., 2004). Both ranges are higher than what is commonly accepted as safe for recharge of human drinking-water sources (1–2 mg of TOC per litre); even for low concentrations, the concern would be what kind of compounds are part of the TOC. High TOC can lead to the formation of disinfection by-products if water is treated for human consumption and disinfected with chlorine (see WHO, 2004a, for more discussion of disinfection by-products). There may also be toxic compounds of industrial origin or possibly endocrine disrupters. Fortunately, absorption of these types of substances is very effective in soils, as described in section 8.1.4.

In order to avoid the negative effects on the environment of using wastewater for agriculture due to its infiltration, it is recommended to (Foster et al., 2004):

- improve agricultural irrigation practices;
- establish criteria to operate wells used to supply water for human consumption in the surroundings (establish safe distances to the irrigation site, depth of extraction and appropriate construction);
- promote wastewater use for agriculture, preferably in zones where aquifers are less vulnerable;
- routinely monitor groundwater.

8.2.3 Surface water

Surface water bodies are affected by wastewater use in agriculture because they receive water from drainage and runoff; although the impact is lower than that from direct discharge of wastewater to them, effects also occur. Impacts depend on the type of water body (rivers, irrigation channels, lakes or dams) and their use, as well as the hydraulic retention time and the function played within the ecosystem. The main impact arises from pathogen contamination of surface water bodies, which might lead to health impacts for downstream users through drinking-water, recreational water contact or contaminated food sources (e.g. shellfish, or crops contaminated when the water source is used for irrigation downstream).

If high amounts of biodegradable organic matter enter surface waters, it can deplete dissolved oxygen, thus impacting aquatic organisms and causing an odour nuisance. If too much nitrogen or phosphorus is washed into water bodies, it can lead to eutrophication and subsequent oxygen depletion, which also harms aquatic plant and animal life and may impair the aesthetic value of the water body. There is also evidence that nutrient enrichment of water bodies may facilitate the growth of algae that produce harmful toxins (Chorus & Bartram, 1999).

Evidence suggests that toxic organic chemicals associated with wastewater will only minimally impact surface water bodies due to their adsorption to soil particles after application.

8.3 Management strategies for reducing environmental impacts

In Tables 8.4 and 8.5, recommendations to control some of the impacts described are presented by polluting agent or problem. Many of the management approaches also conform to good agricultural practices, which are discussed in Annex 1. Management strategies might vary during the course of the growing season. For example, nitrogen concentrations in the wastewater should be matched to the needs of the crops. As crops develop, the amount of nitrogen they need and/or can absorb changes. In some crops (e.g. rice or tomatoes), application of too much nitrogen will cause excessive vegetative growth, diminishing the quality of edible portions. Some of the management strategies involve upstream interventions to reduce salt inputs or the addition of toxic chemicals (both organic substances and heavy metals) from industrial discharges.

Table 8.4 Control measures by polluting agent

Compound	Control measure
Nitrogen in excess	Dilute wastewater with fresh water when possible
	Limit the quantity of wastewater applied
	Remove excess nitrogen from wastewater
Organic matter	Do not continuously apply wastewater, to allow soil to biodegrade it
	Enhance removal of organic matter from wastewater
Salinity	Avoid the use of water with 500–2000 mg TDS/l or 0.8–2.3 dS/m electrical conductivity, depending on the type of soil and land drainage
	Reduce upstream salt use and discharge into wastewater
Chlorides	With sprinklers, only use water with <100 mg/l
	In irrigation by flooding, use water with <350 mg/l
	Irrigate by night to prevent leaf burn
Toxic organic compounds in soil and crops	Pretreat or segregate industrial discharges from sewage
	Promote cleaner production in industries, to avoid using toxic compounds
	Educate society to use less toxic compounds and, when used, dispose of them safely
Metals	Pretreat or segregate industrial discharges from sewage
	Use wastewater only in soils having a pH >6.5
Suspended solids	Use water without solids >2–5 mm
	Remove suspended solids by pretreatment of wastewater
	Plough soils when clogged

TDS, total dissolved solids
Sources: Seabrook (1975); Bole & Bell (1978); Reed, Thomas & Kowal (1980); USEPA (1981); Ayers & Wescot (1985); Phene & Ruskin (1989); Bouwer (1991); Oron et al. (1991, 1992); Pescod (1992); Farid et al. (1993); Chang et al. (1995); National Research Council (1996); Jiménez & Chávez (1997); Strauss (2000); Cornish & Lawrence (2001); AATSE (2004); Ensink, Simmons & van der Hoek (2004); Ensink et al. (2004); Foster et al. (2004).

Table 8.5 Control measures according to the kind of problem

Problem	Control measure
Evaporation and infiltration of water during storage	Use compact lagoons in series lined with impermeable materials (clay, plastic) to prevent loss of water to evaporation and infiltration
Clogging of irrigation systems	Use water with low total suspended solids content
	Use irrigation methods not affected by solids
Sprinkler clogging/corrosion	Clogging and corrosion can be controlled by using water with <100 mg of chlorine per litre, <70 mg of sodium per litre and <1.5 mg of iron and manganese per litre
Soil salinity and sodicity	Increase soil washing, improve ground drainage and/or apply soil amenders
	Dilute water with sodium adsorption ratio >8 and electrical conductivity >2.3 dS/m
Formation of a biological soil layer that blocks water infiltration	Reduce the quantity of water applied and/or increase flood and dry periods
Infiltration to subsoil of low-quality water	Irrigate in places where aquifer level is >3 m below the surface and soil permeability is 60–2000 mm/day
	Reduce the hydraulic load

Table 8.5 (continued)

Problem	Control measure
Joint leaching of nitrogen and organic matter	Promote biological denitrificaction in soil by creating an appropriate carbon to nitrogen ratio, promoting anaerobic conditions in soils and avoiding salt accumulations that inhibit denitrification bacteria
Contamination of water bodies	Adapt irrigation rates according to crop demands and allow sufficient passage of water through soil
	Irrigate in sites located 500–1000 m from surface water bodies or more than 3 m from aquifers used as water supply
Water pollution with pesticides	Do not irrigate immediately after pesticide application
	Do not over-apply pesticides
	Use integrated pest management approaches to reduce pesticide use

9 ECONOMIC AND FINANCIAL CONSIDERATIONS

Economic factors are especially important when studying and appraising the feasibility of a new scheme for the use of wastewater. Even an economically worthwhile project can fail, however, without careful financial planning.

Economic analysis and financial considerations are crucial for encouraging the safe use of wastewater. Economic analysis seeks to establish the economic feasibility of a project and enables comparisons between different options. The (often hidden) cost transfers to other sectors (e.g. the health and environmental impacts on downstream communities) need to be included in a cost analysis. This can be facilitated by the use of the multiple-objective decision-making process.

Financial planning looks at how the project is to be paid for. In establishing the financial feasibility of a project, it is important to determine the sources of revenues and clarify who will pay for what. The ability to profitably sell products grown with wastewater or to sell the treated wastewater themselves also needs analysis. Section 9.3 discusses the assessment of market feasibility.

9.1 Economic feasibility

Economic analyses seek to establish whether a project is affordable and has a positive internal rate of return. There are different methods that can be used to analyse a project and its implementation at the macroeconomic level.

9.1.1 Cost–benefit analysis

Within the framework of a cost–benefit analysis, monetary values are assigned to all expected costs and benefits of the project whenever possible to determine the feasibility of the project in relation to the economy of the country. The economic analysis of a wastewater use project is undertaken to determine the benefits emanating from a project in relation to the economic resources invested in it. It informs a decision as to whether it is worthwhile to proceed with it (Squire & Van Der Tak, 1975; Gittinger, 1982). This requires a calculation of the marginal costs and benefits of the project — that is, the differences between the costs and benefits of the project and the costs and benefits of the alternative. For a scheme to be economically viable, its marginal benefits should exceed its marginal costs. Traditionally, the health sector has used cost-effectiveness analyses for economic evaluations of different options for health interventions, but recently the advent of the DALY has facilitated a shift towards cost–benefit analysis, greatly improving the communications with other sectors on economic issues.

When used to analyse wastewater use schemes, cost–benefit analyses have the advantage of producing comparable data for a range of different options, which can be used for decision-making. As part of the overall costs, appraisals should therefore explicitly include not only those of the system hardware but also those for other components, such as planning and administration, hygiene promotion campaigns and the health and environmental impacts on downstream communities associated with different options. For a given situation, planners should consider the costs of implementing different combinations of health protection measures, as presented in Figure 4.1. Table 9.1 presents information on the costs of different wastewater treatment systems. Costs are meant to be illustrative, as they will vary significantly from location to location.

Table 9.1 Economic considerations for different wastewater treatment systems

System	Land requirements (m^2/ inhabitant)	Power for aeration		Sludge volume		Costs	
		Installed power (W/ inhabitant)	Consumed power (kWh/ inhabitant per year)	Liquid sludge to be treated (litres per inhabitant per year)	Dewatered sludge to be disposed of (litres per inhabitant per year)	Construction (US$/inhabitant)	Operation and maintenance (US$/inhabitant per year)
Primary treatment (septic tanks)	0.03–0.05	0	0	110–360	15–35	12–20	0.5–1.0
Conventional primary treatment	0.02–0.04	0	0	330–730	15–40	12–20	0.5–1.0
Advanced primary treatment (chemically enhanced)	0.04–0.06	0	0	730–2500	40–110	15–25	3.0–6.0
Facultative pond	2.0–4.0	0	0	35–90	15–30	15–30	0.8–1.5
Anaerobic pond + facultative pond	1.2–3.0	0	0	55–160	20–60	12–30	0.8–1.5
Facultative aerated lagoon	0.25–0.5	1.2–2.0	11–18	30–220	7–30	20–35	2.0–3.5
Complete-mix aerated lagoon + sedimentation pond	0.2–0.4	1.8–2.5	16–22	55–360	10–35	20–35	2.0–3.5
Anaerobic pond + facultative pond + maturation pond	3.0–5.0	0	0	55–160	20–60	20–40	1.0–2.0
Anaerobic pond + facultative pond + high-rate pond	2.0–3.5	<0.3	<2	55–160	20–60	20–35	1.5–2.5
Anaerobic pond + facultative pond + algae removal	1.7–3.2	0	0	60–190	25–70	20–35	1.5–2.5
Slow-rate treatment	10–50	0	0	–	–	8–25	0.4–1.2
Rapid infiltration	1.0–6.0	0	0	–	–	12–30	0.5–1.5
Overland flow	2.0–3.5	0	0	–	–	15–30	0.8–1.5
Constructed wetlands	3.0–5.0	0	0	–	–	20–30	1.0–1.5
Septic tank + anaerobic filter	0.2–0.35	0	0	180–1000	25–50	30–50	2.5–4.0
Septic tank + infiltration	1.0–1.5	0	0	110–360	15–35	25–40	1.2–2.0

Table 9.1 (continued)

System	Land requirements (m^2/ inhabitant)	Power for aeration		Sludge volume		Costs	
		Installed power (W/ inhabitant)	Consumed power (kWh/ inhabitant per year)	Liquid sludge to be treated (litres per inhabitant per year)	Dewatered sludge to be disposed of (litres per inhabitant per year)	Construction (US$/inhabitant)	Operation and maintenance (US$/inhabitant per year)
UASB reactor	0.03–0.10	0	0	70–220	10–35	12–20	1.0–1.5
UASB + activated sludge	0.08–0.2	1.8–3.5	14–20	180–400	15–60	30–45	2.5–5.0
UASB + high-rate trickling filter	0.1–0.2	0	0	180–400	15–55	25–35	2.0–3.0
UASB + maturation ponds	1.5–2.5	0	0	150–250	10–35	15–30	1.8–3.0
UASB + facultative aerated pond	0.15–0.3	0.3–0.6	2–5	150–300	15–50	15–35	2.0–3.5
UASB + overland flow	1.5–3.0	0	0	70–220	10–35	20–35	2.0–3.0
Conventional activated sludge	0.12–0.25	2.5–4.5	18–26	1100–3000	35–90	40–65	4.0–8.0
Activated sludge + extended aeration	0.12–0.25	3.5–5.5	20–35	1200–2000	40–105	35–50	4.0–8.0
Conventional activated sludge + tertiary filtration	0.15–0.30	2.5–4.5	18–26	1200–3100	40–100	50–75	6.0–10.0
Low-rate trickling filter	0.15–0.3	0	0	360–1100	35–80	50–60	4.0–6.0
High-rate trickling filter	0.12–0.25	0	0	500–1900	35–80	50–60	4.0–6.0
Rotating biological contactor	0.1–0.2	0	0	330–1500	20–75	50–60	4.0–6.0

UASB, Upflow anaerobic sludge blanket
Source: Adapted from von Sperling & Chernicharo (2005).

9.1.2 Costs and benefits

One difficulty of traditional economic analysis for wastewater use is, however, that the setting of the system boundaries often leads to many important costs or benefits being overlooked. An example of the magnitude of such costs can be seen by considering centralized wastewater treatment works that discharge treated effluent to a surface water body. In addition to the investment, reinvestment and operation and maintenance costs of the sewer network and treatment plant, other costs should be included. It may be necessary to consider important cost transfer implications where wastewater treatment is concerned. For example, wealthier households may benefit from sewerage, but if the sewage is not treated, this may shift costs on to the poor in terms of adverse health impacts and to society in general in terms of environmental impacts. Frequently, the costs of sewage treatment have not been accounted for during planning. Important "downstream" costs of sewage discharges include drinking-water treatment, degradation of the coastal environment, damage to fishing industries, recreational water pollution and lost tourism revenues. Each one of these external costs may in turn incur further costs.

For systems using wastewater, these additional costs may include the necessary transformation costs to adapt the existing infrastructure, additional hygiene promotion activities, monitoring costs and the need for continued research and development of the system. There is, however, also a large number of direct additional benefits when wastewater is safely used, including:

- the value of the water resource;
- the value of the nutrient resource (see Box 9.1);
- increased household food security;
- better household nutrition;
- income generation (see Box 9.2);
- reduced treatment costs (e.g. it is unnecessary to add expensive processes to wastewater treatment facilities to remove nutrients);
- preserving high-quality water sources for high-priority uses such as drinking-water supply (through the use of wastewater for irrigation water instead of high-quality groundwater or surface water and by not discharging effluents to water sources);
- an improvement of soil structure and fertility;
- reduced energy consumption (in the treatment works as well as for fertilizer production).

In order to account for all these costs and benefits, the boundaries used when evaluating wastewater use systems need to be much broader than they are at present.

Some additional economic considerations include the following:

- Sewerage systems are expensive to build, operate and maintain; less expensive alternatives, such as settled sewage, condominial sewers and other technologies, may be available (see Box 9.3).
- The cost of pumping sewage can be substantial; wastewater treatment facilities should be planned in the same areas where the wastewater can be cost-effectively used with minimal pumping (e.g. ponds could be located downhill of treatment facilities).

Box 9.1 Water and nutrient benefits of wastewater use in irrigation

As an example, a city with a population of 500 000 and water consumption of 200 l/day per person would produce approximately 85 000 m^3/day (30 Mm^3/year) of wastewater, assuming 85% inflow to the public sewerage system. If treated wastewater effluent is used in carefully controlled irrigation at an application rate of 5000 m^3/ha per year, an area of some 6000 ha could be irrigated. Products grown on this land could be sold to help offset the costs of treatment and would provide work opportunities for local residents.

In addition to the economic benefit of the water, the fertilizer value of the effluent is of importance. With typical concentrations of nutrients in treated wastewater effluent from conventional sewage treatment processes as follows:

Nitrogen, 50 mg/l
Phosphorus, 10 mg/l
Potassium, 30 mg/l

and assuming an application rate of 5000 m^3/ha per year, the fertilizer contribution of the effluent would be:

Nitrogen, 250 kg/ha per year
Phosphorus, 50 kg/ha per year
Potassium, 150 kg/ha per year

Thus, all of the nitrogen and much of the phosphorus and potassium normally required for agricultural crop production would be supplied by the effluent. In addition, other valuable micronutrients and the organic matter contained in the effluent will provide benefits.

Source: Pescod (1992).

Box 9.2 Wastewater use in Hyderabad and Secunderabad: food security and livelihoods

Wastewater from the cities of Hyderabad and Secunderabad in India flows into the Musi River. During the dry season, 100% of the flow of the river is sewage from the cities. Wastewater from the cities is used to irrigate an estimated 40 600 ha of cropland. The wastewater is available year-round and allows the cultivation of up to three crops per year. Often it is the only source of water due to population growth and overpumping of the aquifers. Over 95% of the irrigated land is used to grow para grass, which is used to feed water buffalo. One hectare of para grass brings in more money than any other crop (e.g. an average of 2812 euros per hectare per year compared with 833 euros per hectare for leafy vegetables). It is estimated that 40 000 people depend directly or indirectly on the cultivation of para grass for their livelihoods.

All of the farmers who grow vegetables on their irrigated plots retain a part of their produce for their own consumption, and the rest is sold. Many of the leafy vegetable producers engage in barter, where they exchange part of their produce for other vegetables to add variety to their diet. In the urban areas, among vegetable producers, 20% of household income is saved because they do not need to purchase vegetables and because they barter their produce for other vegetables. Most of the households in the urban and periurban area with livestock use wastewater-irrigated para grass as fodder and earn income through the sale of the milk. Typically, 25% of the milk produced (assuming that a household of six members owns one buffalo) is retained for household consumption, and 75% is sold. Many of the urban farmers also grow certain fruits, such as lemon, mango, coconut and custard apple, which they retain for household consumption. In the rural areas, it was found that wastewater-irrigated paddies contribute to almost 43% of household food consumption.

Source: Buechler & Devi (2003).

- Low-cost, effective wastewater treatment technologies are available.
- Combinations of different treatment technologies (e.g. primary sedimentation plus polishing ponds) can increase pathogen removal efficiencies at low cost and provide flexibility for upgrading treatment facilities.
- Users of wastewater and excreta are often willing to pay for access to the wastewater and excreta.
- Wastewater and excreta tariffs may help to foster cost recovery.
- Differential prices for treated wastewater and fresh water may provide an incentive for farmers to use wastewater instead of high-quality freshwater sources.
- Wastewater treatment facilities may be able to recover some treatment costs by growing and selling produce at the facility.
- Crop restriction requires costs for agricultural extension workers or inspectors to visit wastewater use areas.
- The initial costs of drip irrigation may be high, but the benefits from the added health protection, need for less wastewater treatment, reduced water use and higher productivity may well outweigh the costs (see Box 9.4).
- As comfortable, affordable gloves and boots become available, farmers are more likely to use them (van der Hoek et al., 2005).
- Posting warning signs may be a low-cost alternative for preventing access to wastewater-irrigated fields.

Box 9.3 Low-cost sewerage

In many Latin American countries, urban households expect to connect to a networked sewerage system. Sewerage is expensive, because it requires extensive underground pipe networks. The pipes have to be a certain diameter to accommodate peak flows. In crowded urban slums or informal settlements, developing conventional sewerage systems can be very difficult, because planning often takes place after the settlement has been established. Narrow streets and crowded conditions also make it difficult to perform the construction activities needed to lay conventional sewerage networks.

In Brazil, an alternative approach was developed more than 20 years ago and is now adopted in many cities and towns. This approach, known as condominial sewerage, uses smaller pipe diameters that are laid on top of the ground, not under it. Smaller-diameter pipes can be effective when the sewage solids are allowed to settle (e.g. in a septic tank) before they are discharged into the sewerage network. Consequently, they are cheaper to build and operate than conventional sewerage systems. The overall costs of conventional sewerage were found to be three times higher than those for condominial or simplified sewerage systems.

Source: Rizo-Pombo (1996).

Wastewater use systems can influence both the individual economic status and the national economy. If wastewater use is managed properly, health risks are significantly reduced. At the individual (household) level, that means money that would have been spent on caring for or curing a sick person can be used to purchase other health-promoting goods or services (e.g. school fees, more nutritious food, etc.). Time gained through reduced illness can be used for education or income-generating activities. At the national level, less monetary and professional resources are dedicated to treating illnesses, and more tax revenues can be collected from increased economic activity.

Box 9.4 Low-cost drip irrigation techniques

Drip irrigation is an effective health protection measure, but the high capital costs often prevent farmers from using this application technique. However, low-cost drip irrigation techniques have been developed in and introduced in a number of different countries, including Cape Verde and India. Drip irrigation systems can use wastewater if it is treated to an adequate level to prevent emitter clogging. In the early 1990s, FAO set up a pilot project in Cape Verde that utilized drip irrigation systems. The new system increased crop production and saved water, allowing for an expansion of irrigated land and cropping intensity. The project was so successful that a number of private farmers adopted the low-cost drip irrigation techniques. Within six years, 22% of all irrigated land in Cape Verde was irrigated with drip systems. As a result, the production of horticultural crops increased from 5700 t in 1991 to 17 000 t in 1999. It is estimated that a plot of 0.2 ha provides farmers with monthly revenues of US$ 1000.

Sources: Postel (2001); FAO (2002).

9.1.3 Multiple objective decision-making processes

The information from economic analysis forms an important input into decision-making processes. It should be used, however, in conjunction with other information so that other factors and externalities may be taken into account. In order to be able to objectively compare different options for wastewater use systems, there is a need for comprehensive, dynamic, integrated, cost–benefit or multicriteria analyses of all types of systems performed over system life cycles or planning periods. This can be achieved using multiple objective decision-making approaches. These involve establishing a range of criteria that consider all key aspects of the system (e.g. health, environmental, sociocultural, economic and technical aspects) and using these to form a basis for decision-making.

A range of different quantification methods can be used in multiple-criteria approaches outside of estimated monetary values, with perhaps DALYs being used to measure health effects and a range of different measurable indicators (e.g. the use of natural resources, discharge to water bodies, etc.) for the environment. Sociocultural aspects, such as the appropriateness of the system or its legal acceptability, can be qualitatively assessed, as can technical issues, such as system robustness or its compatibility with existing systems. The appraisal of a specific project should involve a comparison not only of one system with another, but also of possible variants of the same scheme — for instance, the use of wastewater for different purposes (unrestricted irrigation, restricted irrigation, industrial, non-potable uses).

9.2 Financial feasibility

To ensure sustainable services and cost recovery of wastewater use systems, appropriate financing mechanisms are needed. In drawing up such financing mechanisms, allowances should be made not only for the investment, reinvestment and operation and maintenance of the system, but also for the opportunity and environmental costs and the system's external impacts on individuals and communities (Cardone & Fonseca, 2003).

Resources are needed to ensure institutional capacity building and skills development, monitoring and assessment and the development of an enabling environment for wastewater use. The latter includes awareness-raising campaigns, hygiene promotion, etc. Most of these activities are of a public nature, with both the broader community and the individual households benefiting. Financing for wastewater use, however, mainly comes from two sources: the individual or household and an external source, such as government (Evans, 2004). Trying to mobilize individual household financial resources for activities targeted to the broader community has, however, proven difficult. This raises one of the main challenges of developing financing mechanisms for wastewater use: How can the needs, interests and finances of individuals and households be effectively coordinated and reconciled with those at the community/national level? Ideally, this should be achieved in a way to recover costs, but also to ensure equitable access to resources, particularly for poorer members of society.

Financing mechanisms and institutional responsibilities for collecting user fees or assessing fines are specified in legislation (see chapter 10). Where wastewater is distributed by a separate agency from that which collects and treats it, a charge of some sort is normally payable. Charges are also levied when the wastewater is distributed to individuals.

The level of these charges must be decided at the planning stage. The government must decide whether the charges should be set at a level to cover only the operation and maintenance costs or set higher to recover the capital costs of the scheme as well. While it is, of course, desirable to ensure the maximum recovery of costs, an important consideration is to avoid discouraging the permitted use of wastewater. Some prior investigation of the willingness and ability to pay is therefore essential in determining not only the level of charges, but also the frequency, timing and means of payment. For instance, an annual charge payable after the harvest season may be the easiest to collect.

It may be possible to develop an increased demand for the wastewater by effective marketing. However, the results of a marketing campaign should not be anticipated when setting the initial level of charges, which can be increased progressively as demand is developed.

On the other hand, farmers may sometimes be willing to share in the investment in treatment works that are a prerequisite to obtaining use permits. Their contribution may be in cash or in the form of land for treatment and storage facilities. Experiences in Peru have indicated that farmers may sometimes be willing to perform operational and maintenance tasks associated with treatment, storage and conveyance of wastewater as in-kind contributions to the running costs of the scheme (Bartone & Arlosoroff, 1987).

A farmer will pay for wastewater only if its cost is less than that of the cheapest alternative water and the value of the nutrients it contains. How, then, is the cost of the wastewater determined by the agency that sells it? There are three basic approaches to establishing the price of wastewater. It can be related to:

- its production costs (additional treatment and conveyance);
- the benefits derived from its use; or
- some value judgement based on the user's ability or willingness to pay.

If the first option is selected, it should carry the proviso that costs must be no greater than that of the cheapest alternative source of water available to the user. The nutrient value of the wastewater may be included or ignored.

In the case of agriculture, the price for the wastewater is usually based either on the marginal cost of treatment and conveyance or on the value of the nutrient (usually nitrogen) content, whichever is lower. Box 9.5 shows that even poor farmers are often willing to pay for access to wastewater for irrigation. There are several possible ways of charging for the waste, such as per cubic metre, per hour of discharge from a standard sluice or per hectare of irrigated land.

It can also be paid in various ways: as a specific water rate or purchase price, as a renewal fee for an abstraction permit, as a surcharge on the land rent or as a deduction from the price of centrally marketed crops.

Box 9.5 Payment for access to wastewater

In Pakistan, the right to use wastewater for agriculture costs money (Ensink, Simmons & van der Hoek, 2004). In Quetta, farmers paid US$ 12 000 per year for wastewater, a price that is 2.5 times greater than that of fresh water. In many areas of Pakistan, just the possibility of having wastewater available for irrigation (as opposed to fresh water) makes fees increase from US$ 171 to US$ 351–940 per year, since it allows the harvest of three crops per year instead of one and increases the economic benefits to the household by US$ 300 (Ensink, Simmons & van der Hoek, 2004; Ensink et al., 2004).

Financial considerations regarding different types of health protection measures are discussed below.

Wastewater treatment facilities are expensive to build; the capital investment required exceeds the resources of many municipalities, so it is usually met, together with the cost of the sewerage system, by grants or loans from the central government. The operating costs, on the other hand, can usually be met from a municipal tax or water tariff. The costs of treatment are usually justified for environmental pollution control. In some cases, the costs of treatment systems can be offset by the sale of agricultural products from the system.

However, the treatment of wastewater to a standard of quality adequate for use in agriculture may involve additional costs for construction and maintenance. Some of these additional costs can be met by the sale of the treated wastewater from the fee for the permit allowing its use. In practice, however, the prices charged for the wastewater and the fees levied for permits are often determined by what farmers are able and willing to pay (see Box 9.5). In such cases, the difference may be considered as a government subsidy to promote the safe use of wastewater. The cost of conveyance infrastructure (pipes, channels) and pumping costs also need to be considered in the cost of wastewater provision.

The demands of produce restriction for the purpose of health protection sometimes run against the incentives of the market; fresh vegetables may be more valuable than fodder crops. A producer who complies with produce restriction regulations that prohibit certain crops may make less money than one who disobeys them. This should be considered in the initial planning stage and during a market feasibility analysis.

Regulations, however, have to be enforced, which has associated costs. The enforcement is normally carried out by the body that issues permits to use the wastewater or by local staff of the Ministry of Health. In either case, enforcement of produce restrictions is only one of many tasks performed by the staff responsible, so the cost is usually included in the budget that supports their salaries, transport, etc. However, this is not an excuse for neglecting the cost of establishing an efficient enforcement system. Produce restriction may mean that less needs to be spent on treatment, but it will not be effective if adequate financial provision is not made for its enforcement.

Sprinkler irrigation, which potentially causes more widespread contamination with wastewater than other methods, generally requires less preparation of the land than surface irrigation. If surface or subsurface irrigation is chosen to minimize contamination, the land can often be prepared more easily and cheaply by a central organization than by individual farmers. Alternatively, farmers can be assisted with the loan or hire of the necessary equipment. Since preparation of the fields helps the farmers avoid other expenditure, the cost can be recovered from them in the same way as other irrigation costs — through land rent, water charges or permit fees. Since localized irrigation uses less water and can produce higher yields, farmers themselves may find it worthwhile to change to this method if there are obvious benefits (see Box 9.4). Low-cost drip irrigation systems have been developed and used in Cape Verde and India (see Box 9.4; Postel, 2001; FAO, 2002).

9.3 Market feasibility

In planning for wastewater use, it is important that the market feasibility be assessed. Market feasibility may refer to the ability to sell (treated) wastewater to producers, or it can refer to the marketability of products grown with wastewater (see Table 9.2). For selling treated wastewater, it is important to have an idea of how much people are willing and able to pay. Assessing the market feasibility is particularly important when produce restriction in agriculture is being considered as a partial health protection measure. Producers should be consulted as to which products can be restricted. If farmers or market gardeners cannot make a suitable return on the products that they are allowed to raise, then produce or waste application restrictions are likely to fail.

Table 9.2 Market feasibility: planning questions

Product for sale	Key questions
Treated wastewater	• What is the price for the treated wastewater that people are willing and able to pay?
	• What is the demand in the project area for treated wastewater?
	• Are there extra costs required to get the treated wastewater to where it will be used (e.g. pumping costs, transport, etc.)?
Produce	• Are products acceptable to consumers?
	• Can producers earn acceptable returns with restricted application and produce?
	• Is the project capable of supplying products that meet market quality criteria (e.g. microbial standards for products to be exported)?

Any product derived from the treated wastewater must also be acceptable to the consumers. If the public perception of these products is negative, even if the quality meets WHO or national quality criteria, then producers still may not be able to sell their products. If agricultural products will require post-harvesting processing, the cost and availability of these services need to be considered. In some cases, it will be necessary to market products to increase demand and profit potential.

10
POLICY ASPECTS

The safe management of wastewater use in agriculture is facilitated by appropriate policies, legislation, institutional frameworks and regulations at the international, national and local levels. In many countries where wastewater use in agriculture takes place, these frameworks are lacking. This chapter looks at different country-level strategies for developing appropriate frameworks at each level that will help to encourage the safe use of wastewater in agriculture. It is important that countries create appropriate policies based upon the specific conditions that occur nationally.

As Figure 10.1 shows, policy is the overall framework that sets national development priorities. It can be influenced by international policy decisions (e.g. MDGs, Commission on Sustainable Development), international treaties or commitments (e.g. the United Nations Environment Programme's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities) or multilateral development institutions. Policy leads to the creation of relevant legislation. Legislation establishes the responsibilities and rights of different stakeholders — that is, the institutional framework. The institutional framework determines which agency has the lead responsibility for creating regulations (often as part of a consultative process among ministries) and who has the authority to implement and enforce the regulations.

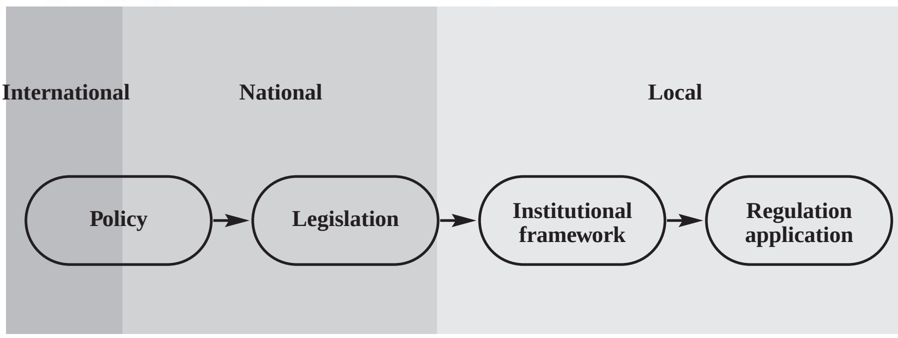

Figure 10.1
Policy framework

10.1 Policy

According to Elledge (2003), policy is the set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities, and strategies allocate resources for their implementation. Policies are implemented through four types of policy instruments:

1) *Laws and regulations:* Laws generally provide the overall framework. Regulations provide the more detailed guidance. Regulations are rules or governmental orders designed to control or govern behaviour and often have

the force of law. Regulations for wastewater use can cover a wide range of topics, including the practices of service providers, design standards, tariffs, treatment requirements, water quality requirements, monitoring requirements, crop restrictions, environmental protection and contracts. These regulations, especially treatment and water quality standards, have to be adapted to local conditions.

2) *Economic measures:* Examples of economic measures are user charges, subsidies, incentives and fines. User charges, or tariffs, are charges that households and enterprises pay in exchange for the removal of wastewater. Subsidies are allocations in cash or kind to communities and households for establishing recommended types of sanitation facilities or services. Fines are monetary charges imposed on enterprises and people for unsafe disposal, emissions and/or risky hygienic behaviours and practices, which are a danger to people and the environment.
3) *Information and education programmes:* These programmes include public awareness campaigns and educational programmes designed to generate demand and public support for efforts to expand sanitation and hygiene services.
4) *Assignment of rights and responsibilities for providing services:* National governments are responsible for determining the roles of national agencies and the appropriate roles of the public, private and non-profit sectors in programme development, implementation and service delivery.

10.1.1 International policy

International policy may affect the creation of national wastewater use policies. Countries agree to treaties, conventions, International Development Targets, etc. that may commit them to carry out certain actions. For example, countries may have commitments with respect to the MDGs (as described in chapter 1) or the Commission on Sustainable Development or in relation to reducing the use and/or contamination of water resources that cross international boundaries (e.g. by requiring less freshwater abstraction or by requiring wastewater discharges to be treated to higher qualities to reduce basin-wide contamination).

Another major issue is the worldwide export of food. As described in chapter 4, the WTO recognizes the rights of countries to establish standards for the safety of foods imported into their countries. Food products raised in compliance with the WHO *Guidelines for the safe use of wastewater, excreta and greywater* are internationally recognized as being developed within an appropriate risk management framework. This can help to facilitate international trade in food products produced with wastewater and excreta.

10.1.2 National wastewater use policies

Policy priorities for each country are necessarily different to reflect local conditions. National policy on the use of wastewater in agriculture needs to consider various issues, including:

- the health implications of wastewater use in agriculture (requirement for a health impact assessment prior to large-scale project implementation; see Annex 3) and setting of appropriate standards and regulations;
- water scarcity;
- wastewater availability now and in the future;

- locations where wastewater is generated;
- the acceptability of wastewater use in agriculture;
- the extent and types of wastewater use currently practised;
- the ability to effectively manage wastewater use safely;
- downstream impacts if wastewater is not used for agriculture;
- number of people dependent upon wastewater use in agriculture for their livelihoods;
- trade implications of exporting crops produced with wastewater.

10.1.3 Wastewater in integrated water resources management

In many arid and semi-arid countries, the renewable freshwater resources available are already heavily exploited. Countries with less than 1700 m^3 of fresh water per person are considered to be water-stressed, while countries with less than 1000 m^3 of fresh water per person face water scarcity (Hinrichsen, Robey & Upadhyay, 1998).

Wastewater is increasingly being viewed in the greater context of integrated water resources management, especially in arid and semi-arid areas. Wastewater is often a reliable water resource, with constant flows even in the dry season. The use of wastewater in agriculture should figure more prominently in water resources management, because it enables communities to reserve higher-quality water resources (e.g. groundwater or uncontaminated surface water) for uses such as drinking-water supply. The use of wastewater as a supplementary water resource is important in many communities in arid or semi-arid regions (see Box 10.1).

Box 10.1 Wastewater as an input into integrated water resource management — Case study: Israel

Oron (1998) estimates that Israel has 1.8–2.0 km^3 of renewable freshwater resources available per year — i.e. less than 300 m^3 per person (Arlosoroff, 2002). Israel is affected by acute and chronic water scarcity.

The Israel Water Commission (2002) estimated that the total freshwater withdrawal for Israel was 1.9 km^3 in 2000, accounting for 95–106% of all renewable freshwater resources. In a drought year, virtually all of the renewable freshwater resources may be withdrawn.

With freshwater resources stretched to the limit, it is necessary to preserve the best-quality water for uses such as drinking-water supply. The best-quality fresh water comes from several aquifers (Nativ & Issar, 1988). Some of these sources are threatened by saline intrusion and contamination from surface activities — e.g. nitrate leaching from agriculture (Oron, 1998).

In Israel, 79% of fresh water is used for agriculture, while domestic use (16%) and industrial use (5%) account for the rest (Gleick, 2000). In the future, less fresh water will be available for agriculture as the population becomes larger and more affluent and water use increases (Oron, 1998). New freshwater sources will have to be identified and developed. Israel is planning to add to freshwater supplies by desalinating seawater and saline groundwater.

In 1999, 337×10^6 m^3 of wastewater was treated (Israel Ministry of the Environment, 2002). In the same year, 80% of the treated wastewater (270×10^6 m^3) was used in agriculture (Fedler, 1999). The volume of treated effluents used in agriculture (270×10^6 m^3) is nearly equal to the volume of Israel's second largest freshwater aquifer — the Coastal Aquifer — at 283×10^6 m^3 (Nativ & Issar, 1988) and thus represents a substantial water resource for the country.

Israel has increased its available freshwater resources by 14% by using wastewater in agriculture. Arlosoroff (2002) predicts that 100% of the total wastewater flow will be used in agriculture by 2010.

Box 10.1 (continued)

Israel manages its wastewater within the broader context of all available water resources. All freshwater resources are closely monitored, and over the years concerted efforts to maximize water use efficiency have reduced the use of water per capita. Water conservation techniques have been applied in agriculture, in urban areas and in industry. The economic value of agricultural production per unit of water has increased fivefold since 1950 (Arlosoroff, 2002). This is largely due to the adoption of more water-efficient irrigation technologies such as drip irrigation and by concentrating production on high-value crops (Arlosoroff, 2002).

Israel has tried to maximize its flexibility for using wastewater by requiring high levels of treatment and developing trading instruments and a water allocation policy that facilitate the exchange of fresh water for treated effluents for use in irrigation (Arlosoroff, 2002).

In addition to the use of wastewater in agriculture, treated wastewater is often used to recharge aquifers to prevent saline intrusion and restore depleted aquifers. Treated wastewater is often stored above and below the ground in reservoirs until it is needed.

10.2 Legislation

Legislation may both facilitate the safe use of wastewater by, for example, creating economic incentives for wastewater treatment and use facilities and create oversight responsibilities. In many cases, it may be sufficient to amend existing legislation, but sometimes new legislation is required. The following areas deserve attention:

- define institutional responsibilities or allocate new powers to existing bodies;
- establish roles and relationships between national and local governments in the sector;
- create rights of access to and ownership of wastewater, including public regulation of its use (see Box 10.2);
- establish land tenure;
- develop public health and agricultural legislation: wastewater quality standards, produce restrictions, application methods, occupational health, food hygiene, etc.

Box 10.2 Water access rights improve health

Giving people access and rights to water is an important step for improving health at the household and community levels through better nutrition and food supply. Many countries lack legal frameworks that ensure access to water rights, especially for the poor. To improve access to water, FAO (2002) suggests that legal reforms that cover the following issues are needed in many countries:

- allocation of water resources between different users, particularly those in rural and urban areas;
- minimizing conflict between those who use the resource for water supply and those who use it for waste disposal;
- promotion of efficient water use;
- regulation of use of wastewater so that it can be safely used;
- reduction of the role of government in rural water projects, increasing the importance of local user groups and removal of impediments to charging for water and recovering costs;
- evolution of systems of land tenure towards written and individual or group titles;
- ensuring legal access to land and water for female heads of household and women generally;
- creation or improvement of an effective water rights administration to manage the water sector in general and the rural water sector in particular.

Sources: IPTRID (1999); FAO (2002).

10.2.1 Institutional roles and responsibilities

Enabling legislation may be required to establish a national coordinating body for wastewater use and to set up local bodies to manage individual schemes. These will require authority either to charge for the wastewater they distribute or to sell any produce. Working within an existing institutional framework may be preferable to creating new institutions.

At the national level, wastewater use in agriculture is an activity that touches the responsibilities of several ministries or agencies. Examples of ministries or agencies that may have jurisdiction over the use of wastewater in agriculture might include:

- *Ministry of Agriculture:* overall project planning; management of state-owned land; installation and operation of irrigation infrastructure; agricultural research and extension, including training; control of marketing.
- *Ministry of Environment:* sets wastewater treatment and effluent quality standards based on environmental concerns; establishes practices for protecting water resources (both surface waters and groundwaters) and the environment; establishes monitoring and analytical testing protocols.
- *Ministry of Health:* health protection, particularly establishment of quality standards and standards for "good practice" (for treated wastewater; products; health protection measures), monitoring methods and schedules for treated wastewater; monitoring implementation of health protection measures; validation of health protection measures for small-scale wastewater irrigation; health impact assessment of new wastewater projects; health education; disease surveillance and treatment.
- *Ministry of Water Resources:* integration of wastewater use into water resources planning and management.
- *Ministry of Education:* develop school curricula concerning sanitation and personal and domestic hygiene and safe practices related to the use of wastewater in agriculture
- *Ministry of Public Works/Local Government:* excreta and wastewater collection, treatment and use.
- *Ministry of Finance and Economic Planning:* economic and financial appraisal of projects; import control (equipment, fertilizers); development of financing mechanisms for wastewater conveyance and treatment and use infrastructure.

Other ministries and government agencies — for example, those concerned with land tenure, rural development, cooperatives and women's affairs — may also be involved.

Cooperation between the relevant agencies is required, particularly between the technical staff involved. Some countries, especially those in which there is water scarcity, may find it advantageous to establish an executive body, such as an interagency technical standing committee, under the aegis of a leading ministry (Agriculture or Water Resources), or possibly a separate organization (with both government and private funding sources), such as an Office for Wastewater Recycling, to be responsible for programmatic development, planning and management.

In many countries, a simple ad hoc committee may be sufficient. Alternatively, existing organizations, such as a National Water Board, may be given responsibility for wastewater use in agriculture, or parts of it. Such an organization should then convene a committee of representatives from the different agencies having sectoral responsibilities. Setting up an interagency or interministerial committee will help to inform others of the challenges or opportunities facing the introduction or strengthening of wastewater use.

In countries with a regional or federal administration, such arrangements for interagency collaboration will be important at the regional or state level. Whereas the general framework of wastewater use policy and standards may be defined at the national level, the regional body will have to interpret and add to these in the light of local conditions.

The local body managing a scheme, or at least the agency collecting the wastewater, often will be under municipal control. If wastewater use is to be promoted in the context of a national policy, this implies careful coordination and definition of the relationship between local and national governments. On the one hand, it may be necessary for the national government to offer incentives to local authorities to promote safe wastewater use; on the other hand, sanctions of some sort may have to be applied to ensure that schemes are implemented without undue risk to public health.

Local governments should be given the authority to develop their own regulations. For example, they should have the ability to collect fees for wastewater treatment or other services, issue permits, conduct inspections, develop produce restrictions, inspect markets, develop decentralized wastewater treatment and use facilities, etc.

Local authorities should have the ability to issue permits for the use of wastewater in agriculture from a public conveyance network. Permits may be issued by the local agricultural or water resources administration, local governments or the body controlling the wastewater distribution system. In many urban and periurban areas the use of wastewater (frequently untreated) for irrigation is widespread. These activities often arise spontaneously and are usually not controlled by local health authorities. Because of the small scale and dispersion of these operations, it may be difficult to provide proper oversight. Local authorities may be able to establish permitting requirements for land use contingent upon the implementation of specified health protection measures — i.e. the observance of sanitary practices regarding application methods, produce restriction and exposure control.

It is common for the body administering the distribution of wastewater to deal with the landowners through users' associations, which may develop from traditional institutions. Permits to use the wastewater can then be issued to the associations, simplifying the administrative task of dealing separately with a large number of small users. Under such an arrangement, the task is also delegated to the associations of enforcing the regulations that must be complied with for a permit to be renewed.

A joint committee or management board, which may include representatives of these associations as well as any particularly large users, the authorities that collect and distribute the wastewater and also the local health authorities, is required. Even in small-scale organizations, some arrangement, such as a committee with community representatives, is important for the users to participate in the management of the project.

In some cases, farmers will be able to directly negotiate contracts for a specified supply of treated wastewater with the utility that treats the wastewater.

10.2.2 Rights of access

Farmers will be reluctant to install infrastructure or treatment facilities unless they have some confidence that they will continue to have access to the wastewater. This access may be regulated by permits and dependent on efficient or sanitary practice by the farmer. In Mexico, the authorities' power to withhold water from farmers who do not comply with crop restrictions is a major factor in their success. Legislation may therefore be required to define the users' rights of access to the wastewater and the powers of those entitled to allocate or regulate those rights (see Box 10.3).

Box 10.3 Rights to wastewater

Customary rights to water are widely recognized. Thus, the present use of wastewater for agriculture may create rights even if it is not a planned activity and does not fulfil health and environmental norms. These rights can conflict with future planned wastewater use projects, especially if treated wastewater is expected to be sold at a higher price than that paid by the original user of the wastewater. For example, in Mexico, the development of a new wastewater treatment plant caused problems for traditional downstream users of the wastewater. The new treatment plant was able to treat the wastewater to a high quality standard and, as part of its planned cost recovery activities, has been investigating potential sales of the water to industrial users. Untreated wastewater has traditionally been discharged into canals and used for downstream irrigation. Mexico issues water concession titles, which guarantee a landowner access to water. However, only 30% of the wastewater-irrigated land has a concession title linked to it. If the wastewater treatment facility goes through with water sales to industrial users, a significant portion of the water might be diverted from downstream users. Since many of the users do not have officially recognized water rights, they will lose their livelihoods (Silva-Ochoa & Scott, 2004).

In Pakistan, a large number of court cases initiated by local water utilities or sanitation agencies have been brought against local farmers, challenging their rights to use wastewater resources. The outcome of these court cases was that farmers were forced either to pay for wastewater or to abandon its use. In Faisalabad, a group of wastewater farmers successfully appealed against one of these court orders once they proved that they had no access to another suitable water source (Ensink et al., 2004).

10.2.3 Land tenure

Security of access to wastewater is worth little without security of land or water tenure. Existing tenure legislation is likely to be adequate for most eventualities, although it may be necessary to define the ownership of virgin land newly brought under cultivation. If it is decided to amalgamate individual agricultural farms under a single management, powers of compulsory purchase may be needed.

10.2.4 Public health

The area of public health includes rules governing produce restrictions and methods of application, as well as quality standards for treated wastewater used in agriculture, product quality standards and other health protection measures discussed in chapter 5 of these Guidelines. The factors affecting the feasibility of enforcing crop restrictions, discussed in chapter 5, are relevant to both new and existing wastewater use schemes. Consumers also have the right to expect safe food products (see Box 10.4).

Box 10.4 Consumers' rights to safe produce

Consumers have the right to demand safe food. Public health concerns have led to several court cases in Pakistani cities (Ensink et al., 2004). In Quetta, after a trial, the farmers were forced by local residents to test the pathogen content in their products by a national certified laboratory. After demonstrating that their wastewater-irrigated crops were not contaminated, farmers were allowed to continue with the practice. In Hyderabad, farmers and the local municipality have come to an agreement to use wastewater only in crops whose edible parts grow above the ground. Potatoes, onions, carrots and garlic, therefore, cannot be cultivated, although salad crops (e.g. lettuce) are allowed.

New legislation may be needed with regard to the implementation, oversight and monitoring of health protection measures. Public health legislation also covers other aspects of health protection, such as occupational health and food hygiene, water and sanitation services, health promotion, school curriculum development, water resources management and vector control, which may not require new measures but may need to be changed to better reflect specific risks associated with wastewater use in agriculture. Where new wastewater irrigation schemes are proposed or existing activities will be expanded, health impact assessment is often conducted to quantify health impacts on local populations. Health impact assessment is discussed in more detail in Annex 3.

10.3 Regulations

Regulations governing the use of wastewater in agriculture should be practical and focus on protecting public health (other issues will also be relevant, such as environmental protection). Most importantly, regulations should be feasible to implement, given the local circumstances.

A framework of regulations could be set up around the different health protection measures (i.e. wastewater treatment, produce restriction, wastewater application, exposure control, immunization/chemotherapy). Regulations may already exist for some of the protective measures. Without some complementary measures, such as regulations that control market hygiene (e.g. availability of adequate sanitation and safe water supplies, market inspectors, periodic laboratory analysis of wastewater-irrigated crops), safe food products raised in compliance with the wastewater use regulations could easily become recontaminated in the market, mitigating any impact of previous health protection measures that have been implemented (see Table 10.1 for examples of activities that might require regulations).

10.4 Developing a national policy framework

In developing a national policy framework to facilitate safe wastewater use in agriculture, it is important to define the objectives of the policy, assess the current policy environment and develop a national approach.

10.4.1 Defining objectives

The use of wastewater in agriculture can have one or more of several objectives. Defining these objectives is important for developing a national policy framework (Mills & Asano, 1998). The main objectives might be:

- to increase national or local economic development;
- to increase crop production;

Table 10.1 Examples of activities that might be covered in regulations

Activities or components	Regulatory considerations
Wastewater	Access rights, tariffs, management (e.g. municipalities, communities, user groups, etc.)
Conveyance	Agency responsible for building infrastructure and operations and maintenance, pumping costs, delivery trucks
Treatment	Treatment requirements depending upon final use, process requirements
Monitoring	Types of monitoring (e.g. process monitoring, analytical, parameters), frequency, location, financial responsibilities
Wastewater application	Fencing, need for buffer zones, requirements for spray drift control
Produce restrictions	Types of produce permitted, not permitted, enforcement, education of farmers/public
Exposure control	Access control for use areas (e.g. sign posting, fences), protective clothing requirements, provision of water and sanitation facilities for workers, hygiene education responsibilities
Market hygiene	Market inspection, provision of safe water and adequate sanitation facilities at markets
Food safety	Crop analysis for other pathogens and toxic metals, consumer education, beef carcass inspection for *Taenia* cysts

- to augment supplies of fresh water and otherwise take full advantage of the resource value of wastewater;
- to dispose of wastewater in a cost-effective, environmentally friendly manner;
- to improve household income, food security and/or nutrition.

Where wastewater is already used, sub-objectives might be to incorporate health and environmental safeguards into management strategies or improve product yields through better practice.

10.4.2 Assessment of policy environment

The right policies can facilitate the safe use of wastewater in agriculture. Current policies often already exist that affect wastewater use in agriculture, both negatively and positively. Conducting an assessment of current policies is often helpful for developing a new national policy or for revising existing policies. The assessment should take place at two levels: from the perspective of both a policy-maker and a project manager. Policy-makers will want to assess the national policies, legislation, institutional framework and regulations to ensure that they meet the national wastewater use objectives (e.g. maximize economic returns without endangering public health or the environment). Project coordinators will want to ensure that current and future wastewater use schemes will be able to comply with all relevant national and local laws and regulations.

The main considerations are:

- *Policy:* Are there clear policies on the use of wastewater in agriculture? Is wastewater use in agriculture encouraged or discouraged?

- *Legislation:* Is wastewater use governed in legislation? What are the rights and responsibilities of different stakeholders?
- *Institutional framework:* Which ministry/agency, mass organizations, etc. have the authority to control the use of wastewater in agriculture, at the national level and at the district/community level? Are the responsibilities of different ministries/agencies clear? Is there one lead ministry, or are there multiple ministries/agencies with overlapping jurisdictions? Which ministry/agency is responsible for developing regulations? Which ministry/agency monitors compliance with regulations? Which ministry/agency enforces the regulations?
- *Regulations:* Do regulations exist? Are the current regulations adequate to meet wastewater use objectives (protect public health, prevent environmental damage, meet produce quality standards for domestic and international trade, preserve livelihoods, conserve water and nutrients, etc.)? Are the current regulations being implemented? Is regulatory compliance being enforced?

It is easier to make regulations than to enforce them. In drafting new regulations (or in choosing which existing ones to enforce), it is important to plan for the institutions, staff and resources necessary to ensure that the regulations are followed. It is important to ensure that the regulations are realistic and achievable in the context in which they are to be applied. It will often be advantageous to adopt a gradual approach or to test a new set of regulations by persuading a local administration to pass them as by-laws before they are extended to the rest of the country.

10.4.3 Developing national approaches based on the WHO Guidelines

Developing national approaches for safe wastewater use practices based on the WHO Guidelines will protect public health the most when they are integrated into comprehensive public health programmes that include other sanitary measures, such as health and hygiene promotion and improving access to safe drinking-water and adequate sanitation. For example, if the Guidelines are followed during crop production but there is recontamination of the crops at the market, then some of the potential health gains are likely to be erased. Other complementary programmes, such as chemotherapy campaigns, should be accompanied by health promotion/education to change behaviours that lead to intestinal helminth infection and the transmission of other diseases.

National approaches need to be adapted to the local sociocultural, environmental and economic circumstances, but should be aimed at progressive improvement of public health. Interventions that address the greatest local health threats first should be given the highest priority. As resources and new data become available, additional health protection measures can be introduced. Box 10.5 illustrates some steps that might be used to develop a progressive national approach for increasing the safety of waste-fed agriculture.

10.4.4 Research

Research on minimizing health impacts associated with wastewater use in agriculture should be conducted at national institutions, universities or other research centres. It is important to conduct research at the national level, because data concerning local conditions are the most important for developing effective health protection measures and may well vary considerably between countries. Pilot schemes can be developed to

Box 10.5 Developing a national approach to wastewater use in agriculture

Approaches to ensure the safe use of wastewater in agriculture should be based on knowledge of local practices, the health implications of these practices and the need to comply with existing legislation/regulation. The first step is often to assess the situation.

Assess the situation
Examples of the types of information that might be helpful in developing an approach are presented below:

- the availability and types of wastewater treatment available;
- the types of agricultural products grown in the area (e.g. eaten cooked or raw);
- techniques for wastewater conveyance/application in agriculture (e.g. pipes, lined channels, unlined channels, pumping requirements, carts and trucks, proximity to local communities, presence of fences, signs, etc.);
- human exposure to wastewater during agricultural practices (e.g. do workers wear protective clothing? do they practise good hygiene? are hygiene and sanitation facilities available at the field level?);
- hygienic conditions of current harvesting techniques and during storage and transport of produce to markets;
- practices in markets where crops are sold (e.g. is there access to safe water and adequate sanitation facilities in markets? do vendors practise good hygiene? is safe water used to wash/freshen produce?).

Public health risks vary from place to place. It is important to understand what health problems may arise in relation to wastewater use. Schistosomiasis occurs only in limited geographic areas but may be an important disease locally. Also, the incidence of vector-borne diseases will vary and should be considered in relevant situations. Information on local public health priorities can be obtained through scientific studies of disease, review of clinical data, outbreak information and prevalence data and interviews with health staff (doctors, nurses, pharmacists) and farmers. There should also be an effort to quantify positive health impacts — for example, on household nutrition and food security.

Involve stakeholders
When possible, relevant stakeholders should be involved in the development of public health approaches. Without their involvement, health protection measures are less likely to succeed. Stakeholders can be involved in the development of policies through participation in national or district-level workshops or through agricultural extension outreach activities.

Strengthen national/local capacity
The implementation of health protection measures will require both national and local institutional oversight. In some cases, institutional capacities may need to be defined or strengthened. Local health authorities should understand their responsibilities for implementing, monitoring, enforcing and promoting health protection measures.

Phased implementation of health protection measures
Health protection measures can be progressively phased in over time if resources are not available. The first measures to be implemented should try to address the greatest public health priorities first. For example, in areas where intestinal helminth infections are endemic, initial steps might be to encourage farmers to wear shoes, to keep their children out of wastewater-irrigated areas or to grow only crops that are eaten cooked. Development of educational materials and local workshops to educate farmers about how to reduce helminth infections could be initiated quickly. Similar programmes could be implemented at markets to improve food hygiene. Wastewater treatment might be initiated over time with progressive upgrades of the system until it is capable of achieving the WHO microbial pathogen reduction targets discussed in chapter 4.

investigate feasible health protection measures and answer production-related questions. In situations where wastewater irrigation is practised in small-scale diffuse facilities, often at the household level, national research may be used to validate health protection measures and then develop guidelines and standards to be used by small-scale farmers. Research results should be disseminated to various groups of stakeholders in a form that is useful to them.

A pilot project is particularly useful in countries with little or no experience of managing wastewater use in agriculture or when the introduction of new techniques is envisaged. Health protection is an important consideration, but there are other questions that are difficult to answer without local experience of the kind a pilot project can give. These questions are likely to include important technical, social and economic aspects. A pilot scheme can help to identify potential health risks and develop ways to control them.

Pilot projects should be planned — that is, a variety of crops (both old and new) should be investigated, with different application rates of wastewater. Information is required not only on yields but also on microbial contamination levels, uptake of toxic metals in plants, the types and concentrations of toxic chemicals and pathogens typically present in local wastewater and effects on the environment.

A pilot project should operate for at least one growing season, or at least one year if production through the seasons is to be investigated. It should be carefully planned so that the work involved is not underestimated and can be carried out correctly; otherwise, repetition in the following year is required. After the experimental period, a successful pilot project may be translated into a demonstration project with training facilities for local operators and farmers.

11
PLANNING AND IMPLEMENTATION

Planning and implementation of wastewater use programmes require a comprehensive progressive approach that responds to the greatest health priorities first. Strategies for planning should include elements on communication to stakeholders, interaction with stakeholders and the collection and use of data. This chapter describes key considerations for planning and implementation of wastewater use programmes at the national level.

Additionally, planning for projects at a local level requires an assessment of several important underlying factors. The sustainability of wastewater use in agriculture relies on the assessment and understanding of eight important factors. These eight factors — health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility — have been described in previous chapters. A brief description of how these factors relate to planning and implementation of wastewater use projects is included in this chapter.

The protection of public health in wastewater irrigation requires the development and use of mechanisms for promoting improvement. This is an important planning aspect. The focus on improvement (whether as an investment priority at the regional or national level, development of hygiene education programmes or enforcement of compliance) will depend on the nature of the wastewater use practices and the types of problems identified (WHO, 2004a). A checklist of mechanisms for improvement of wastewater use in agriculture is given below:

- ✓ *Establishing national priorities:* When the most common problems and shortcomings in wastewater use have been identified, national strategies can be formulated for improvements and remedial measures; these might include changes in training (of managers, administrators, extension workers or field staff), rolling programmes for improvement or changes in funding strategies to target specific needs.
- ✓ *Establishing regional priorities:* Regional or local health agencies can determine the communities in which to work and which improvement activities are priorities; public health criteria should be considered when priorities are set.
- ✓ *Establishing hygiene education programmes:* Many of the health-related issues associated with wastewater use in agriculture are related to personal hygiene and food hygiene and cannot be solved by technology alone. The solutions to many of these problems are likely to require participatory educational and promotional activities.
- ✓ *Auditing of systems and upgrading:* Wastewater use systems should be audited or inspected. The results of these audits can be used to encourage farmers to improve their practices. Enforcement of local regulations to improve health protection measures may be difficult with small-scale producers. It may be more productive to work with farmers through extension workers to improve practices by educating them about health protection measures and risk reduction strategies.
- ✓ *Ensuring community operation and maintenance:* Support should be provided by a designated authority to enable community members to be trained so that

they are able to assume responsibility for the operation and maintenance of small-scale and community wastewater use operations.

✓ *Establishing public awareness and information channels:* Publication of information on public health aspects of wastewater use in agriculture can encourage farmers to follow good practices, mobilize public opinion and response and reduce the need for regulatory enforcement, which should be an option of last resort.

In order to make best use of limited resources, it is advisable to start with a basic programme that develops in a planned manner. An example of a step-by-step approach, with actions to be taken at initial, intermediate and advanced phases, is described below:

- **Initial phase**
  - Establish requirements for institutional development.
  - Provide training for staff involved in the programme.
  - Define the role of participants (e.g. agricultural extension staff, local health authorities, food safety inspectors, etc.).
  - Develop health protection measures suitable for the area.
  - Implement health protection measures in priority areas.
  - Monitor performance, but limit verification monitoring to a few essential parameters and known hazards of the greatest importance.
  - Establish reporting, filing and communication systems.
  - Advocate improvements according to identified priorities.
  - Establish reporting to local communities, media and regional authorities.
  - Establish liaison with communities; identify community roles in developing health protection measures and means for promoting community participation.

- **Intermediate phase**
  - Train staff involved in the programme.
  - Establish and expand systematic implementation of health protection measures.
  - Expand access to analytical capability for monitoring (often by means of regional laboratories, national laboratories being largely responsible for analytical quality control and training of regional laboratory staff).
  - Develop capacity for statistical analysis of data.
  - Establish a national database.
  - Identify common problems, and promote activities to address them at regional and national levels.
  - Expand reporting to include interpretation at the national level.
  - Draft or revise health-based targets for wastewater use in agriculture.
  - Use legal enforcement where necessary.
  - Involve communities routinely in the development and implementation of health protection measures.

- **Advanced phase**
  - Institutionalize a staff training programme.
  - Establish routine testing for all health-related parameters at defined frequencies.

— Use a national risk management framework for wastewater use in agriculture.
— Improve wastewater use practices on the basis of national and local priorities, hygiene education and enforcement of standards.
— Establish regional databases compatible with the national database.
— Disseminate data and other information at all levels (local, regional and national).
— Involve communities routinely in the development and implementation of health protection measures.

11.1 Reporting and communication

An important element of a safe wastewater use programme is the sharing of information with stakeholders. It is useful to establish appropriate systems of communication with all relevant stakeholders. Proper communication involves both the provision of information and the solicitation of feedback from interested parties. The ability to improve wastewater use practices is highly dependent on the ability to analyse and present information in a meaningful way to different target audiences (see Box 11.1). The target audiences may include:

- public health officials at local, regional and national levels;
- organizations or utilities that manage the collective treatment of wastewater;
- local administrations;
- communities and agricultural producers; or
- local, regional and national authorities responsible for development planning and investment.

11.2 Interaction with community and consumers

Community participation is a desirable component of the planning and implementation of wastewater use programmes. Communities often share both the benefits of wastewater use and exposure to the hazards. The community represents a resource that can be drawn upon for local knowledge and experience. They are the people who are likely to first notice health problems associated with wastewater use and thus can help to solve the problems. Communication strategies should include provision of summary information to product consumers and producers and establishment and involvement of consumer associations at the local, regional and national levels.

It may not always be feasible to provide information directly to an entire community. Thus, it may be appropriate to use community organizations, where they exist, to provide an effective channel for providing feedback and other information to users. By using local organizations to relay information, it is often easier to initiate a process of discussion and decision-making within the community. The most important elements in working with local organizations are to ensure that the organization selected can access the whole community and can initiate discussion on the health protection measures selected and used in wastewater use programmes.

Box 11.1 Communicating health issues

A key issue in the planning process is the communication of important health issues to different stakeholders. Communicating health-related issues to the public and policy-makers should be based on scientific evidence, transformation of the evidence into meaningful information, the development of feasible solutions, impact assessment and engagement and communication with key stakeholders. These are discussed below.

- ***Evidence*** of a particular environmental or health problem or issue develops. This may be via formal scientific research or analysis or via the monitoring of various environmental and health indicators. Alternatively, evidence may surface anecdotally, in the media or as a result of a catastrophic event. Usually, the evidence, whether formal or informal, will relate directly to local conditions.

- ***Transformation*** of formal scientific evidence into evidence that is meaningful to policy-makers and/or the general public takes place. This may be via a process of epidemiological/burden of disease assessment, cost-effectiveness and cost–benefit analysis, risk assessment or the aggregation of environmental and health monitoring data into a few key indicators that are readily understandable to decision-makers.

- ***Solutions*** (i.e. policy alternatives) are considered, along with a discussion of the environmental and health problems. For politicians, the emphasis on or discussion of problems that have no apparent solution may be politically unappealing. Conversely, problems that have solutions may be transformed into political capital.

- ***Impact assessment*** must occur, to consider the evidence in light of existing and proposed policies. That process may be formalized as part of a health impact assessment (see Annex 3), a loan process, a poverty reduction strategy, a national plan or a budget debate. Alternatively, it may be a completely informal process. In all cases where government articulates policy explicitly, some sort of "impact assessment" is taking place.

- ***Engagement*** of key decision-makers and stakeholders takes place, considering new evidence and new policy options. That engagement may be facilitated by the activities of local nongovernmental organizations and academic institutions, the activities of a local or international champion or processes triggered by international and intergovernmental agencies, including new conventions or protocol agreements. Commitment by key decision-makers to consider new evidence may require attitude change on the personal, as well as the institutional, level. This change usually occurs incrementally.

- ***Communication*** of the health risks, and the potential solutions or policies that may address the problem, takes place alongside the engagement and impact assessment process. Optimally, that communication should involve actors in government, the media and all interest groups and stakeholders. Communication is most effective when it is "hands-on," demonstrates the tangible results of the intervention and is interactive, not frontal or passive — e.g. getting key decision-makers, media and stakeholders involved in observing or participating in the improvement of wastewater use in agriculture, sampling/tracking water quality results or running through an estimate of savings to health. Communication materials should be multilayered — e.g. one-page briefs for top officials, more detailed backgrounders for the professional level, media materials, etc.

Source: Fletcher (2005).

11.3 Use of data and information

Strategies for regional prioritization are typically of a medium-term nature and have information requirements. While the management of information at a national level is aimed at highlighting common or recurrent health issues, the objective at a regional level is to assign a degree of priority to individual interventions. It is therefore important to derive a relative measure of health risk. Feasible health protection measures that address the hazards associated with the highest relative risks can then be developed and implemented.

In many situations, especially where production occurs at very small scales, wastewater use practices may fail to adequately protect public health. In such circumstances, it is important that realistic goals for progressive improvement are agreed upon and implemented.

11.4 Project planning criteria

Eight criteria should be considered when planning wastewater use projects: health, economic feasibility, social impact and public perception, financial feasibility, environmental impact, market feasibility, institutional feasibility and technical feasibility (see Figure 11.1) (Mills & Asano, 1998). Failure to meet any one of these criteria may cause a project to fail. Meeting all the criteria can help to ensure that the project is sustainable.

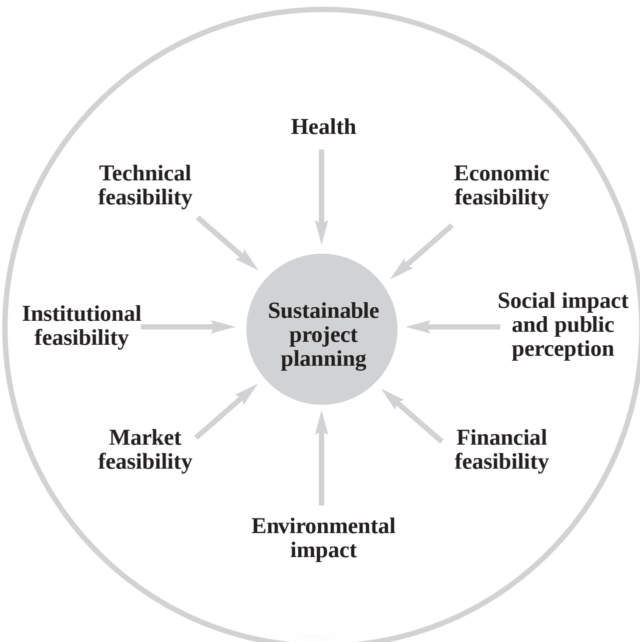

Figure 11.1
Project planning: Eight criteria that impact project success

Most of the eight criteria have been discussed in previous chapters, but a brief discussion of each follows:

1) *Health:* Health is the focus of these Guidelines. Because health issues may vary from one location to the next in the same country, it is important to understand and determine which health issues associated with wastewater use in agriculture are likely to be the most important. Studies are often necessary to identify the key issues. Conducting a health impact assessment prior to the development of new projects or as part of an assessment of ongoing projects is an important planning tool (see Annex 3). Health impact assessment helps to identify populations (e.g. local communities in close proximity to wastewater use areas) that might be at increased risk from different exposures (e.g. vector-borne diseases or schistosomiasis) but may not be considered in other studies. Health impacts, both positive and negative, on the most susceptible populations (e.g. subsistence-level practitioners) need to be considered in the project planning.
2) *Economic feasibility:* Economic feasibility is discussed in chapter 9. Health protection measures that provide the greatest health benefit at the lowest cost should be considered first during project planning.
3) *Social impact and public perception:* These issues were discussed in chapter 7. Cultural practices with respect to wastewater and excreta use, food consumption patterns and other behaviours are very important in the development of health protection measures. It may be very difficult to change long-held beliefs or practices. Health protection measures should be planned to accommodate or even incorporate traditional beliefs and practices. Public perception can be a powerful tool for the acceptance or rejection of a scheme for wastewater use in agriculture. It is important to involve the public in project planning and communicate with different stakeholders. If there is a perceived need for the activity (e.g. because of economic reasons or other factors such as water scarcity), then the public is more likely to accept it.
4) *Financial feasibility:* This is discussed in more detail in chapter 9. Financial planning looks at how a project can be funded. A sustainable project will need to be able to fund the project at all of its stages (i.e. start-up to completion), including equipment, operations and maintenance activities, staff training, monitoring, etc. In some cases, project planners may want to create user's fees or sell products grown in the wastewater-based agricultural system to offset costs.
5) *Environmental impact:* This is discussed in greater detail in chapter 8. Wastewater use often has positive environmental benefits associated with the recycling of important nutrient resources and offering a form of wastewater treatment. However, it can lead to contamination of surface waters and groundwaters, especially if the aquifers are near the surface. Project management to reduce environmental consequences should also assess whether wastewater use activities could lead to increased habitats for vector or snail breeding.
6) *Market feasibility:* The demand for products produced with wastewater should be assessed before they are produced. For example, if one of the health protection measures chosen to meet the health-based target is crop restriction, there has to be sufficient market demand to ensure that the product can be profitably sold in the market (this does not apply to products for household consumption). This also applies to an agency that treats wastewater and wants to create a user fee to recover costs. Treated wastewater can only be sold at a price that farmers are willing and able to pay.

7) *Institutional feasibility:* Project planners should understand the legal and regulatory requirements concerning wastewater use in agriculture. They should be aware of what national and local institutions control wastewater-based agricultural activities and involve them in the planning process. Institutional feasibility is further discussed in chapter 10.
8) *Technical feasibility:* Wastewater use projects should be technically feasible to succeed. Technologies include aspects such as hardware used in the treatment, storage, distribution and use of wastewater and other aspects, such as technical support services and technical training. The most sustainable technologies will be cost effective, upgradable and easy to operate and maintain with local resources. The main technical aspects that should be considered during planning are listed in Box 11.2.

Box 11.2 Technical information to be included in a project plan

- Current and projected generation rates of the wastewater, proportion of industrial effluents, dilution by surface water
- Existing and required wastewater treatment facilities, pathogen removal efficiencies, physicochemical quality
- Existing and required land areas: size, location, soil types, proximity to nearby villages
- Evaporation, especially in waste stabilization ponds (impacts salinity and need for dilution water)
- Conveyance of treated wastewater to farms
- Storage requirements for the wastewater
- Wastewater application rates and methods
- Types of crops to be grown, and their requirements for wastewater quality
- Estimated yields of crops per hectare of land per year
- Strategies for health protection

11.4.1 Support services

Various support services to farmers are particularly relevant to the implementation of health protection measures, and detailed consideration should be given to them at the planning stage. They include the following:

- machinery (sales and servicing, or hire);
- pumps, fences, protective clothing, etc.;
- facilities for processing crops;
- extension and training;
- marketing services, especially where new products are to be introduced or new land is to be brought into productive use;
- primary health care, possibly including regular health checks for workers and their families.

11.4.2 Training

Training requirements must be carefully evaluated at the planning stage, and it may often be necessary to start training programmes, especially for farmers and treatment facility operators, before the project begins, in order to ensure that adequately trained staff is available. Sewage treatment plant operators require on-the-job training in all aspects of the operation of the treatment plant, delivery systems and pumping stations; farmers will need training in agricultural methods most suitable for wastewater use; and technicians will require training in sample collection and analysis.

Similarly, the likely need for agricultural extension services must be estimated and provision made for them to be available to farmers after implementation of the project. Extension officers will themselves need training in the methods appropriate to health protection, as will the staff responsible for enforcing sanitary regulations regarding crop restriction, occupational health, food hygiene, etc.

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Annex 1
Good irrigation practice

A1.1 Introduction

In addition to mitigating possible health effects associated with the use of wastewater in agriculture, good irrigation practices will need to be followed to ensure a good crop yield and minimize risks to the environment. Irrigation practices with wastewater or with other water sources are similar and depend on the local conditions, including climate, physical and chemical soil properties, drainage conditions and the salt tolerances of the crops to be grown. Good irrigation practices will vary but are based on:

- water quantity;
- water quality;
- soil characteristics (infiltration, drainage);
- crop selection;
- irrigation techniques (see discussion in chapter 5);
- leaching;
- management practices.

This chapter will provide a brief overview of these subjects. For a more thorough discussion of these topics, see Tanji & Kielen (2002), Pescod (1992) and Ayers & Westcot (1985).

A1.2 Water quantity

The amount of water available for irrigation will ultimately determine what types of crops can be grown and what types of irrigation techniques can be used. Most water applied to crops is lost by evapotranspiration from the plant surface. Therefore, the water required by the crops is usually equal to the amount of water lost by evapotranspiration. The evapotranspiration requirement is largely dependent on crops and climatic factors and thus can be estimated based on local meteorological data (Allen et al., 1998). FAO has developed a computer program (CROPWAT) to help farmers determine crop water requirements based on climatic factors (Pescod, 1992). CROPWAT is available at http://www.fao.org/landandwater/aglw/cropwat.stm. The appropriate quantity of water to use will need to be adjusted for the amount of rainfall, leaching requirements, application losses and other factors (Pescod, 1992).

Crops have different sensitivities to water supply. For example, groundnuts (peanuts) and safflower have low sensitivities to water supply, while rice and bananas have high sensitivities to water supply. For more information on the water requirements and sensitivities to water supply for different crops, see Pescod (1992).

A1.3 Water quality

Often, the limits on concentrations of many chemicals in the wastewater will be determined by crop requirements and not by health concerns (see Table A1.1). The nutrients in wastewater (i.e. nitrogen, potassium, phosphorus, zinc, boron and sulfur) should be present in the right concentrations, or they can damage the crops and/or the environment. For example, wastewater often contains high concentrations of nitrogen. Although plants require nitrogen for growth, excessive nitrogen can cause overstimulation of growth, delayed maturity or poor-quality produce. Plants require different amounts of nitrogen based on their growth stage. In the first stages of growth, plants may require high quantities of nitrogen (in the earliest stages of growth, plants require lots of nitrogen, but may be too small to usefully assimilate all that is applied), but in the later flowering and fruiting stages, they may require less. In some cases, nitrogen levels will need to be adjusted by blending water supplies (Ayers & Westcot, 1985). This is also an important consideration to reduce leaching of nitrate into groundwater supplies, which would pose a potential health risk to consumers of the drinking-water (see chapter 3).

Table A1.1 Water quality for irrigation

Parameter		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity EC_w[a]		dS/m	<0.7	0.7–3.0	>3.0
TDS		mg/l	<450	450–2000	>2000
TSS		mg/l	<50	50–100	>100
SAR[b]	0–3	meq/l	>0.7 EC_w	0.7–0.2 EC_w	<0.2 EC_w
SAR	3–6	meq/l	>1.2 EC_w	1.2–0.3 EC_w	<0.3 EC_w
SAR	6–12	meq/l	>1.9 EC_w	1.9–0.5 EC_w	<0.5 EC_w
SAR	12–20	meq/l	>2.9 EC_w	2.9–1.3 EC_w	<1.3 EC_w
SAR	20–40	meq/l	>5.0 EC_w	5.0–2.9 EC_w	<2.9 EC_w
Sodium (Na^+)	Sprinkler irrigation	meq/l	<3	>3	
Sodium (Na^+)	Surface irrigation	meq/l	<3	3–9	>9
Chloride (Cl^-)	Sprinkler irrigation	meq/l	<3	>3	
Chloride (Cl^-)	Surface irrigation	meq/l	<4	4–10	>10
Chlorine (Cl_2)	Total residual	mg/l	<1	1–5	>5
Bicarbonate (HCO_3^-)		mg/l	<90	90–500	>500
Boron (B)		mg/l	<0.7	0.7–3.0	>3.0
Hydrogen sulfide (H_2S)		mg/l	<0.5	0.5–2.0	>2.0
Iron (Fe)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Manganese (Mn)	Drip irrigation	mg/l	<0.1	0.1–1.5	>1.5
Total nitrogen (TN)		mg/l	<5	5–30	>30
pH			Normal range 6.5–8		
Trace elements (see Table A1.2)					

TDS, total dissolved solids; TSS, total suspended solids
Sources: Ayers & Westcot (1985); Pescod (1992); Asano & Levine (1998).
[a] EC_w means electrical conductivity in deciSiemens per metre at 25 °C.
[b] SAR means sodium adsorption ratio ($[meq/l]^{1/2}$); see section A1.5.

Sodium chloride, boron and selenium should be monitored carefully. Many plants are sensitive to these substances. Boron is frequently present in wastewater because it is used in household detergents. Many types of trees (e.g. citrus and stone fruits) will have impaired growth even when low boron concentrations are present in the water (Ayers & Westcot, 1985). Selenium can be toxic to plants in very low concentrations and can accumulate in plant tissue to toxic concentrations — for example, in alfalfa grown for forage (Tanji & Kielen, 2002). Concentrations of these elements in the irrigation water may be improved by blending water supplies if other water sources are available. See FAO Publication 61, chapter 6, on details regarding blending of water supplies for irrigation (Tanji & Kielen, 2002).

Water quality is also a factor in selecting the type of irrigation method. For example, sprinkler irrigation with water that contains relatively high concentrations of sodium or chloride ions can cause leaf damage to sensitive crops, especially when climatic conditions favour evaporation (i.e. high temperatures and low humidity) (Ayers & Westcot, 1985). Similar damage to crops occurs when wastewater with high levels of residual chlorine (>5 mg/l) is sprayed directly onto leaves (Asano & Levine, 1998).

Municipal wastewater may contain a range of other toxic substances, including heavy metals, as a result of industrial effluents entering the municipal wastewater stream (Pescod, 1992). Some of these substances may be removed during wastewater treatment processes when available, but others may remain in quantities large enough to cause toxicity to the crops. In cases where industrial wastes are released into the general wastewater stream or where crops exhibit signs of trace element toxicity, it may be necessary to test the water and soil for these elements. Heavy metals are usually fixed by the soil matrix and tend to be mobile only in the topmost soil layers. When water containing toxic trace elements is applied to crops, these elements may be concentrated in the soil as the water is lost into the atmosphere (Tanji & Kielen, 2002). Table A1.2 shows the threshold values for plant toxicity for selected trace elements.

Table A1.2 Threshold levels of trace elements for crop production

Element		Recommended maximum concentration[a] (mg/l)	Remarks
Al	Aluminium	5.0	Can cause non-productivity in acid soils (pH <5.5), but more alkaline soils at pH >7.0 will precipitate the ion and eliminate any toxicity.
As	Arsenic	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be	Beryllium	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	Cobalt	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	Chromium	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu[b]	Copper	0.20	Toxic to a number of plants at 0.1–1.0 mg/l in nutrient solutions.
F	Fluoride	1.0	Inactivated by neutral and alkaline soils.
Fe[b]	Iron	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.

Table A1.2 (continued)

Element		Recommended maximum concentration[a] (mg/l)	Remarks
Li	Lithium	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn[b]	Manganese	0.20	Toxic to a number of crops at a few-tenths to a few mg/l, but usually only in acid soils.
Mo	Molybdenum	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	Nickel	0.20	Toxic to a number of plants at 0.5–1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd	Lead	5.0	Can inhibit plant cell growth at very high concentrations.
Se	Selenium	0.02	Toxic to plants at concentrations as low as 0.025 mg/l, and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. Essential element to animals, but in very low concentrations.
V	Vanadium	0.10	Toxic to many plants at relatively low concentrations.
Zn[b]	Zinc	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH >6.0 and in fine textured or organic soils.

Source: Adapted from Ayers & Westcot (1985); Pescod (1992).

[a] The maximum concentration is based on a water application rate that is consistent with good irrigation practices (5000–10 000 m^3/ha per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3/ha per year. The values given are for water used on a continuous basis at one site.

[b] Synergistic action of Cu and Zn and antagonistic action of Fe and Mn have been reported in certain plants species' absorption and tolerance of metals after wastewater irrigation. If the irrigation water contains high concentrations of Cu and Zn, Cu concentrations in the tissue may increase greatly. In plants irrigated with water containing a high concentration of Mn, Mn uptake in the plants may increase, and, consequently, the concentration of Fe in the plant tissue may be reduced considerably. Generally, metal concentrations in plant tissue increase with concentrations in the irrigation water. Concentrations in the roots are usually higher than in the leaves (Drakatos, Kalavrouziotis & Drakatos, 2000; Drakatos et al., 2002; Kalavrouziotis & Drakotos, 2002).

A1.4 Soil characteristics

Soil infiltration

The infiltration rate of the soil determines how much water will reach the crop root zone and eventually percolate to the subsoil and is dependent upon soil texture and structure and the structural stability of the soil. The infiltration rate is also dependent upon both the salinity of the water and the sodium adsorption ratio (SAR) of the soil (see Table A1.1). The SAR is a measure of the ratio of sodium ions to calcium and magnesium ions in the soil. The SAR can be calculated using the following formula:

$$SAR = Na^{+}/[(Ca^{++} + Mg^{++})/2]^{1/2}$$

where the ionic concentrations of Na, Ca and Mg are expressed in meq/l.

Water with a low salinity content (<0.5 dS/m) leaches soluble minerals and salts. If calcium is leached, soil structure can be destabilized and fine soil particles become dispersed. These fine soil particles clog the pore spaces. This leads to reduced water infiltration rates, soil crusting and crop emergence problems (Ayers & Westcot, 1985). Water with excessive sodium (relative to the concentration of total dissolved salts in the soil) also will impair water infiltration (Pescod, 1992). Water infiltration problems usually occur in the top 10 cm of the soil (Asano & Levine, 1998).

Drainage

To maintain a favourable salt balance, excess water must be able to drain from the surface and from the root zone. Excess water can damage plants and increase soil salinity. Good drainage is particularly important in arid and semi-arid areas. If land drainage is insufficient, the water table can rise. When the water table gets too close to the surface (within 2 m), during dry periods water can rise to the surface by capillary action, evaporate and leave behind dissolved salts. Salt accumulation in the soil reduces crop yields and can ultimately make the soil unfit for agriculture (Pescod, 1992). In areas where the water table is high and the groundwater has a high salinity, it may be necessary to construct open or tile drains to stabilize the depth of the groundwater (Ayers & Westcot, 1985). The long-term sustainability of irrigation with wastewater requires soils with good drainage (Asano & Levine, 1998). As the drainage water can contain components that may be harmful to the environment (e.g. salts, pesticide and fertilizer residues), the quality of the drainage water should be controlled and must be disposed of properly, particularly if it is reused in agriculture or for other purposes. (Tanji & Kielen, 2002). Wescot (1997) describes quality characteristics of drainage water from agriculture.

A1.5 Crop selection

Crops vary by as much as 10-fold in their ability to tolerate salt. In situations where soil salinity is high or the irrigation water (wastewater in this case) has a salinity above 3 dS/m, it may be necessary to grow more salt-tolerant crops (Pescod, 1992). Another alternative may be to adopt an integrated farm drainage management approach. Under such an approach, water is used sequentially to irrigate crops, trees and halophytes with progressively increasing salt tolerance (Tanji & Kielen, 2002). Comprehensive information on crops and their salt tolerances is given in FAO Publications 29, 47 and 61 (Ayers & Westcot, 1985; Pescod, 1992; Tanji & Kielen, 2002).

A1.6 Leaching

One of the most important water quality parameters for irrigation is salinity. Excess salinity can alter soil properties and damage plants or reduce crop yields (Asano & Levine, 1998). Wastewater that has too much salinity (measured as total dissolved solids, or TDS; see Table A1.1) may cause salt to build up to excessive levels in the crop root zone. One way to control salinity problems is to apply enough water to ensure that the salts are carried below the root zone. This is called leaching. For irrigation to be sustainable over a long period of time, the soil must have good drainage properties. To ensure that salts move downwards from the upper root zone through the lower root zone, sufficient leaching must take place. The proportion of irrigation water that passes through the entire root zone is called the leaching fraction (LF) (Asano & Levine, 1998).

LF = depth of water leached below the root zone / depth of water applied at the surface

The salt concentration in the root zone is inversely proportional to LF. For irrigation with wastewater, it is best to have LF >0.5 (for heavy clay soils, this number will be >0.1). In cases where the salinity of the irrigation water and LF are known, the salinity of the drainage water below the root zone can be predicted from the following equation (Asano & Levine, 1998):

$$EC_{DW} = EC_W/LF$$

where EC_{DW} and EC_W are the electrical conductivities of the drainage water and the irrigation water, respectively.

A1.7 Management practices

Good management practices are important in any irrigation scheme. In addition to those practices previously described for controlling health impacts, it is also necessary for optimal plant growth to properly manage water application rates and timing, land and soil and crops. A summary of these considerations is presented below. More detailed information on irrigation management strategies is given in Pescod (1992) and Ayers & Westcot (1985).

It is necessary to manage water application rates and to time applications appropriately. It is important to:

- assess the water-holding capacity of the soil;
- assess the need for pre- and post-planting irrigation to avoid water stress and leach salts from soil prior to and after planting;
- maintain optimal soil moisture levels;
- estimate the evapotranspiration rate (mostly based on the prevailing climatic conditions — e.g. radiation, temperature, humidity and wind speed);
- time water applications appropriately — e.g. water can be applied at night to reduce losses to evaporation and reduce sodium and chloride toxicity to plants;
- determine the quantity of water to be applied, based on rainfall, drainage, soil infiltration, plant and leaching requirements;
- adjust the nitrogen level to match plant requirements through water blending;
- evaluate the irrigation method (e.g. water with residual chlorine applied via sprinkler irrigation can harm the leaves of many plants);
- assess soil drainage properties.

Land and soil management are important for overcoming salinity, sodicity (sodium concentration in the soil) and toxicity to plants and reducing health hazards. The following practices need to be considered to optimize plant growth in specific conditions:

- grading the land to reduce erosion and runoff;
- deep ploughing to break up compact soil pans and improve water movement through the soil;
- soil amendments to improve soil structure, drainage, infiltration or pH.

Crop management can also be used to improve yields. Irrigation with wastewater may require management practices similar to those for irrigation with saline water. Seed germination is most sensitive to soil salinity. Seeds can be placed in such a way as to minimize the impacts of soil salinity by:

- crop selection according to salt tolerance;
- planting seeds on the shoulder(s) of the ridge during furrow irrigation;
- planting seeds on the sloping side of seed beds (seeds should be placed above the water line);
- irrigating alternate rows so that salts move beyond the single seed row;
- choosing alternatives to furrow irrigation when the wastewater is highly saline.

A1.9 Conclusion

Once the barriers for health protection are put into place, the use of wastewater in agriculture requires many of the management practices used for irrigation with any type of water. Special attention needs to be given to water quality (contents of salts, nutrients and toxic trace elements), as these may have an impact on crop growth, yield and soil properties. Several FAO Irrigation and Drainage Papers and Water Reports provide more detailed information on good irrigation and drainage practices.

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[1] Most FAO publications can be found online at http://www.fao.org/documents/ or http://www.fao.org/ag/agl/public.stm.

Annex 2

Summary of impacts of heavy metals and trace elements associated with wastewater irrigation

Table A2.1: Summary of studies that analyse the effects of metals in wastewater irrigation

Description of the study	Type of study			References
	In field	Demonstration projects	Laboratory study	
Sewage				
In San Angelo, Texas, USA, the long-term application of treated wastewater to forage grasses did not increase the Cd, Cu or Zn content above regional background values. Only Cr and Ni displayed high concentrations, but without exceeding guidelines.	X			Hossner, Kao & Waggoner (1978)
In Dickinson, North Dakota, USA, a long-term effects study found, in forage grasses watered with treated wastewater, a 28% increase in B, a 47% increase in Mn and a 68% increase in Zn levels without exceeding the permissible limits. Cd, Cr, Co, Pb and Mo did not show any change, while Cu diminished by 8%.	X			Benham-Blair & Affiliates, Inc. & Engineering Enterprises, Inc. (1979)
Long-term irrigation with reclaimed water in the USA did not produce negative effects in tomatoes, broccoli, forage grasses, grain corn, barley, alfalfa sorghum, pasture, beans, carrots, lettuce, peas, radishes, sweet corn and wheat.	X			USEPA (1981)
In an overflow soil aquifer treatment system in Mississippi, USA, no adverse effects were observed in grasses. Metal accumulation was higher near the site of the application of the wastewater (uphill) and decreased with distance down the treatment slope. Grass uptake accounted only for 1.2, 1.4, 4.0 and 7.6% of the applied Cd, Ni, Cu and Zn, respectively.	X			Peters, Lee & Bates (1980)
In Melbourne, Australia, irrigation for 76 years with treated wastewaters showed no significant accumulation of Cd in soils and plants in comparison with sites receiving fresh water.	X			Metcalf & Eddy, Inc. (1991)
In Isfahan, Iran, the use of wastewater in agriculture for eight years did not significantly increase Zn, Mg, Cu or Fe levels in soil (up to 40 cm depth). However, the contents of these metals in corn, wheat and tomato were significantly higher than those in crops irrigated with well water, although the United States Environmental Protection Agency guidelines were not surpassed in any case.	X			Feizi (2001)
Metal content in municipal wastewaters has not presented difficulties for irrigation in Australia, unless a local metal industry discharges effluents to the sewerage system.	X			AATSE (2004)
In Haroonabad, India, irrigation with domestic wastewater for 35 years has caused a significant accumulation of Pb and Cu within the top 0–15 cm of soil (9 vs 8 mg Pb/kg and 87 vs 22 mg Cu/kg), but not of Zn, Co, Cr and Mn. Despite this, all heavy metal concentrations in soils were within European Economic Community maximum permissible levels. At the current rate of	X			

Table A2.1 (continued)

Description of the study	**Type of study**			**References**
	In field	**Demonstration projects**	**Laboratory study**	
accumulation, metals will not prove to be a risk in the coming decades, although strategic monitoring is recommended.				
A comparison of metal absorption in different crops watered with sewage, a 50% dilution with fresh water and fresh water only showed that the amount of metals absorbed depended on the type of crops and not only on the metal concentration in water; metal absorption was not necessarily greater when using sewage.			X	Simmons & Pongaskul (2002)
Irrigation with wastewater for more than 80 years in the Mezquital Valley, Mexico, has increased the original metal content in soils by 3–6 times, but concentrations are still below international criteria. Contamination has not been reported in crops. Metals were found to be bound to soil due to its organic matter content.	X			Siebe & Fischer (1996)
Type of wastewater not specified				
Soils having about 0.4–0.5 mg Cd/kg produced brown rice with 0.08 mg Cd/kg; and soils with a content of 0.82–2.1 mg Cd/kg produced heavily contaminated brown rice (1 mg Cd/kg).		X		Morishita (1988)
Wastewaters with industrial influence				
In the Bahr Bagar Drain in Egypt, which is used for irrigation, 75% of the flow is wastewater. Irrigated soils contain 5 mg Cd/kg, which is double the original value. There is evidence that Cd is being absorbed by crops. The Cd content in rice is 1.6 mg/kg.	X			FAO (2003)
Industrial wastewaters				
Reed canary-grass and maize were irrigated for six years with an effluent containing Cu, Cd, Pb and Zn without creating health problems. Nevertheless, when sludge was added in addition to wastewater for seven years, the Cu was thought to pose a risk to sheep fed with these crops. It was determined that crop removal in areas where heavy metal application was low could possibly increase the disposal life of the site.		X		Sidle, Hook & Kardos (1976)
A textile industry effluent diluted with fresh water used to irrigate rice, kidney beans and lady's fingers increased productivity due to its organic matter content up to a 75% effluent; beyond this dilution, effluent inhibited growth.		X		Ajmal & Khan (1985)
In India, an effluent from a paper mill industry was used to irrigate coconut trees. It was found that the Cu, Pb, Zn, Co and Cd content exceeded Codex Alimentarius Commission guidelines in crops.			X	Fazel et al. (1991)

Table A2.1 (continued)

Description of the study	Type of study			References
	In field	Demonstration projects	Laboratory study	
A paper industry effluent was used with different dilutions of fresh water to irrigate rice. As the proportion of effluent increased, the quality of germination, the growth rate and the pigments were negatively impacted.		X		Misra & Behera (1991)
An oil refinery treated effluent was used to irrigate four varieties of wheat for eight years. Fresh water was used as a control. Productivity was found to increase, so it was recommended that the metal content be periodically monitored to avoid possible risks.		X		Aziz et al. (1996)
An effluent spiked with Cd, Cr and Pb (up to 100 mg/l) was used to irrigate soils at different pH values (including acid ones), soil grain size (<180–2000 µm), TOC content in solution (0 and 6.3 mg C/l) and water flow (0.3 and 0.7 m^3/m^2 per hour). All the metals were quickly adsorbed in soils, even at pH 4.3. Metal concentration in wastewater was found to be the variable that most determined adsorption.			X	Lee et al. (2004)

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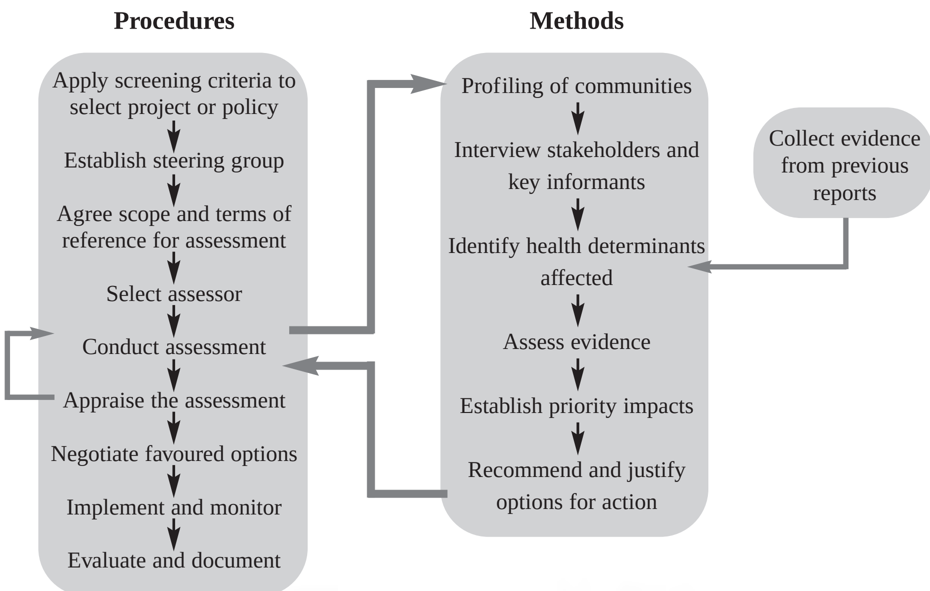
Annex 3
Health impact assessment

Health impact assessment (HIA) is an instrument for safeguarding the health of vulnerable communities in the context of accelerated changes in environmental and/or social health determinants resulting from development. WHO/ECHP (1999) defined HIA as "A combination of procedures, methods and tools by which a policy, programme or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population." A health impact is a change in health risk reasonably attributable to a project, programme or policy. A health risk is the likelihood of a health hazard affecting a particular community at a particular time. Assessments can be retrospective or prospective. Retrospective assessments measure and record what has happened, while prospective assessments facilitate development planning and help to predict the consequences of a future project based on available evidence (WHO, 2000).

A3.1 Procedures and methods

In Figure A3.1, the sequence of essential HIA procedures is presented, with an indication of when each method is applied. Effective HIA requires health hazards, risks, determinants and potential impacts to be defined and monitored (WHO, 2001). Implementation of these procedures should be done in such a way that all relevant stakeholders are involved — especially the local communities that will be impacted.

Figure A3.1



Procedures and methods of HIA (WHO, 2000)

When policy and procedure have been established, the actual assessment can take place. It consists of inferring changes in health determinants that are reasonably attributable to the project and that could affect each stakeholder community during each stage of the project. The changes, taken together, produce health outcomes or changes in health status. These are expressed in a minimum of three ranks: no change, increased health risk and increased health enhancement. Quantification is generally difficult, either because the data are lacking or because there are no known functional relationships between cause and effect. Research is needed to improve the predictive models for other health concerns.

The best forecast of what will happen is the history of what has happened with similar wastewater-based agricultural activities in comparable regions (WHO, 2000).

The assessment would start by collecting baseline data on wastewater use in agriculture and health risks over a period of at least two years prior to final agreement on project design. This will provide a profile of the existing communities, their environment, seasonal changes in health risks and the capabilities of their institutions. The data collection would be repeated after the project was operational, and the difference would provide a record of health impact and its likely causes. The record would add to the available knowledge base and improve the assessment of future projects.

The objective of HIA is to present evidence, infer changes and recommend actions to safeguard, mitigate and enhance human health. The inferences may not always be founded on extensive data, but they must be persuasive (WHO, 2000).

A3.2 Management of health risks and enhancements

The final stage of the assessment is to recommend and budget socially acceptable measures to safeguard, mitigate and promote human health (WHO, 2000). The most important principle for health promotion is dialogue between project proponents, health professionals and stakeholder communities at the planning stage. The technical recommendations for managing health risks are diverse. A broad classification is:

- appropriate health regulations and enforcement;
- modifications to project plans and operations;
- improved management and maintenance;
- supportive infrastructure, such as the installation or improvement of wastewater treatment and use facilities;
- timely provision of accessible health care, including diagnosis and treatment;
- special disease control operations;
- individual protective measures;
- health education;
- redistribution of risk through insurance schemes.

A3.3 References

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Annex 4
Glossary of terms used in the Guidelines

This glossary does not aim to provide precise definitions of technical or scientific terms, but rather to explain in plain language the meaning of terms frequently used in these Guidelines.

Abattoir – Slaughterhouse where animals are killed and processed into food and other products.

Advanced or tertiary treatment – Treatment steps added after the secondary treatment stage to remove specific constituents, such as nutrients, suspended solids, organics, heavy metals or dissolved solids (e.g. salts).

Anaerobic pond – Treatment pond where anaerobic digestion and sedimentation of organic wastes occur; usually the first type of pond in a waste stabilization pond system; requires periodic removal of accumulated sludge formed as a result of sedimentation.

Aquaculture – Raising plants or animals in water (water farming).

Aquifer – A geological area that produces a quantity of water from permeable rock.

Arithmetic mean – The sum of the values of all samples divided by the number of samples; provides the average number per sample.

Biochemical oxygen demand (BOD) – The amount of oxygen that is required to biochemically convert organic matter into inert substances; an indirect measure of the amount of biodegradable organic matter present in the water or wastewater.

Buffer zone – Land that separates wastewater, excreta and/or greywater use areas from public access areas; used to prevent exposures to the public from hazards associated with wastewater, excreta and/or greywater.

Cartage – The process of manually transporting faecal material off site for disposal or treatment.

Coagulation – The clumping together of particles to increase the rate at which sedimentation occurs. Usually triggered by the addition of certain chemicals (e.g. lime, aluminium sulfate, ferric chloride).

Constructed wetlands – Engineered pond or tank-type units to treat faecal sludge or wastewater; consist of a filtering body planted with aquatic emergent plants.

Cost–benefit analysis – An analysis of all the costs of a project and all of the benefits. Projects that provide the most benefits at the least cost are the most desirable.

Cyst – Environmentally resistant infective parasitic life stage (e.g. *Giardia*, *Taenia*).

Cysticercosis – Infection with *Taenia solium* (pig tapeworm) sometimes leads to cysticerci (an infective life stage) encysting in the brain of humans, leading to neurological symptoms such as epilepsy.

Depuration – Transfer of fish to clean water prior to consumption in an attempt to purge their bodies of contamination, potentially including some pathogenic microorganisms.

Diarrhoea – Loose, watery and frequent bowel movements, often associated with an infection.

Disability adjusted life years (DALYs) – Population metric of life years lost to disease due to both morbidity and mortality.

Disease – Symptoms of illness in a host, e.g. diarrhoea, fever, vomiting, blood in urine, etc.

Disinfection – The inactivation of pathogenic organisms using chemicals, radiation, heat or physical separation processes (e.g. membranes).

Drain – A conduit or channel constructed to carry off stormwater runoff, wastewater or other surplus water. Drains can be open ditches or lined, unlined or buried pipes.

Drip irrigation – Irrigation delivery systems that deliver drips of water directly to plants through pipes. Small holes or emitters control the amount of water that is released to the plant. Drip irrigation does not contaminate aboveground plant surfaces.

Dual-media filtration – Filtration technique that uses two types of filter media to remove particulate matter with different chemical and physical properties (e.g. sand, anthracite, diatomaceous earth).

Effluent – Liquid (e.g. treated or untreated wastewater) that flows out of a process or confined space).

Encyst – The development of a protective cyst for the infective stage of different parasites (e.g. helminths such as foodborne trematodes, tapeworms, and some protozoa such as *Giardia*).

Epidemiology – The study of the distribution and determinants of health-related states or events in specified populations, and the application of this study to the control of health problems.

***Escherichia coli* (*E. coli*)** – A bacterium found in the gut, used as an indicator of faecal contamination of water.

Excreta – Faeces and urine (see also faecal sludge, septage and nightsoil).

Exposure – Contact of a chemical, physical or biological agent with the outer boundary of an organism (e.g. through inhalation, ingestion or dermal contact).

Exposure assessment – The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent of exposure to one or more contaminated media.

Facultative pond – Aerobic pond used to degrade organic matter and inactivate pathogens; usually the second type of pond in a waste stabilization pond system.

Faecal sludge – Sludges of variable consistency collected from on-site sanitation systems, such as latrines, non-sewered public toilets, septic tanks and aqua privies. Septage, the faecal sludge collected from septic tanks, is included in this term (see also excreta and nightsoil).

Flocculation – The agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means.

Geometric mean – A measure of central tendency, just like a median. It is different from the traditional mean (which is called the arithmetic mean) because it uses multiplication rather than addition to summarize data values. The geometric mean is a useful summary when changes in the data occur in a relative fashion.

Greywater – Water from the kitchen, bath and/or laundry, which generally does not contain significant concentrations of excreta.

Groundwater – Water contained in rocks or subsoil.

Grow-out pond – Pond used to raise adult fish from fingerlings.

Hazard – A biological, chemical, physical or radiological agent that has the potential to cause harm.

Health-based target – A defined level of health protection for a given exposure. This can be based on a measure of disease, e.g. 10^{-6} DALY per person per year, or the absence of a specific disease related to that exposure.

Health impact assessment – The estimation of the effects of any specific action (plans, policies or programmes) in any given environment on the health of a defined population.

High-growing crops – Crops that grow above the ground and do not normally touch it (e.g. fruit trees).

High-rate treatment processes – Engineered treatment processes characterized by high flow rates and low hydraulic retention times. Usually include a primary treatment step to settle solids followed by a secondary treatment step to biodegrade organic substances.

Hydraulic retention time – Time the wastewater takes to pass through the system.

Hypochlorite – Chemical frequently used for disinfection (sodium or calcium hypochlorite).

Indicator organisms – Microorganisms whose presence is indicative of faecal contamination and possibly of the presence of more harmful microorganisms.

Infection – The entry and development or multiplication of an infectious agent in a host. Infection may or may not lead to disease symptoms (e.g. diarrhoea). Infection can be measured by detecting infectious agents in excreta or colonized areas or through measurement of a host immune response (i.e. the presence of antibodies against the infectious agent).

Intermediate host – The host occupied by juvenile stages of a parasite prior to the definitive host and in which asexual reproduction often occurs (e.g. for foodborne trematodes or schistosomes the intermediate hosts are specific species of snails).

Legislation – Law enacted by a legislative body or the act of making or enacting laws.

Localized irrigation – Irrigation application technologies that apply the water directly to the crop, either through drip irrigation or bubbler irrigation. Generally use less water and result in less crop contamination and reduce human contact with the wastewater.

Log reduction – Organism removal efficiencies: 1 log unit = 90%; 2 log units = 99%; 3 log units = 99.9%; and so on.

Low-growing crops – Crops that grow below, on or near the soil surface (e.g. carrots, lettuce).

Low-rate biological treatment systems – Use biological processes to treat wastewater in large basins, usually earthen ponds. Characterized by long hydraulic retention times. Examples of low-rate biological treatment processes include waste stabilization ponds, wastewater storage and treatment reservoirs and constructed wetlands.

Maturation pond – An aerobic pond with algal growth and high levels of bacterial removal; usually the final type of pond in a waste stabilization pond system.

Median – The middle value of a sample series (50% of the values in the sample are lower and 50% are greater than the median).

Membrane filtration – Filtration technique based on a physical barrier (a membrane) with specific pore sizes that traps contaminants larger than the pore size on the top surface of the membrane. Contaminants smaller than the specified pore size may pass through the membrane or may be captured within the membrane by some other mechanism.

Metacercariae (infective) – Life cycle stage of trematode parasites infective to humans. Metacercariae can form cysts in fish muscle tissue or on the surfaces of plants, depending on the type of trematode species.

Multiple barriers – Use of more than one preventive measure as a barrier against hazards.

Nightsoil – Untreated excreta transported without water, e.g. via containers or buckets; often used as a popular term in an unspecific manner to designate faecal matter of any origin; its technical use is therefore not recommended.

Off-site sanitation – System of sanitation where excreta are removed from the plot occupied by the dwelling and its immediate surroundings.

On-site sanitation – System of sanitation where the means of storage are contained within the plot occupied by the dwelling and its immediate surroundings. For some systems (e.g. double-pit or vault latrines), treatment of the faecal matter happens on site also, through extended in-pit consolidation and storage. With other systems (e.g. septic tanks, single-pit or vault installations), the sludge has to be collected and treated off site (see also faecal sludge).

Oocyst – A structure that is produced by some coccidian protozoa (i.e. *Cryptosporidium*) as a result of sexual reproduction during the life cycle. The oocyst is usually the infectious and environmental stage, and it contains sporozoites. For the enteric protozoa, the oocyst is excreted in the faeces.

Operational monitoring – The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control measure is operating within design specifications (e.g. for wastewater treatment turbidity). Emphasis is given to monitoring parameters that can be measured quickly and easily and that can indicate if a process is functioning properly. Operational monitoring data should help managers to make corrections that can prevent hazard break-through.

Overhanging latrine – A latrine that empties directly into a pond or other water body.

Pathogen – A disease-causing organism (e.g. bacteria, helminths, protozoa and viruses).

pH – An expression of the intensity of the basic or acid condition of a liquid.

Policy – The set of procedures, rules and allocation mechanisms that provide the basis for programmes and services. Policies set priorities and often allocate resources for their implementation. Policies are implemented through four types of policy instruments: laws and regulations; economic measures; information and education programmes; and assignment of rights and responsibilities for providing services.

Primary treatment – Initial treatment process used to remove settleable organic and inorganic solids by sedimentation and floating substances (scum) by skimming. Examples of primary treatment include primary sedimentation, chemically enhanced primary sedimentation and upflow anaerobic sludge blanket reactors.

Quantitative microbial risk assessment (QMRA) – Method for assessing risk from specific hazards through different exposure pathways. QMRA has four components: hazard identification; exposure assessment; dose–response assessment; and risk characterization.

Regulations – Rules created by an administrative agency or body that interpret the statute(s) setting out the agency's purpose and powers or the circumstances of applying the statute.

Restricted irrigation – Use of wastewater to grow crops that are not eaten raw by humans.

Risk – The likelihood of a hazard causing harm in exposed populations in a specified time frame, including the magnitude of that harm.

Risk assessment – The overall process of using available information to predict how often hazards or specified events may occur (likelihood) and the magnitude of their consequences.

Risk management – The systematic evaluation of the wastewater, excreta or greywater use system, the identification of hazards and hazardous events, the assessment of risks and the development and implementation of preventive strategies to manage the risks.

Secondary treatment – Wastewater treatment step that follows primary treatment. Involves the removal of biodegradable dissolved and colloidal organic matter using high-rate, engineered aerobic biological treatment processes. Examples of secondary treatment include activated sludge, trickling filters, aerated lagoons and oxidation ditches.

Septage – Sludge removed from septic tanks.

Septic tank – An underground tank that treats wastewater by a combination of solids settling and anaerobic digestion. The effluents may be discharged into soak pits or small-bore sewers.

Sewage – Mixture of human excreta and water used to flush the excreta from the toilet and through the pipes; may also contain water used for domestic purposes.

Sewer – A pipe or conduit that carries wastewater or drainage water.

Sewerage – A complete system of piping, pumps, basins, tanks, unit processes and infrastructure for the collection, transporting, treating and discharging of wastewater.

Sludge – A mixture of solids and water that settles to the bottom of latrines, septic tanks and ponds or is produced as a by-product of wastewater treatment (sludge produced from the treatment of municipal or industrial wastewater is not discussed in this document).

Source separation – Diversion of urine, faeces, greywater or all, followed by separate collection (and treatment).

Subsurface irrigation – Irrigation below the soil surface; prevents contamination of aboveground parts of crops

Surface water – All water naturally open to the atmosphere (e.g. rivers, streams, lakes and reservoirs).

Thermotolerant coliforms – Group of bacteria whose presence in the environment usually indicates faecal contamination; previously called faecal coliforms.

Tolerable daily intake (TDI) – Amount of toxic substance that can be taken on a daily basis over a lifetime without exceeding a certain level of risk

Tolerable health risk – Defined level of health risk from a specific exposure or disease that is tolerated by society, used to set health-based targets.

Transmissivity – Flow capacity of an aquifer measured in volume per unit time per unit width – soil transmissivity refers to the percolation capacity of the soil.

Turbidity – The cloudiness of water caused by the presence of fine suspended matter.

Ultraviolet radiation (UV) – Light waves shorter than visible blue-violet waves of the spectrum (from 380 to 10 nanometres) used for pathogen inactivation (bacteria, protozoa and viruses).

Unrestricted irrigation – The use of treated wastewater to grow crops that are normally eaten raw.

Upflow anaerobic sludge blanket reactor – High-rate anaerobic unit used for the primary treatment of domestic wastewater. Wastewater is treated during its passage through a sludge layer (the sludge "blanket") composed of anaerobic bacteria. The treatment process is designed primarily for the removal of organic matter (biochemical oxygen demand).

Validation – Testing the system and its individual components to prove that it is capable of meeting the specified targets (i.e. microbial reduction targets). Should take place when a new system is developed or new processes are added.

Vector – Insect that carries disease from one animal or human to another (e.g. mosquitoes).

Vector-borne disease – Diseases that can be transmitted from human to human via insects (e.g. malaria).

Verification monitoring – The application of methods, procedures, tests and other evaluations, in addition to those used in operational monitoring, to determine compliance with the system design parameters and/or whether the system meets specified requirements (e.g. microbial water quality testing for *E. coli* or helminth eggs, microbial or chemical analysis of irrigated crops).

Waste-fed aquaculture – Use of wastewater, excreta and/or greywater as inputs to aquacultural systems.

Waste stabilization ponds (WSP) – Shallow basins that use natural factors such as sunlight, temperature, sedimentation, biodegradation, etc., to treat wastewater or faecal sludges. Waste stabilization pond treatment systems usually consist of anaerobic, facultative and maturation ponds linked in series.

Wastewater – Liquid waste discharged from homes, commercial premises and similar sources to individual disposal systems or to municipal sewer pipes, and which contains mainly human excreta and used water. When produced mainly by household and commercial activities, it is called domestic or municipal wastewater or domestic sewage. In this context, domestic sewage does not contain industrial effluents at levels that could pose threats to the functioning of the sewerage system, treatment plant, public health or the environment.

Withholding period – Time to allow pathogen die-off between waste application and harvest.

The third edition of the WHO ***Guidelines for the safe use of wastewater, excreta and greywater*** has been extensively updated to take account of new scientific evidence and contemporary approaches to risk management. The revised Guidelines reflect a strong focus on disease prevention and public health principles.

This new edition responds to a growing demand from WHO Member States for guidance on the safe use of wastewater, excreta and greywater in agriculture and aquaculture. Its target audience includes environmental and public health scientists, researchers, engineers, policy-makers and those responsible for developing standards and regulations.

The Guidelines are presented in four separate volumes: ***Volume 1: Policy and regulatory aspects; Volume 2:Wastewater use in agriculture; Volume 3: Wastewater and excreta use in aquaculture; and Volume 4: Excreta and greywater use in agriculture.***

Over the past decade, wastewater has become a significant resource for agricultural production in its own right. Volume 2 of the Guidelines explains requirements to promote safe use concepts and practices, including health-based targets and minimum procedures. It also covers a substantive revision of approaches to ensuring the microbial safety of wastewater used in agriculture. It introduces health impact assessment of new wastewater projects.

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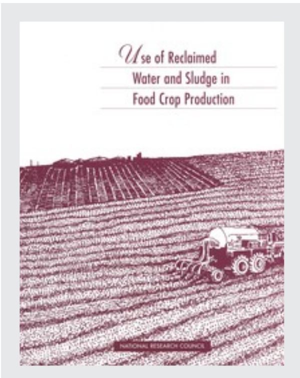

Use of Reclaimed Water and Sludge in Food Crop Production

DETAILS

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