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Design and Application of an Innovative Composting Unit for the Effective Treatment of Sludge and other Biodegradable Organic Waste in Morocco

MOROCOMP (*LIFE TCY05/MA000141*)

Deliverable 2:

Assessment of the existing situation and the related legislation in the EU in connection to sludge management

Evaluation de l’état actuel de la gestion des boues et leur législation dans l’ UE

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1 Introduction

This report assesses the existing situation in the European Union (EU) in connection to sludge management. Furthermore, the related EU Legislation is presented. The report is produced in the framework of Task 1: Assessment of the existing situation in Morocco and in the EU. The aim is to present the existing situation in the EU regarding sludge waste management as well as the relevant EU legislation.

The report draws upon the following issues:

- The hierarchy of the EU with respect to solid waste management
- The generation of sewage sludge within the Member States of the EU
- The analysis of pollutants (i.e. heavy metals, pathogens, organics) that are present in sludge
- The presentation and analysis of the EU legislative framework that is related to sewage sludge management
- The disposal and the recycling regimes of sewage sludge within the Member States of the EU

1.1 Waste Management Hierarchy in the EU

The European Union has developed a specific waste management hierarchy, favouring certain management routes for the treatment and disposal of waste. The Waste Framework Directive (91/156/EEC amending 75/442/EEC on waste) establishes the waste management hierarchy so that Member States should take the appropriate measures for the optimisation of their waste management schemes. This includes both the treatment alternatives and the final disposal. According to Article 3 of the Directive, hierarchy preference has to be given to waste prevention followed by waste reduction, material re-use, recycling and energy recovery. This means that waste is viewed as a material with added-value and not merely as a useless by-product that must be disposed off. Although some efforts have been made to reduce the waste that is produced in the European Union (EU), these are still in their embryonic stages of development. The Member States have focused mostly either on energy or material recovery practices. The generation of municipal waste is growing in Western Europe, while it remains stable in Central and Eastern Europe. The target of the 5th environment action programme to reduce municipal waste generation in the EU countries by the year 2000 to the levels of waste production of the year 1985 has not been accomplished. The 6th environment action plan has set the following targets regarding waste management in the EU (European Environmental Agency, 2005):

- Improvement of the resource efficiency as well as of the resource and waste management in order to achieve more sustainable consumption and production patterns. This way the use of resources and the consequent waste generation can be decoupled from economic growth
- Employment of waste reduction initiatives and better resource efficiency in order to reduce the quantities of waste produced
- Encouragement of reuse and recovery practices in order to reduce the amount of waste that is disposed

1.2 Sewage Sludge

There has recently been detected a growing interest in Europe on sludge generation, its disposal and recycling. The most important reason for this interest is the concern about the potential risks on human health and the environment of the pollutants contained in sewage sludge used in agriculture. In an attempt to control this risk, legislation has been developed both at European and national level. This legislation focuses mainly on the definition of the maximum loads of nutrients, organic matter and pollutants in sludge applicable on land. Slowly but steadily, the quality requirements that can be demanded to sludge for using it in different applications are being better known.

The amount of sludge generated in Europe grows continuously as a result of the progressive implementation of the European Urban Wastewater Treatment Directive (91/271/EEC). Wastewater treatment plants are built across Europe, producing increasing quantities of sludge and a large demand of appropriate management and disposal methods. In response to this demand, technologies are continuously being developed and have been progressively been introduced in the market.

Not all disposal routes for sewage sludge are equally covered by they European Union legislation. The reference document of the disposal and utilisation of sludge in Europe is the Directive on the use of sludge in agriculture (86/278/EEC), which last version dates from 1986. The Directive covers only the application of sludge on land.

The environmentally sound and commercially feasible management of sewage sludge is a major issue that all European countries face regardless of size or location. Sewage sludge represents a priority waste stream. In 2003, the total amount of sewage sludge produced annually in the 15 old EU member countries was approximately 7.5 million tonnes of dry solids, presenting an increase of 44% since the year of 1992 (WHO, 2005). Currently, it is estimated that approximately 8.3 million tonnes of dry solids of sewage sludge are produced annually in the 15 Member States. The implementation of the Urban Wastewater Treatment Directive 91/271/EEC has resulted in a significant increase in the produced sewage sludge. Furthermore, the enlargement of the EU which took place in 2004 has added 10 new Member States. Sludge disposal into sea has been banned since 1998, while its disposal in landfills will gradually cease in all Member States, as they will be required to fulfill the targets of Directive 1999/31/EC which bans liquid waste disposal to landfills. Furthermore, sludge incineration is a difficult and expensive option to be implemented due to the stringent limit values of the air emissions and due to the problem of disposing the remaining ash that is considered a toxic residue. Consequently, sludge recycling through application to agriculture becomes an increasingly attractive option.

Sewage sludge is the residual by-product resulting from the treatment of urban and industrial wastewater. The environmentally sound and commercially feasible management of sewage sludge is a major issue that all European countries confront. Sewage sludge arises from the processes of wastewater treatment and represents one of the ten priority waste streams (Langenkamp & Marmo, 2000).

The characteristics of sludge depend on the original pollution load of the treated water, on the technical characteristics of wastewater and on the type of sludge treatment that is carried out. Sewage sludge is as termed as ‘biosolid’, since the useful organic fraction usually accounts for 40-70% of the solids. This term emphasises the advantages of the bulk quantity of sludge and at the same time reflects a certain degree of optimism regarding the potential problems that may be caused by a negligible in quantity, but great in significance, portion of sludge related to pollutants (i.e. metals, organic pollutants and pathogens) which originate from domestic uses, runoff rain water and connected industrial wastewaters (ICON, 2001); (WHO, 2005).

There are three main categories of sludge (WHO, 2005):

a. Sludge originating from the treatment of urban wastewater, consisting of domestic wastewater or of the mixture of domestic wastewater together with industrial wastewater and/or runoff rain water.

b. Sludge originating from the treatment of industrial wastewater.

c. Sludge originating from drinking water treatment.

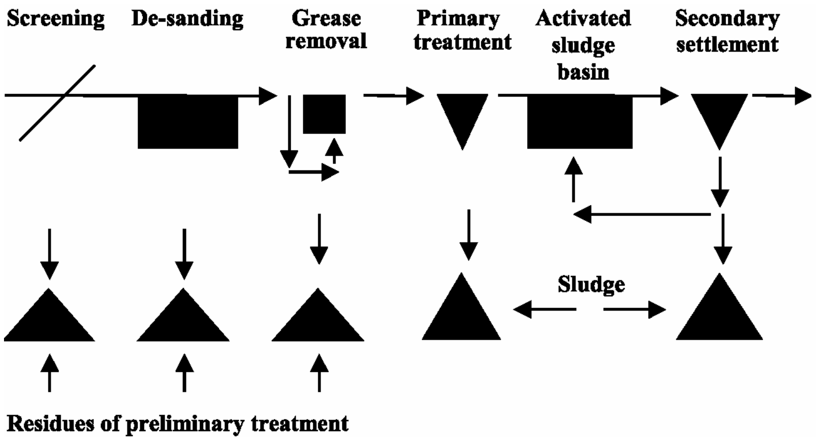


Figure 1: Wastewater Treatment Processes where Sludge is Produced

Sludges from conventional wastewater treatment plants are derived from primary (physical and/or chemical), secondary (biological) and potentially tertiary (often nutrient removal processes) treatment processes. The residues generated during the pre-treatment stages of the plants are not considered as sludge. These residues are mainly coarse solid particles, grit, sand and grease. Figure 1 presents a typical (primary and secondary) wastewater treatment facility indicating the stages where sludge is produced (European Commission Joint Research Centre, 2000). Depending on the type wastewater treatment processes and on the type of treatment the generated sludge receives the following types of sewage sludge are recognized (WHO, 2005); (Metcalf & Eddy, 2003):

- Primary sludge: Primary sludge is produced following primary treatment. This type of treatment is physical and/or chemical and aims to remove suspended matter (i.e. solids, grease and scum). The most common physical treatment is sedimentation, which involves the removal of suspended solids from liquids by gravitational settling. Another physical treatment is flotation, in which air bubbles are introduced in the wastewater, so that particles rise to the wastewater surface and are removed by skimming. Sedimentation method removes about 40-50% of the suspended solids and produces sludge with a solids concentration ranging between 1.5% to 5% depending on the type and frequency of sludge removal. Chemical primary treatment can also be employed. This consists of coagulation and flocculation, which are used to separate suspended solids when their normal sedimentation rates are too slow to provide effective settling through gravity. These chemical processes can achieve 90% removal of suspended solids and produce larger quantities of sludge not only due to the enhanced solids removal, but also due to the production of additional chemical sludge by as much as 25% to 150% depending on the chemical used.

- Secondary sludge: Secondary sludge results from the growth of micro-organisms, which oxidize the organic material and use part of it for synthesis, during biological treatment of sewage. The types of biological processes employed are either suspended growth (mainly activated sludge) or attached growth biomass. The produced sludge is called secondary sludge consisting mostly of biomass, having a dry solids content of approximately 1% (suspended growth systems) to 4-5% (attached growth systems).
- Mixed sludge: Primary and secondary sludge can be mixed together generating a type of sludge known as mixed sludge.
- Tertiary sludge: Tertiary sludge is generated when tertiary treatment is conducted. This is an additional process to secondary treatment that removes remaining nutrients (mainly N and P) through biological and/or chemical processes. Physico-chemical removal of phosphorus increases the quantity of sludge produced in an activated sludge plant by about 30 %. Biological treatment employs specific micro-organisms, which are able to store phosphorus, which accumulates within the bacteria enabling its removal with the rest of the sludge. Tertiary sludge can also be associated with sand filtration following biological treatment, aiming to produce a high effluent quality free of suspended solids.
- Digested sludge: This term applies to the primary, secondary or mixed sludge after it has undergone aerobic or more commonly anaerobic digestion. Anaerobic digestion is a typical sludge treatment process in a wastewater treatment plant that aims to stabilise the organic matter of sludge and to reduce pathogens.

- Dewatered - Stabilised sludge: For the reduction of the water content and of the volume of sludge, dewatering, often in combination with thickening, is usually employed. The methods applied to remove water from sludge range from drying beds to mechanical dewatering devices, such as filter-presses, belt-presses and centrifuges. The solids content of the dewatered sludge varies from 15% to 35% depending on the type of sludge and the dewatering method applied.

As a solid, semi-solid or liquid residue generated during the treatment of wastewater, sewage sludge treatment and disposal is a major challenge for societies, but at the same time provides the opportunity of beneficial use by its application to land in order to close the cycle of nutrients and obtain a sustainable and ecologically sound management of these materials. However, this has to be performed in a way that human health and the environment are not adversely affected.

2 Sludge Contaminants

By its own nature and due to the physico-chemical processes involved in the treatment of wastewater, sewage sludge is potentially contaminated by a whole range of polluting substances. The three categories of pollutants which affect the sludge quality are: heavy metals, pathogen micro-organisms and persistent organic pollutants (POPs). These pollutants must be considered before sludge is deposited into the soil. Table 1 presents certain sources of pollutants which are introduced in urban wastewater facilities and hence in sewage sludge (ICON Consultants, 2001).

The polluting load in raw wastewater is transferred to sludge as settled solids at the primary stage and as settled biological sludge at the secondary stage. The percentage of heavy metal removal during the secondary wastewater treatment is dependent upon the uptake of metals by the microbial biomass and the separation of the biomass during secondary sedimentation. The remaining heavy metals are to be considered as potential toxic elements according to their concentration. On the other hand the organic compounds in sewage sludge mainly originate from human and animal excreta. Organic compounds do not pose the same concern to human health and to environment pollution, as heavy metals do. Nevertheless, organic compounds impact on the soil quality to which sludge is applied. Careful land-spreading of sludge is required in order to recycle nutrients and to enrich organic matter to soils without over-exploiting agricultural land (Langenkamp & Marmo, 2000).

Table 1: Sources of Pollutants in Urban Wastewater (European Commission Joint Research Centre, 2001)

Pollutant sources	**Domestic use and services**	**Run-off rain water (combined system)**
Pathogens	Human metabolism	Animals faeces (pets)
Heavy metals	Paints (Pb), Amalgam fillings (Hg), Thermometers (Hg), pipe corrosion (Pb, Cu)	Rain (Pb, Cd, Zn), Tyres (Cu, Cd), Roof corrosion (Zn,Cu), Oil (Pb)…
POPs	Paints, Solvents, Wood treatment, Medicines, Detergents, Cosmetics	Oil, Pesticides (gardens), Tar, Road de-icing, Rain, (pesticides, combustion)

Another parameter that must be considered when it comes to sewage sludge usage in agriculture is the wide variety of pathogens introduced in wastewaters and hence in sewage sludge, which can be infectious for different species of animals and plants as well as for humans. Although pathogenic micro-organisms impact on the quality of sewage sludge, there is no specific legislation in the European Community, which regulates the pathogen population for sewage sludge usage into soil.

2.1 Pathogens

Most pathogens in sludge originate from human population, companion animals and livestocks. The sanitary level of the population is directly related to the pathogen load of sludge, whereas rodents and flora that may develop in sewers and animal droppings through runoff, also contribute to wastewater contamination (WHO, 2005). Through the wastewater treatment processes the pathogen levels are reduced, but they are not eliminated. The primary and secondary sedimentation as well as tertiary treatment result in the production of sludge together with the accumulating pathogens. Depending on the type of wastewater, pathogens will be different (Table 2) (Carrington, 2001).

Pathogens found in sewage sludge are of five main types: bacteria, viruses, fungi and yeast, parasitic worms, and protozoa. Their accumulation in sludge occurs either by direct settling (mainly eggs, cysts and protozoa that have sufficient density) or by adsorption on suspended matter such as activated sludge flocs (bacteria and viruses) (WHO, 2005).

Table 2: Origin of Pathogens Present in Sludge (Lepeuple et al., 2004)

Sewage Origin	**Pathogens**
Urban type sewage	Pathogens present in humans and animals
Dairy sewage	Pathogens present in milk
Slaughterhouse sewage	Pathogens present in animal blood, faeces, digestive tract

Moreover, the nature and level of pathogens in sludge could be influenced by numerous factors such as the type of processes, the health and size of the population, the presence of hospitals, meat-processing factories and weather conditions. The usual types of pathogens introduced in wastewaters and consequently in sludge consist of bacteria, viruses, protozoa, nematodes and fungi. These attack the human immune system causing diseases of the gastrointestinal tract such as typhoid, paratyphoid fever, dysentery, diarrhoea and cholera. These pathogens are highly infectious and are responsible for many deaths in developing countries where the sanitation level is poor. (Malamis, 2000). Table 3 provides a list of the various pathogens found in sludge, while Table 4 presents the densities of sewage sludge pathogens.

Table 3: Pathogens in Sewage Sludge (Lepeuple et al., 2004)

Virus	**Bacteria**	**Fungi**
Enteric virus	Arizona hinshawii	Aspergillus fumigatus
-Poliovirus	Aeromonas spp	Candida albicans
-Coxsachivirus	Bacillus cereus	Candida guillermondii
-Echovirus	Bacillus anthracis	Candida krusei
Respiratory virus	Brucella spp	Candida tropicalis
-influenza	Campylobacter jejuni	Cryptococcus
Adenovirus	Citrobacter spp	Epidermophyton spp
Astrovirus	Clostridium botulinum	Geotrichum candidum
Calicivirus	Clostridium perfringens	Microsporum spp
Coronavirus	Enterobacteriaceae	Phiolophora richardsii
Enterovirus	Escherichia coli	Trichosporon
Parovirus	Klebsiella spp	Trichosporon spp
Reovirus	Leptospira	
Rotavirus	icterohaemorrhagiae	
Norwalk virus	Listeria monocytogenes	**Helminths**
Hepatitis A virus	Mycobacterium tuberculosis	Ankylostoma duodenale
Hepatitis E virus	Pasteurella	Ascaris lumbricoides
	Pseudotuberculosis	Echinococcus
	Proteus spp	Echinococcus

Protozoa	Providencia spp	multilocularis
Acanthomoeba	Pseudomonas aeruginosa	Enterobium vermicularis
Dientamoeba	Salmonella spp	Hymenolepsis nana
fragilis	Serratia spp	Necator americanus
Entamoeba	Shigella spp	Strongyloides stercoralis
hystolitica	Staphylococcus aureus	Taenia saginata
Giardia lamblia Giardia	Enterococcus spp Vibrio parahaemoliticus	Taenia solium Toxocara cati
Isospora belli	Vibrio cholerae	Toxocara canis
Naeglaria fomleri	Yersinia enterocolitica	Trichuris trichura
Palantidium coli		
Sarcocystis spp		
Toxoplasma gondii		

Table 4: Densities of Pathogens and Indicators in Sludge (Lepeuple et al., 2004)

Type	**Organism**	**Density in primary sludges (/g of dry wt)**	**Density in secondary sludges (/g of dry wt)**
Virus	Various enteric viruses Bacteriophages	10^2 - 10^4 10^5	$3x10^2$ -
Bacteria	Total coliforms Faecal coliforms *Enterococci* *Salmonella* spp *Clostridium* spp *Mycobacterium Tuberculosis*	10^8 - 10^9 10^7 – 10^8 10^6 – 10^7 10^2 –10^3 10^6 10^6	$7x10^8$ $8x10^6$ $2x10^2$ $9x10^2$ - -
Protozoa	*Giardia* spp	10^2 - 10^3	10^2 – 10^3
Helminths	*Ascaris* spp *Trichuris vulpis* *Toxocara* spp	10^2 – 10^3 10^2 10 - 10^2	10^3 < 10^2 $3x10^2$

There are 3 main types of risks which are connected with the collection and processing of sludge; these are occupational health risks, risk concerning the product safety and environmental risks. Pathogens can present a public threat if they are transferred to food crops grown on land, where sewage sludge has been applied (WHO, 2005).

Below a brief analysis of the most important pathogens is provided:

Bacteria: Bacteria found in sludge are numerous. Table 5 presents a selection of bacterial pathogens typically found in sewage sludge and the diseases or symptoms related to their presence (Epstein, 2002).

Table 5: Selection of Bacterial Pathogens of Concern in Sewage Sludge (Epstein, 2002)

Bacterial pathogen	Disease / Symptoms
Salmonella	salmonellosis gastroenteritis
Salmonella typhi	typhoid fever
Mycobacterium tuberculosis	tuberculosis
Shigella sp.	shigellosis, bacterial dysentery, gastroenteritis
Campylobacter jejuni	gastroenteritis
E. coli (pathogenic strains)	gastroenteritis
Yersinia sp.	yersiniosis
Vibrio cholerae	cholera

Salmonella is the most important one because of the risk on grazing animals; *Salmonella spp*. is naturally present in the environment. *Escherichia Coli* is naturally present in the human and animal digestive tract. *E. Coli* are not necessarily pathogenic, but are useful indicators of faecal pollution of water. *Shigella spp, Pseudomonas, Yersinia, Clostridium, Listeria, Mycobacterium, Streptococcus* and *Campylobacter* are types of pathogenic bacteria also found in sludge (WHO, 2005).

Viruses: Many types of viruses may be found in sludge such as *Enteroviruses*, *Adenovirus*, *Reovirus*, *Astrovirus*, *Calcivirus* and *Parvovirus*. *Enteroviruses* occur widely in sewage sludge in concentrations 10^2-10^4 per g of dry matter. Hepatitis A virus which is a human specific virus may also be present.

Parasites: Parasites are organized living bodies, which need a host to grow or reproduce during one or many steps of their life cycle. Different types of parasites exist, such as helminths, mushrooms or protozoa; some of them may develop a cyst or egg. Helminths are worms and include Cestodes and Nematodes. Parasites are found in sludge in concentrations

10^2-10^3 per g of dry matter. Pathogens may survive for a remarkable period of time in sludge, in the soil environment (usually within the top 2-3cm of the soil layer) and in plants (Table 6).

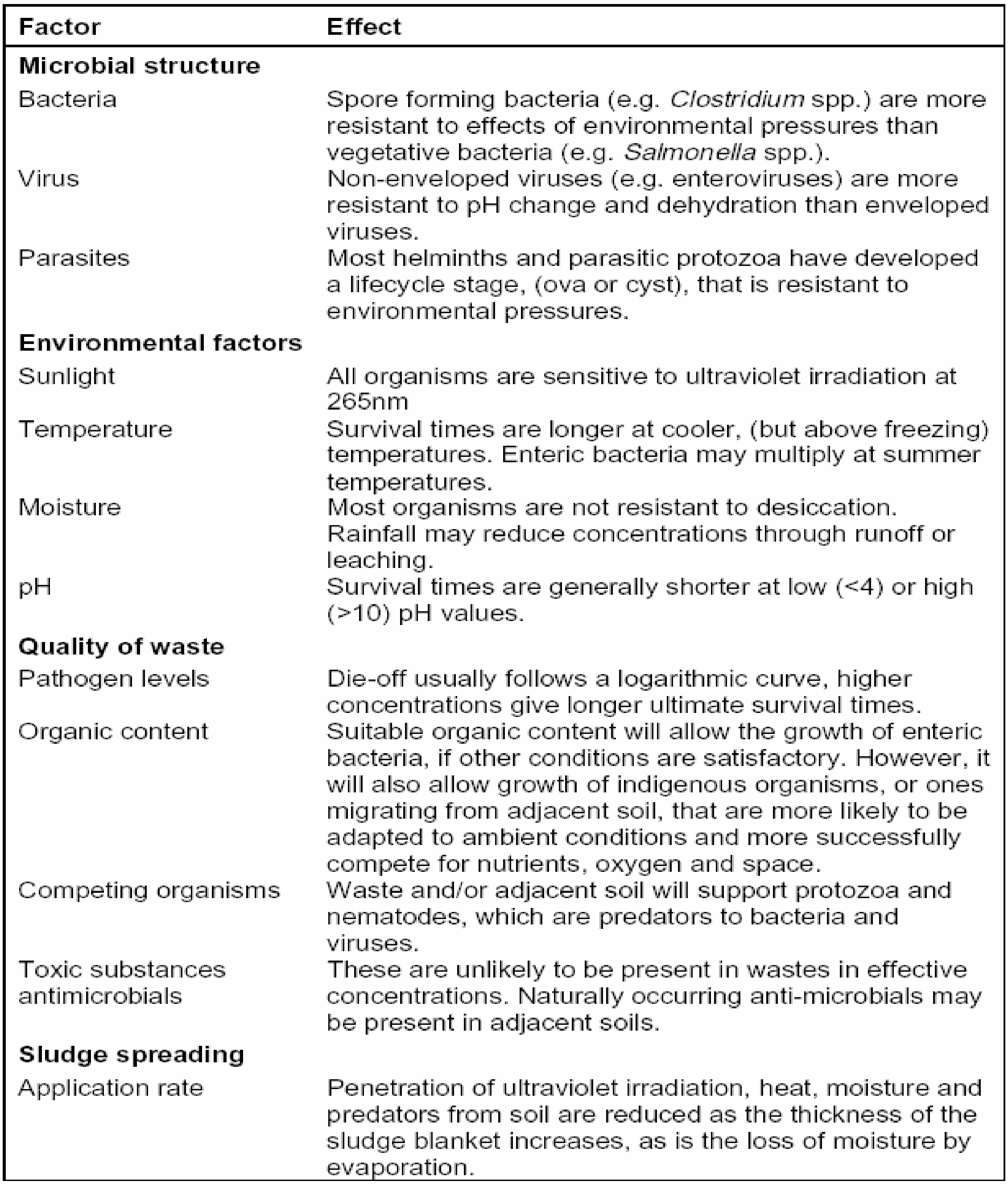
Table 6: Survival of Pathogens in Soil and Plants (WHO, 2005)

Pathogens	Survival in soil	Survival in plants
Bacteria: *Salmonella*, Coliforms	< 70 days (often < 20 d)	< 100 days (often < 20 d)
Enteroviruses	< 100 days (often < 20 d)	< 60 days (often < 15 d)
Helminths: *Ascaris, Taenia saginata*	Several months	< 60 days (often < 30 d)
Protozoa: *Entamoeba histolytica*	< 20 days (often < 10 d)	< 10 days (often < 2 d)

Although a relatively rare event, direct transmission to humans by handling contaminated products in the households, must be regarded as a risk. In addition, accidental contact of individuals to contaminated sludge or sludge products may result in infection. The occupation risks in processing and handling of sludge and related products must also be taken into account. The indirect transmission to humans is of special importance, because the introduction of pathogens into the food chain via contaminated fertiliser leading to contaminated animal feed and thus to infection of farm animals and/or excretion of pathogens is of basic epidemiological importance. The risk of transmission of pathogens to human food by living vectors such as insects, rodents and birds from processing, handling and agricultural utilisation of slurry must also be considered (WHO, 2005); (Arthur Andersen, 2001a). Table 7 provides a list of the factors that influence the survival of pathogens in sludge that is spread to land, while Table 8 gives a list of the ways pathogens are transmitted.

Prevalence of infection is only one of the factors influencing the likelihood of pathogens being available at the soil surface for transport by overland flow. The actual numbers of pathogens is important and this is affected by a number of factors such as animal age, diet, stress and season. The pathogens transmission at the soil surface is also influenced significantly by the duration and conditions of storage prior to land spreading. In the case of soilborne pathogens, the most familiar diseases are probably rots that affect tissues and vascular wilts initiated through root infections. Soilborne pathogens can be divided into soil inhabitants which are able to survive in soil for a relatively long period and soil transients which are only able to survive in soil for a relatively short time. Fungi are the most important soilborne pathogens group. Few soilborne viruses and parasites (Nematodes) affect vegetable crops (Lepeuple et al., 2004).

Table 7: Factors Influencing the Survival of Pathogens in Sludge Spread on Land (FAO, 2002)



Factor	Effect
Microbial structure	
Bacteria	Spore forming bacteria (e.g. *Clostridium* spp.) are more resistant to effects of environmental pressures than vegetative bacteria (e.g. *Salmonella* spp.).
Virus	Non-enveloped viruses (e.g. enteroviruses) are more resistant to pH change and dehydration than enveloped viruses.
Parasites	Most helminths and parasitic protozoa have developed a lifecycle stage, (ova or cyst), that is resistant to environmental pressures.
Environmental factors	
Sunlight	All organisms are sensitive to ultraviolet irradiation at 265nm
Temperature	Survival times are longer at cooler, (but above freezing) temperatures. Enteric bacteria may multiply at summer temperatures.
Moisture	Most organisms are not resistant to desiccation. Rainfall may reduce concentrations through runoff or leaching.
pH	Survival times are generally shorter at low (<4) or high (>10) pH values.
Quality of waste	
Pathogen levels	Die-off usually follows a logarithmic curve, higher concentrations give longer ultimate survival times.
Organic content	Suitable organic content will allow the growth of enteric bacteria, if other conditions are satisfactory. However, it will also allow growth of indigenous organisms, or ones migrating from adjacent soil, that are more likely to be adapted to ambient conditions and more successfully compete for nutrients, oxygen and space.
Competing organisms	Waste and/or adjacent soil will support protozoa and nematodes, which are predators to bacteria and viruses.
Toxic substances antimicrobials	These are unlikely to be present in wastes in effective concentrations. Naturally occurring anti-microbials may be present in adjacent soils.
Sludge spreading	
Application rate	Penetration of ultraviolet irradiation, heat, moisture and predators from soil are reduced as the thickness of the sludge blanket increases, as is the loss of moisture by evaporation.

Table 8: Epidemiological Importance of Processed Wastes and Residuals and of the Resulting Products (Arthur Andersen, 2001)

A. Direct transmission to farm animals - Contamination of meadows - Introduction of pathogens by storage and processing close to susceptible animals - Aerogenic transmission by spreading the materials into farm land
B. Direct transmission to humans - Handling of contaminated products in the household - Occupational exposure to contaminated products - Accidental transmission to immuncompromised persons
C. Indirect transmission to farm animals - Via feed from contaminated sites - Via living vectors
D. Indirect transmission to humans - Via introduction of zoonotic agents into the food chain - Via food contaminated by living vectors
E. Introduction into the environment - Generation of carriers in the fauna - Introduction into the microflora

2.2 Heavy Metals

Numerous heavy metals are present in sludge. Heavy metals may affect plant health and growth, soil properties and micro-organisms, livestock and human health. The most important heavy metals which are present in sludge are the following: lead (Pb), zinc (Zn), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg) and nickel (Ni) (WHO, 2005).

Lead: There are two main origins for lead in sludge: water from road runoff and alteration of old pipes. Industrial effluents may also contain lead. Only 5 to 10% of lead ingested via drinking water or foodstuffs to humans is assimilated; 90% of it is stored in the skeleton and is then slowly transferred into the blood. The principal excretion route is urine. Under exposure at high levels (1,200 µg/l in blood), paralysis of upper members and encephalopathy have been observed. Long-lasting absorption of lead in blood at concentrations of 400 µg/l results in chronic intoxication.

Zinc: Zinc in sludge originates mostly from pipe alteration and at a secondary extent from industrial effluents. Zinc is essential in the animal kingdom for many physiological processes (e.g. growth and cellular differentiation, reproductive functions etc).

Cadmium: Cadmium is principally used as a constituent in alloys and in the electroplating industry. Cadmium can also originate from household effluents as it is present in cosmetic products and in gardening pesticides. It may also result from the runoff of raining water after atmospheric deposition of the metal. Cadmium accumulates in the organism as its biological half-life is about 30 years. It is particularly toxic to animals and has been found to cause growth deficiencies and provoke cancers on some animal species. Cadmium and cadmium compounds have been classified as carcinogenic.

Nickel: Nickel in sludge originates from household effluents (cosmetic products and pigments), but also from industrial effluents. Nickel accumulates to a significant extent throughout the food chain.

Copper: Copper in sludge and wastewater results mainly from household effluents (domestic products, pipe corrosion), but can also have an industrial origin (surface treatments, chemical and electronic industry).

Chromium: Chromium may be found in several forms, mainly trivalent, or hexavalent. According to the level of industrialisation of a region, the origin of chromium found in sludge can be attributed to:

- 35-50 % from industry (surface treatment, tannery, chemical oxidation)
- 9-50 % from runoff (dust, pesticide, fertilisers)
- 14-28 % from household effluent

The two different oxidation states do not present the same level of toxicity, the hexavalent form being more toxic (EPA, 1995). Chromium VI has been classified as carcinogenic to humans.

Mercury: Mercury in sludge originates from pharmaceutical products, broken thermometers, runoff water and industrial discharges. Metal mercury impacts on human health since it attacks the nervous system. Symptoms are trembling and emotional fragility. Neuromuscular affections have also been observed.

2.3 Organic Contaminants

There are thousands of chemically synthesised compounds that are in products and materials commonly used in everyday life. Many of them end up in wastewater and are potential contaminants of sewage sludge, although their low concentration or easiness to be broken down by micro-organisms means that they do not cause a threat to the environment. However, poorly biodegradable organic compounds, commonly known as persistent organic pollutants (POPs), are not easily broken down during the treatment of wastewaters and tend to accumulate in sludge (Langenkamp & Part, 2001). POPs occurring in sewage can persist through treatment processes such as anaerobic digestion and can accumulate in soils to which sewage sludge is applied. On the whole, the persistent compounds are quite hydrophobic and they bind to soil organic matter (WHO, 2005).

Many persistent organic pollutants like PCBs, dioxins and pesticides (DDT) are known as endocrine disrupters and due to their physico-chemical properties (low water solubility), accumulate in sewage sludge. Reuse of sludge may lead to re-circulation of these persistent compounds to human food items and to animal feed. Most organic pollutants are not taken up by plants. However, a risk of contamination of the food chain exists when spreading sludge directly onto crops, especially on plants which are consumed raw or semi-cooked (WHO, 2005).

According to their chemical and physical properties the organic compounds differentiate through their water solubility. Hydrophobic and water insoluble organics result in low bioavailability to plants, of which growth depends upon their ability to absorb the necessary nutrients and minerals, which are transported via water. Therefore, if sludge is to be used in agriculture there may be problems due to the eco-toxicity of these compounds or their bio-accumulation in plants, animals or humans (Langenkamp & Part, 2001).

Soil and sludge ingestion to land used for grazing is the main route for animal contamination by organic micro-pollutants. Accumulation of compounds such as PCDD/Fs, PCBs or PAHs may occur in meat and milk. However, it is presently not possible to assess the quantities and fates of organic compounds ingested by animals. Nevertheless, it appears that the consumption of animal products is the major source of human exposure to sludge-borne organic pollutants, due to the ingestion of soil by livestock (WHO, 2005). The majority of the organic load in sludge originates from human excreta, which consists of a complex mixture of fats, proteins, carbohydrates, lignin amino acids, sugars, celluloses, humic material and fatty acids. This organic matter comprises a large proportion of both live and dead micro-organisms which provide a large surface area (0.8-1.7 m^2 g^{-1}) where the hydrophobic organic material is being absorbed and it is within this fraction that many synthetic organic compounds are located (Langenkamp & Part, 2001).

As in the case of heavy metals, it is assumed that the specific contribution of sludge-borne organic pollutants to the human diet is very low, when considering the reduced proportion of the utilised agricultural area onto which sludge spreading takes place. Due to the low concentrations in which they are found organic contaminants are not expected to pose major health problems to the human population when sludge is applied for agricultural purposes.

The “Working document on sludge” (third draft document) proposes that the following organic compounds or compound groups should be under consideration if sludge is to be used in agriculture (Langenkamp & Part, 2001):

- AOX, the so-called ‘sum of halogenated organic compounds’
- linear alkylbenzene sulphonates (LAS)
- di(2-ethylhexyl)phthalate (DEHP)
- ‘NPE’ (nonylphenole and nonylphenole ethoxylates with 1 or 2 ethoxy groups)
- polynuclear aromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs)

Table 9 provides information over the origin of the organic pollutants listed above as well as the range of their average concentration in sludge for the EU Member States.

Table 9: Origin and Average Concentration of most Important Organic Pollutants in Sewage Sludge (Huyard et al., 2001)

Organic pollutants	**Origins**	**Concentration in sludges (EU member states) Range in mg/kg DS**
PAH	Smoke – exhaust gases Strormwater runoff Industries – Oils	0.018-10
PCB	Industries – Oils	0-250
PCDD/F	Strormwater runoff Industries	few µg/kg
AOX	Oxidation by-products Papermill industries	0-250*
LAS NP/NPE	Soap and laundry by-products	50-15000
DEHP	Plastic industries Food conditioning and packaging	20-660

It should be noted that at the present time no universally accepted and validated analytical method exists for analysing most organic compounds. There is also a lack of data concerning the levels of organic pollutants in European sewage sludge as no regular survey has been performed in the past. Concern has been expressed by several countries (Denmark, Germany, Sweden, Poland) as well as by the European Commission regarding the following groups of organic pollutants: PAH (Polycyclic aromatic hydrocarbons), PCB (Polychlorinated biphenyls), PCDD/F (Polychloro-dibenzo-dioxins/furans), AOX (Sum of organohalogenous compounds), LAS (Linear alkylbenzenesulphonates), NPE (Nonylphenol and Nonylphenolethoxylates) and DEHP (Di-2-ethylexyl-phthalate). It is therefore important to briefly analyze the most important organic contaminants found in sludge (WHO, 2005):

PAH (Polycyclic aromatic hydrocarbons): PAHs are a by-product of incomplete combustion, their main source being the burning of fossil fuels. Many PAHs are known or suspected carcinogens/mutagens. PAHs are generated as by products of incomplete combustion in certain industries in which carbon and hydrogen are pyrolysed. PAHs can be acutely toxic, but generally at very high doses, making acute systemic toxicity observable in some animal tests, but not likely to occur in humans, except in industrial context.

There are three sources of PAH in sludge (WHO, 2005):

- PAHs are contained in exhaust gas and in the runoff of raining water on roads

- PAHs are generated in the fumes of industrial thermal units and may reach the soil through raining water
- PAHs are also found in industrial effluents

PAHs can concentrate strongly in sludge and are slowly degraded by biological processes of wastewater treatment. Generally PAH uptake by crops is low and does not represent a risk for the human food chain. In accordance with the aforementioned, it may be assumed that there are very few transfers of PAHs to the environment media and the food chain. Therefore, human exposure level to sludge-born PAHs is likely to be low (Langenkamp & Part, 2001)

PCB (Polychlorinated biphenyls): PCB is a group of substances obtained by chlorination of biphenyls. PCBs are not naturally present in the environment and used to be incorporated in inks or as dielectric or heat-exchange fluid. Higher chlorinated PCB mixtures are carcinogenic. Recent research also indicates that exposure to PCBs may cause reproductive changes in exposed laboratory animals and in some people with environmental exposure to PCBs. They also may have a teratogenic action, as well as impacts on the liver and thyroid. Uptake of PCB by plants under field conditions is fairly well documented and appears to be very limited (WHO, 2005).

PCDD/F (Polychloro-dibenzo-dioxins/furans): PCDD/Fs are ubiquitous in the environment at extremely low levels. In the industry, PCDD/Fs are not used as such, but are by-products of combustion reaction. They appear during the manufacture of insecticides, herbicides, antiseptics, disinfectants and wood preservatives (WHO, 2005). Therefore one significant potential source of dioxins and furans is the incineration of waste. They are destroyed at high temperature, but they may reform during the cooling phase at about 400 – 500^{o}C.

AOX: AOX stands for 'Adsorvable Organically bound halogens' expressed as chloride. AOXs are substances that are adsorbed from water onto activated carbon. AOX are formed during drinking-water disinfection with both chlorination and ozone treatment. Another main source of organic halogens has been the bleaching of paper pulp. Several other industries such as the manufacture of polyvinyl chloride (PVC) and waste incineration are important sources of AOX formation. Finally, it must be mentioned that in contaminated soils with AOX, some organic halogens may be transformed into more toxic compounds such as vinyl chloride, which is a known human carcinogen (Langenkamp & Part, 2001)

NPE: 4-Nonylphenole is a widespread degradation product of non-ionic alkylphenole polyethoxylate surfactants. Due to the problems caused by foaming on surface waters, there has been an increase in the adoption of more readily biodegradable detergents such as non-ionic 4-alkylphenole polyethoxylates, which are used in large quantities in detergents. 4-nonylphenole has been identified as a toxic degradation product of alkylphenole polyethoxylate. NPEs are used as surface active agents in cleaning products, cosmetics and hygienic products, and in emulsifications of paints and pesticides (Langenkamp & Part, 2001)

LAS: Linear alkylbenzene sulphonates (LAS) are the most widely used anionic surfactants in cleaners and detergents. Production is 1.5 to 2 million tonnes/year worldwide and 300.000 tonnes/year within the EU. LAS are readily degraded under aerobic conditions, but not at all in anaerobic environments. Since a large part of the LAS is adsorbed onto sewage solids during primary settlement of sewage, it will bypass the aeration tank and hence will not degrade in the regular treatment process. Degradation can only occur when aerobic conditions are restored during storage of sludge, and after application to land thus preventing LAS accumulation in the soil environment (Langenkamp & Part, 2001); (WHO, 2005).

DEHP: Phthalates are incorporated into plastics as plasticisers. Di-2-(ethyl-hexyl)-phthalate (DEHP) is the most common of the phthalate esters. Phthalates are used as softeners in plastic (PVCs). Other uses include additive functions in paints, laquers, glues, inks, etc. Many phthalates are degradable under both aerobic and anaerobic conditions but the sorption to particles reduces the actual degradation rate considerably. The substances have a potential for uptake in plants. They are toxic to soil organisms and some phthalates are suspected to have hormone mimic properties (Langenkamp & Part, 2001); (WHO, 2005)

PCDD/Fs: PCDD/Fs are two groups of tricyclic, planar aromatic compounds. They are not intentionally produced, but may form during the production of chlorinated compounds or during combustion processes where chlorinated substances are present (Langenkamp et al., 2001).
http://glossary.eea.europa.eu/EPER2/H/Halogenated_Organic_Compounds_AOX%20

Table 10 provides a brief overview on the behaviour of the organic compounds in soils which should be considered whenever sludge is to be used in agriculture.

Table 10: Classification of Organic Substances (Langenkamp & Part, 2001)

Substance	**Mammalian/ Human toxicity (acute)**	**Ecotoxicity**	**Water solubility**	**Persistence**	**Concentration levels**
AOX (summative parameter)	-	-	-	high	indicator
LAS	Medium	aquatic: high; terrestrial:medium; bioaccumulation: high	high; enhances mobility of other pollutants	medium	high
DEHP	low; suspected estrogenic effect	aquatic: medium to high; terrestrial: low; bioaccumulation: high	low	medium	high
Nonylphenole	medium; suspected estrogenic effect	aquatic: high; terrestrial: medium; bioaccumulation: high	high	medium	high
(PAH) B[a]P single substance	carcinogenic, mutagenic, teratogenic	high; bioaccumulation: high	low	high	High
PCBs, single substances/ summative parameter	medium; tumour promoting, immunotoxic	aquatic: high; terrestrial: high; bioaccumulation: high	low	High	low and continuing to decline
PCDD/Fs, single substance/summative parameter	high; carcinogenic	aquatic: high; terrestrial: high; bioaccumulation: high	low	High	Low
TBT Tributyltin oxide	high	aquatic: high; bioaccumulation: high; endocrine effect	medium	high	high

3 Legislative Framework on Sewage Sludge

This Section aims to provide a comprehensive analysis of the European Union (EU) legislative framework related to sewage sludge management, by identifying and introducing the legal requirements which apply when sewage sludge is treated, is applied to land and/or is disposed. The legal framework regulating sludge management is mainly based on Directive 86/278/EEC that concerns the application of sludge in agriculture. However, there are other Directives that influence sludge generation and management, which must be considered. More specifically, EU legislation on sludge is based on the following:

- ✓ The Council Directive 86/278/EEC on the protection of the environment, and in particular of soil, when sewage sludge is applied in agriculture. This Directive sets minimum quality standards for the soil and sludge used in agriculture in order to regulate its use in such a way as to prevent harmful effects on soil vegetation, animals and humans, while encouraging its correct use (i.e. land application). The limit values defined in this Directive concern heavy metal concentration for sewage sludge as well as for soil when sewage sludge is applied on land and the maximum heavy metals loads, which may be added annually to agricultural land via the application of sewage sludge. The Directive also mentions the obligations for sludge treatment and the analysis foreseen before its use in agriculture, the surfaces on which its use is prohibited as well as further requirements of sludge usage. (Council Directive 86/278/EEC)
- ✓ The Council Directive 91/271/EEC of the 21th May 1991 concerning urban wastewater treatment (91/271/EEC), known as the Urban Wastewater Treatment Directive aims to protect the environment from the adverse effects of wastewater discharges to water recipients. This Directive is concerned with the construction of sewerage collection systems and treatment plants and the discharge of wastewater to water recipients. It sets minimum sewerage collection works and treatment standards to be achieved and necessitates effective wastewater treatment methods for the removal of COD, suspended solids, and in the case of sensitive water recipients for nitrogen and phosphorus removal. In order to fulfil the requirements of Directive 91/271/EEC Member States have invested heavily in the construction of sewerage systems and of

wastewater treatment plants. As a result, the annual production of sewage sludge has risen significantly in all EU Member States (Council Directive 91/271/EEC).

✓ The Council Directive 91/676/EEC of the 12th December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources, known as the Nitrates Directive, requires the identification by the Member States of Nitrates Vulnerable Zones (NVZ). These zones are defined as areas where water quality has or will exceed EC drinking water standard in terms of nitrates concentration. The latter are defined in Directive 75/440/EEC concerning the surface water quality of surface water intended for the abstraction of drinking water in Member States (Council Directive 91/676/EEC).

✓ The Directive 2000/76/EC of the 4th December 2000 on the Incineration of Waste sets strict limit values for emissions of pollutants to air due to waste incineration (including sludge), thus making feasible only specific treatment technologies that produce very low air emission levels. Such technologies may not be affordable by certain Member States. (Council Directive 2000/76/EC)

✓ The Council Directive 1999/31/EC of 26th April 1999 on the landfill of waste impacts on sewage sludge management, as it bans the disposal of liquid waste (e.g. sludge) to landfills. This Directive aims at reducing the quantity of biodegradable waste going to landfills, and prohibits the landfilling of both liquid and untreated wastes. Consequently, it will eventually eliminate the disposal of sludge to landfills (Council Directive 1999/31/EC).

Apart from the aforementioned Directives, there is also a draft working document on sludge. More specifically, the 3rd draft “Working document on sludge” was developed in 2000 in order to promote the use of sewage sludge in agriculture, to ensure safety of land application and to harmonize quality standards. The document provides suggestions for limit values for concentrations of heavy metals and organic compounds that should restrict the use of sewage sludge in agriculture and provides suggestions for good practices in the treatment and agricultural use of sewage sludge (European Commission, 2000).

In most cases, central government is responsible for developing policy and establishing legal requirements concerning sludge management. Regional authorities often have controlling or supervisory functions. In several cases, other bodies have controlling power (e.g. the Danish Plant Directorate). In certain Member States, local authorities have competence for sludge management policy. This is the case in Austria, where there is no federal legislation for sludge. In Germany, the federal government is responsible for the general environmental framework regulations. In Spain the regions have full regulatory power and are also responsible for controlling sludge quality. In these countries, regional regulations are usually more detailed than federal legislation on sludge (Arthur Andersen, 2001b).

3.1 Sewage Sludge Generation

According to Article 2 of Directive 86/278/EEC *"Sludge" is defined as:*

(i) *residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of composition similar to domestic and urban waste waters;*

(ii) *residual sludge from septic tanks and other similar installations for the treatment of sewage;*

(iii) *residual sludge from sewage plants other than those referred in (i) and (ii) provided that its use is regulated by the Member State concerned.*

The progressive implementation of the Urban Wastewater Treatment Directive 91/271/EEC is increasing the quantities of sewage sludge in all Member States. Consequently, from an annual production of approximately 5.5 million tonnes of dry matter in 1992, the Community is heading towards nearly 9 million tonnes by the end of 2005. This increase is mainly due to the practical implementation of the Directive as well as due to the slow but constant rise in the number of households connected to sewers and in the increase in the level of treatment (up to tertiary treatment with removal of nutrients in some Member States – Figure 2) (Council Directive 86/278/EEC); (Council Directive 91/271/EEC).

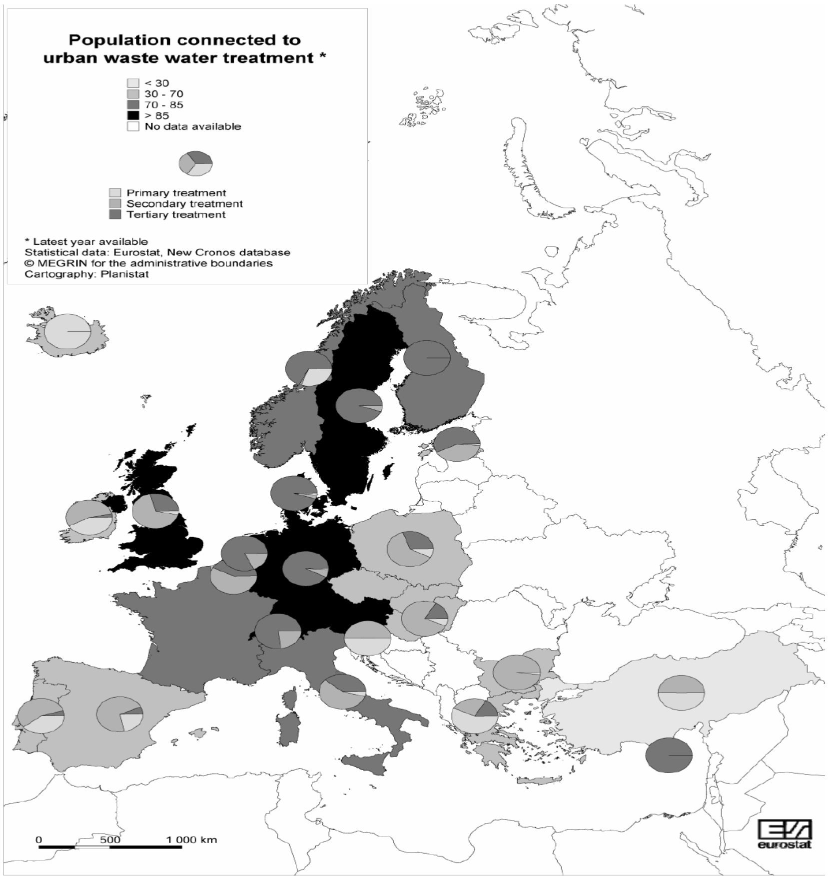


Figure 2: Population connected to UWWT and their level of treatment (Wieland, 2003)

Directive 91/271/EEC states in Article 4 that:

"Member States shall ensure that urban waste water entering collecting systems shall before discharge be subject to secondary treatment or an equivalent treatment as follows:

- *at the latest by 31 December 2000 for all discharges from agglomerations of more than 15,000 p.e. (population equivalent);*
- *at the latest by 31 December 2005 for all discharges from agglomerations between 10,000 and 15,000 p.e.;*
- *at the latest by 31 December 2005 for discharges to fresh waters and estuaries from agglomerations of between 2,000 and 10,000 p.e.*

Directive 91/271/EEC obliges Member States to (Langenkamp & Marmo 2000); (Council Directive 91/271/EEC):

- Provide prior regulation or specific authorisation for all discharges of urban wastewater and industrial wastewater from the particular sectors mentioned in the

Directive, as well as for all discharges of industrial wastewater into urban wastewater systems;

- Provide urban wastewater collection systems (sewerage) and treatment plants for all agglomerations having a p.e.[a] above 2,000
- Usually the specified level of treatment that must be provided is that of secondary treatment (i.e. biological treatment). However, the treatment must be more stringent (i.e. tertiary treatment) for discharges to sensitive areas as these are identified by Member States and may be less stringent (i.e. primary treatment) for discharges to coastal waters and estuaries identified as less sensitive areas. This less stringent treatment is subject to certain conditions and has to be authorised. The deadlines for the application of the Directive are 31/12/1998, 31/12/2000 or 31/12/2005 depending of the size of the agglomeration and the sensitivity of the receiving waters;
- Ensure that by 31/12/2000 the industrial wastewater from the covered sectors respects before discharge the established conditions for all discharges from plants having a p.e. of 4,000 or more
- Ensure by 31/12/1998 that the urban wastewater that enters collecting systems before it is discharged to sensitive areas, is subjected to more stringent treatment
- Provide prior to 31/12/1998 general rules or registration or authorisation for the sustainable disposal of sludge arising from wastewater treatment and, by the same date, phase out any dumping or discharge of sewage sludge into surface waters;
- Ensure that the urban wastewater discharges and their effects are monitored;
- Publish situation reports every two years and establish implementation programmes

Table 11 summarizes the obligations and deadlines of the Member States for the application of Directive 91/271/EEC. It clearly shows that, by the end of the year 2000, all the large cities of Europe should have provided with wastewater collection and treatment plants. In addition, the small agglomerations (less than 10,000 p.e. in sensitive areas and less than 15.000 p.e. in other areas) must have complied until 31/12/2005.

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[a] Population equivalents = a widely used measurement unit for the organic pollution of wastewater equal to the average pollution load of one person per day

Table 11: Obligations and Deadlines of Directive 91/271/EEC (Langenkamp & Marmo, 2000); (Council Directive 91/271/EEC)

Sensitivity of the receiving waters	Size of the agglomeration (p.e.)	0-2,000	2,000-10,000	10,000-15,000	15,000-150,000	>150,000
Sensitive areas		If collection [a] 31/12/2005 Appropriate treatment	Collection 31/12/2005 Secondary [b] treatment	Collection 31/12/1998 More advanced treatment	Collection 31/12/1998 More advanced treatment	Collection 31/12/1998 More advanced treatment
Normal areas		If collection [a] 31/12/2005 Appropriate treatment	Collection 31/12/2005 Secondary [b] treatment	Collection 31/12/2005 Secondary treatment	Collection 31/12/2000 Secondary treatment	Collection 31/12/2000 Secondary treatment
Less sensitive areas		If collection [a] 31/12/2005 Appropriate treatment	Collection 31/12/2005 Appropriate treatment	Collection 31/12/2005 Primary or secondary treatment	Collection 31/12/2000 Primary or secondary treatment	Collection 31/12/2000 Primary (exceptional) or secondary treatment

The Directive also focuses on the quality of the final wastewater effluent that is to be discharged to water recipients. Specific limits for Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) are provided for disposal to normal recipients (Table 12), while for disposal to sensitive recipients limits are set also for nitrogen and phosphorus (Table 13). Sensitive water recipients are defined as areas particularly susceptible to eutrophication, surface waters intended for the abstraction of

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[a] In small agglomerations (p.e. < 2000) collection systems are not obligatory

[b] Appropriate treatment if discharge to coastal waters

drinking water with high nitrate levels and other waters that require a higher standard of treatment to satisfy the requirements of other Directives.

The implementation of the above mentioned obligations has resulted in an overall increase of secondary and tertiary sewage sludge that is produced.

Table 12: Requirements for Discharges from Urban Wastewater Treatment Plants (Council Directive 91/271/EEC)

Parameter	Limit Concentrations (mg/l)	Minimum Percentage Reduction (%)[b]
Biochemical Oxygen Demand (BOD_5 at 20°C)	25	70-90
Chemical Oxygen Demand (COD)	125	75
Total Suspended Solids (TSS)	35[c] for P.E. > 10,000 60 for P.E. = 2,000-10,000	

Table 13: Requirements for Discharges from Urban Wastewater Treatment Plants to Sensitive Areas (Council Directive 91/271/EEC)

Parameter	Concentration (mg/l)	Minimum Percentage of Reduction (%)[d]
Total Nitrogen	15 for p.e 10,000-100,000 10 for p.e. >100,000	80
Total Phosphorus	2 for p.e 10,000-100,000 1 for p.e. >100,000	70-80

Consequently, the implementation of the Urban Wastewater Treatment Directive in the Member States has already resulted in an increase of the produced sludge. In the years to come the quantities of generated sewage sludge will continue to grow, particularly in the ten

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[b] Reduction in relation to the influent load
[c] Optional requirement
[d] Reduction in relation to the influent load

new Member States, as they will seek to conform fully to the Directive's requirements. It is important to mention that the Directive implementation has also resulted in a change on the proportion of the different types of sludge (increase of the proportions of secondary and tertiary sludge). Consequently, the management of sewage sludge and particularly the various management-disposal routes are of paramount importance.

Directive 86/278/EEC was adopted in order to regulate the use of sewage sludge in agriculture, in such a way as to prevent harmful effects on soil, vegetation, animals and humans. The term "sludge" is defined as (Council Directive 86/278/EEC):

(i) *Residual sludge from sewage plants treating domestic or urban waste waters and from other sewage plants treating waste waters of composition similar to domestic and urban waste waters;*

(ii) *Residual sludge from septic tanks and other similar installations for the treatment of sewage;*

(iii) *Residual sludge from sewage plants other than those referred in (i) and (ii) provided that its use is regulated by the Member State concerned*

Member States have transposed these specifications into their national legislation of sludge. However, the sludge regulations in Belgium, Denmark, Italy and the Netherlands apply to the use in agriculture of both urban sewage sludge and industrial sludge (Arthur Andersen, 2001b):

- ✓ In Belgium, the Walloon Government Order of 12 April 1995 covers residual sludge originating from domestic and industrial waste water treatment plants. In Flanders, the Decree of 16 April 1998 covers the land spreading of both industrial waste and urban sewage sludge.
- ✓ In the case of Denmark, the Order No. 49 of January 20, 2000 on the "*Application of waste products for agricultural purposes*" applies to the land spreading of industrial and municipal waste (including sludge).
- ✓ In Italy, the Decree 99/92 defines sludge as residues from the treatment of urban waste waters and of industrial waste waters. The Decree applies both to urban sewage sludge and to industrial sludge of similar characteristics.
- ✓ According to the Dutch National Legislation (Decree of 20 November 1991) sludge is defined as industrial sludge as well as urban sewage sludge.

The scope of national regulations on sludge is in most cases very similar to the definitions provided by the Directive 86/278/EEC. Very few specific provisions for sludge from septic tanks are included in national regulations. In most countries, requirements for sludge originating from specific industrial sectors are not mentioned. Land spreading of industrial sludge is in fact covered in the majority of countries by regulations on the use of waste on land or on waste management. Nevertheless, the Danish regulation (Statutory Order No. 2000/49) specifies treatments and possible uses for several types of industrial sludge. In France, specific provisions on land spreading of industrial waste or sludge are provided in the Order of August 17, 1998. This Order prohibits land spreading of certain types of abattoir sludge. In addition, the same Order states that only waste products likely to be of positive or nutritive effect for the crops can be used in agriculture. It is also important to note that in the United Kingdom, several types of industrial sludge, applied to agricultural land, are exempt from licensing under waste regulations to permit the beneficial recovery of certain wastes (Arthur Andersen, 2001b).

3.2 Land Application of Sludge

According to Article 2 of Directive 86/278/EEC land spreading of sludge is defined as the spreading of sludge on the soil or any other application of sludge on or in the soil. The most common recycling route of sewage sludge is its land spreading to agricultural land. The application of sludge in agriculture is beneficial as it improves the physical, chemical and biological properties of soils, which may enhance crop growth. Land application of treated sludge is high in the hierarchy of the EU as it results in the recycling of the essential nutrients and it enriches the soil with organic matter. In addition, the use of sludge as a fertilizer decreases the amounts of chemical fertilizers needed in agriculture and supplies micro-nutrients which are not commonly restored in routine agricultural practices. Thus, sludge use in agriculture could help save non-renewable materials; the latter is a prerequisite to achieve sustainable production (Langenkamp & Marmo, 2000)); (Tidestrom, 1997); (OCDE, 1992).

Directive 86/278/EEC was adopted in order to regulate the use of sludge in agriculture in such a way as to prevent harmful effects on soil, vegetation, animals and humans, thereby encouraging the correct use of such sewage sludge (Council Directive 86/278/EEC).

The Directive 86/278/EEC sets maximum allowable limits for specific contaminants in sludge and in soil where sludge is applied. The Directive also specifies certain surfaces on which the use or the supply of sludge is prohibited. More specifically, Article 7 provides restrictions concerning the spreading of sludge on:

(a) *grassland or forage crops if the grassland is to be grazed or the forage crops to be harvested before a certain period has elapsed. This period, which shall be set by the Member States taking particular account of their geographical and climatic situation, shall under no circumstances be less than three weeks;*

(b) *soil in which fruit and vegetable crops are growing, with the exception of fruit trees;*

(c) *ground intended for the cultivation of fruit and vegetable crops which are normally in direct contact with the soil and normally eaten raw, for a period of 10 months preceding the harvest of the crops and during the harvest itself.*

These provisions have been adopted by Member States, but in different ways depending on the country. For instance, Ireland, Portugal and the United Kingdom have transposed the exact requirements of the Directive. Other countries such as Belgium, Italy and Austria have introduced longer periods before sludge spreading. Austria and Germany have introduced restrictions on specific crops or on agricultural practices in order to privilege the ploughing down of sludge. The differences between the national regulations and Directive’s requirements over the usage of sludge in certain surfaces are summarised in the Table 14 (Council Directive 86/278/EEC); (Arthur Andersen, 2001b). For example, according to the German Fertilizer Act, which coordinates sewage sludge usage in agriculture, sludge cannot be applied in fruit and vegetable cultivation, on grassland, in nature conservation areas, in forests and near water catchments/wells respectively in water protection areas.

Table 14: Comparison Between National Legislations in Member States and Directive 86/278/EEC Requirements over the Application of Sludge in Certain Surfaces (Arthur Andersen, 2001b)

Directive 86/278/EEC	**Grassland** or **forage crops** if the grassland is to be grazed or the forage crops to be harvested before a certain period has elapsed. This period, shall under no circumstances be less than **three weeks**	Soil in which **fruit and vegetable crops are growing**, with the exception of fruit trees	Ground **intended** for the cultivation of **fruit and vegetables** crops which are normally in **direct contact with the soil and normally eaten raw**, for a period of **10 months** preceding the harvest of the crops and during the harvest itself
Austria	Prohibition on meadows, pasture, alpine pastures	=	Prohibition on vegetable crops, berries or medicinal herbs; no growing of these crops before 1 year
Belgium (Flanders)	6 weeks delay	=	=
Belgium (Walloon)	6 weeks delay	=	=
Denmark	=	=	=
Finland	Ploughing down compulsory	=	Potatoes, root crops and vegetables may not be cultivated on arable land before a 5 year delay
	Sludge may be used only on soil on which grain, sugar beet, oil-bearing crops or crops not used for human food or animal feed are cultivated		
France	=	=	=
Germany	Prohibition		
Greece	=	=	=
Ireland	=	=	=
Italy	5 weeks delay	=	=
Luxembourg	4 weeks delay	=	=
Netherlands	Prohibition on forage crops land prohibition during the grazing season	=	=

	on grazing land		
Portugal	=	=	=
Spain	=	=	=
Sweden	Prohibition on grazing land, in arable land which is to be used for grazing or if fodder crops are to be harvested within ten months of the time the sludge is spread	=	=
UK	=	=	=
Estonia	2 months for fodder crops		1 year delay
Latvia	Prohibition	No restriction	Restriction concerning spreading period according to crop type
Poland	Prohibition	No restriction	18 months delay

= stands for no difference from the Directive

Moreover, many Member States have included more specifications than those provided by the Directive by providing additional requirements on sludge spreading in order to reduce the negative impact that land spreading can introduce to the environment. These restrictions prohibit the use of sludge for agricultural purposes near surface water areas, on wet land, on forest soils, on frozen or snow-covered ground and on sloping land. Table 15 summarises the restrictions on land application of sludge which are adopted by each country. This table takes into account only mandatory prescriptions and does not address potential existing recommendations, codes of practice or voluntary agreements (Arthur Andersen, 2001b).

Table 15: Surfaces on which Land Spreading of Sludge is Prohibited (Arthur Andersen, 2001b)

Requirements Introduced in National Legislation by Member States, in Comparison to Directive 86/278/EEC (Article 7)

	Frozen or snow covered ground	Sloping land	Wet land or after heavy rain	Groundwater protection areas	Near surface waters	Forest soil	Additional restrictions
Austria	X	X[a]			X[b]	X	
Belgium (Flanders)				X		X	
Belgium (Walloon)	X		X		X[c]	X	Natural reserves areas
Denmark				X	X	X[d]	On surfaces where sludge is likely to cause significant nuisances or unsanitary conditions
Finland							
France	X	X	X	X	X	X[e]	Not regularly worked out land In areas close to human settlements and public buildings
Germany				X	X	X	
Greece							
Ireland							
Italy		X[f]	X				Soils of pH < 5, and CEC< 8 meq/100 g
Luxembourg			X			X[g]	On biotopes and protected areas as defined in the Act on nature and natural resources protection
Netherlands	X					X[h]	On « miscellaneous » land and undisturbed ground

Portugal			X	X	X		In areas close to individual houses and human settlements
Spain							
Sweden							
UK							Soils of pH < 5
Estonia	X		X				Soils of pH < 6
Latvia	X	X[j]		X	X		
Poland	X	X[j]	X	X	X		National parks and protected areas Near individual housing and human settlements Soils of high permeability Crops grown under greenhouses

[a] for sludge containing less than 10% of DM = dry mass

[b] caution must be taken to avoid impacts on those waters

[c] below 10 m from surface watersd restricted use allowed

[e] use allowed in case of risk minimisation

[f] slope higher than 15% when the DM content is less than 30%

[g] after licensing from the Ministry of environment. Same restriction within 30 m near forests borders

[h] allowed for certain kinds of plantations

[j] slopes higher than 10 %

The working document on sludge recommends avoiding the use of sludge on soils whose pH is less than 5.0, on water saturated, flooded, frozen or snow-covered ground. Land spreading of sludge must take place in such a way as not to cause sludge run-off and minimize soil compaction as well as the production of aerosols. Sludge can be used on land only if the conditions listed below are followed (European Commission, 2000).

- The load limits set in Table 25 must not be exceeded, with the possible exception of land reclamation for one-off applications
- There must be an agronomic interest for nutrients or for the improvement of the content of organic matter in soil
- The quantity of nutrients introduced must be adapted to the needs of the crops or the soil according to best practice
- Sludge application must not cause unreasonable odour nuisance to the nearest dwellings

If it is decided that sludge should be applied on soil then it is recommended that advanced and conventional treatment processes take place as specified on Table 16.

Certain Member States have specified maximum quantities of sludge, which can be spread on land. These range between 1 ton (Netherlands, on grassland) and 10 tonnes (Denmark) per hectare per year, as summarised in Table 17. However, in practice, the quantities used on land usually do not exceed 2 tonnes per hectare per year.

Table 16: Surfaces on which Advanced and Conventional Treatment of Sludge are Recommended According to the Working Document on Sewage Sludge (European Commission, 2000)

Type of land or crop	Advanced treatment	Conventional treatment
Pastureland	Yes	Yes, deep injection and no grazing in the six following weeks
Forage crops	Yes	Yes, no harvesting in the six weeks following spreading
Arable land	Yes	Yes, deep injection or immediate ploughing down
Fruit and vegetable crops in contact with the ground	Yes	No. No harvest for 12 months following application
Fruit and vegetable crops in contact with the ground eaten raw	Yes	No. No harvest for 30 months following application
ruit trees, vineyards, tree plantations and re-afforestation	Yes	Yes, deep injection and no access to the public in the 10 months following spreading
Parks, green areas, city gardens, all urban areas where the general public has access	Yes	No
Forest	No	No
Land reclamation	Yes	Yes, no access to the public in the 10 months following spreading

Table 17: Maximum Quantities of Sludge to be Spread on Land (Arthur Andersen, 2001a) This table has to be read as follows: “4/2 years” stands for 4 tonnes of dry matter per ha every 2 years

	Application rate (tonnes DM per ha)
Directive 86/278/EEC	-
Austria	2.5-10/2 years [a]
Belgium (Flanders)	4 / 2 years (arable land) 2 / 2 years (pasture land)
Belgium (Walloon)	12 / 3 years (arable land) 6 / 3 years (pasture land)
Denmark	10 / year
Finland	-
France	-
Germany	5 / 3 years
Greece	-
Ireland	2/ year
Italy	-
Luxembourg	3 / year
Netherlands	2 – 4/year on arable land [b] 1 – 2 /year on grassland [b]
Portugal	6 / year
Spain	-
Sweden	-
UK	-
Estonia	-
Latvia	-
Poland	-

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[a] depending on the Land, the DM content and the sludge type
[b] depending on the sludge structure (liquid or solid sludge)

3.2.1 Pollutant Limits in Sludge and Soil

Directive 86/278/EEC specifies limit concentrations of heavy metals for sludge and soil where sludge is applied. However, no limit values are specified for organic pollutants or for pathogenic micro-organisms.

Heavy Metals

One of the most important causes of concern in the application of treated sludge to land is the presence of high concentrations of micro-pollutants and particularly heavy metals, which can penetrate the soil and pose a serious threat to human health and other living organisms, including plants.

The top layer of soil is of crucial importance for the well-being of soil micro-organisms, plants and animals. Heavy metals may have the effect of impairing the natural mechanisms through which soil microbes reproduce and therefore deplete the bio-potential of the soil eco-system. Moreover, if the concentration is high enough, heavy metals can penetrate the natural cell barriers in plant roots and end up in the edible part of vegetables. Some heavy metals can then accumulate in animal and human organs and cause poisoning effects, induce cancer or produce mutagenic changes (Langenkamp & Marmo, 2000).

Directive 86/278/EEC seeks to prevent the accumulation of heavy metals in the soil above a threshold limit; this threshold value is deemed to be safe for crop yields, animals and humans. Therefore, in accordance to Article 5 of the Directive the use of sludge (which is defined in Article 2 as the spreading of sludge on the soil or any other application of sludge on or in the soil) in agriculture is prohibited if the heavy metals concentrations exceed specific limit values. Directive 86/278/EEC sets limit values for heavy metals in soil where sludge is applied (Table 18) and for heavy metals of the actual sludge that is applied to land (Table 19) (Council Directive 86/278/EEC).

The Directive quotes that sludge application on land shall be prohibited when at least one of the heavy metals concentration exceeds the limit values on soil, which have been set out in the Directive as indicated on Table 18. In addition, Member States have to ensure that those limit values are not exceeded as a result of the use of sludge.

Table 18: Limit Values for Concentrations of Heavy Metals in Soil (mg/kg of dry matter, soil with a pH of 6 to 7) (Council Directive 86/278/EEC)

Parameters	Limit Values[1]
Cadmium	1 - 3
Copper[2]	50 - 140
Nickel[2]	30 - 75
Lead	50 - 300
Zinc[2]	150 - 300
Mercury	1 - 1.5
Chromium	-

Moreover, at the same article, the Directive allows the Member States to regulate the use of sludge by two processes so that the accumulation of heavy metals does not reach the limit values. Therefore, Member States are allowed to choose between the two following procedures:

- ✓ Deposit the maximum quantities of sludge expressed in tonnes of dry matter, which may applied to the soil per unit of area per year, so that the limit values, indicated in Table 19 are not exceed.
- ✓ Ensure the limit values for amounts of heavy metals which may be added annually to agricultural land, based on a 10-year average are not exceeded, as shown in Table 20

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[1] Member States may permit the limit values they fix to be exceeded in the case of the use of sludge on land which at the time of notification of the Directive is dedicated to the disposal of sludge but on which commercial food crops are being grown exclusively for animal consumption. Member States must inform the Commission of the number and type of sites concerned. They must also seek to ensure that there is no resulting hazard to human health or the environment.

[2] Member States may permit the limit values they fix to be exceeded in respect of these parameters on soil with a pH consistently higher than 7. The maximum authorized concentrations of these heavy metals must in no case exceed those values by more than 50%. Member States must also seek to ensure that there is no resulting hazard to human health or the environment and in particular to ground water

Table 19: Limit Values for Heavy Metal Concentrations in Sludge for use in Agriculture (Council Directive 86/278/EEC)

Parameters	Limit Values (mg/kg of dry matter)
Cadmium	20 - 40
Copper	1000 - 1750
Nickel	300 - 400
Lead	750 - 1200
Zinc	2500 - 4000
Mercury	16 - 25
Chromium[3]	-

Table 20: Limit Values for Amounts of Heavy Metals which may be Added Annually to Agricultural Land, based on a 10-year Average (Council Directive 86/278/EEC)

Parameters	Limit Values[1] (kg/ha/yr)
Cadmium	0.15
Copper	12
Nickel	3
Lead	15
Zinc	30
Mercury	0,1
Chromium	-

Certain Member States such as Finland, France, Luxembourg, Netherlands and Sweden have chosen to establish limit values for heavy metals in sludge and for maximum annual average loads of heavy metals (Table 19), while others, such as United Kingdom, define limit values for the quantities of metals introduced in the soil due to sludge application as a 10-year mean value in accordance with Table 20 (Arthur Andersen, 2001b).

Most of the old EU Member States have adopted Council Directive 86/278/EEC between 1988 and 1993; however, as stated in article 12 "*where conditions so demand Member states have taken more stringent measures than those provided by the Directive*". Therefore, in many

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[1] Member States may permit these limit values to be exceeded in the case of the use of sludge on land which at the time of notification of this Directive is dedicated to the disposal of sludge but on which commercial food crops are being grown exclusively for animal consumption. Member States must inform the Commission of the number and type of sites concerned. They must also ensure that there is no resulting hazard to human health or the environment.

cases the limit values for heavy metals in sludge, defined in national regulations, have been set significantly below the requirements of Directive 86/278/EEC as shown in Table 21.

Table 21: Limit values for Heavy metals in Sludge (mg/kg DM) (Shaded shells represent limit values below those required by Directive 86/278/EEC) (Arthur Andersen, 2001b)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Mo	Co
Directive 86/278/EEC	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000	-	-	-
Austria	2^a 10^b 10^c 4^d 10^e 0,7-$2,5^f$	50^a 500^b 500^c 300^d 500^e 70-100^f	300^a 500^b 500^c 500^d 500^e 70-300^f	2^a 10^b 10^c 4^d 10^e 0,4-$2,5^f$	25^a 100^b 100^c 100^d 100^e 25-80^f	50^a 500^b 500^c 300^d 500^e 70-100^f	1500^a 2000^b 2000^c 1800^d 2000^e 200-1800^f	20^e	20^e	10^a 100^e
Belgium (Flanders)	6	250	375	5	100	300	900^f	150	-	-
Belgium (Walloon)	10	500	600	10	100	500	2000		-	-
Denmark -dry matter basis -total phosphorus basis	0,8 100	100	1000	0,8 200	30 2500	120^g 10000^g	4000	25^h		
Finland	3 $1,5^i$	300	600	2 1^i	100	150 100^i	1500	-	-	-
France	20^j	1000	1000	10	200	800	3000	-	-	-
Germany	10	900	800	8	200	900	2500	-	-	-
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000	-	-	-
Ireland	20	-	1000	16	300	750	2500	-	-	-
Italy	20	-	1000	10	300	750	2500	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000	-	-	-
Netherlands	1,25	75	75	0,75	30	100	300	-	-	-
Portugal	20	1000	1000	16	300	750	2500	-	-	-
Spain -soil pH<7 -soil pH>7	20 40	1000 1750	1000 1750	16 25	300 400	750 1200	2500 4000			
Sweden	2	100	600	2,5	50	100	800	-	-	-
UK	-	-	-	-	-	-	-	-	-	-
Estonia	15	1200	800	16	400	900	2900	-	-	-
Latvia	20	2000	1000	16	300	750	2500	-	-	-
Poland	10	500	800	5	100	500	2500	-	-	-

[a] Lower Austria (grade II)

[b] Upper Austria

[c] Burgenland
[d] Vorarlberg

[e] Steiermark

[f] Carinthia

[f] These values are reduced to 125 (Cu) and 300 (Zn) from 31/12/2007

[g] For private gardening, lead value is reduced to 60 mg/kg DM or 5000 mg/kg P
[h] For private gardening
[i] Target limit values for 1998
[j] 15 mg/kg D mg/kg DM from January 1, 2001 and 10 mg/kg DM from January 1, 2004

Table 21 shows that EU countries such as Denmark, Finland, Sweden and Netherlands have laid down in there national legislations the most stringent limit values on heavy metals concentration, which in some cases represent less than 10% of the limit value established by Directive 86/278/EEC. For instance, the limit value for cadmium in sludge according to Danish legislation is 0.8 mg/kg of dry matter, a value that is 25 times less than the limit value set by the Directive (20 mg/kg of dry matter). However, it has to be noticed that Nordic countries generally use extraction methods based on nitric acid (HNO_3), which are weaker than methods based on “aqua regia” more common in the rest of Europe. Without questioning the severity of some legislation this should be kept in mind when considering differences. On the other hand Member States like Greece, Luxembourg, Ireland, Italy, Portugal and Spain have set limit values for heavy metals in sludge, which are mostly similar to the limit values set by Directive 86/278/EEC (Arthur Andersen, 2001b).

As far as the ten new Member States are concerned, the situation is quite diverse. For example, Poland has set more stringent limits for heavy metals in sludge, while Estonia and Latvia have set limit values similar to those of the Directive 86/1278/EC. The limit values set in the Polish regulation are significantly lower than EU standards. In particular, limit values in Poland for cadmium content in sludge is 10 mg/kg of dry matter and 5 mg/kg of dry matter for mercury. Table 22 shows which Member States have set more stringent or similar limit values for heavy metals in comparison to the Directive 86/278/EEC (Arthur Andersen, 2001b).

Table 22: National Requirements Compared to EU Requirements for Heavy Metal Concentration in Sludge

Much more stringent	Denmark, Finland, Sweden, Netherlands
More stringent	Austria, Belgium, France, Germany Poland
Similar	Greece, Ireland, Italy, Luxembourg, Portugal, Spain, United Kingdom, Estonia, Latvia

The latest working document on sludge (3rd draft document), initiated by the EU, recommends further and more stringent limit values for the heavy metal concentration in soil where sludge is applied. More specifically, the document states that sludge application on land shall be prohibited when at least one of the heavy metals concentrations exceeds the limit values on soil as indicated in Table 23. Furthermore, the working documents suggests new limit values for heavy metals in sludge which usually lie at the lower range of the allowable values set by Directive 86/278/EEC (Table 24) (European Commission, 2000).

Table 23: Limit Values for Concentration of Heavy Metals in Soil According to the Directive 86/278/EEC and to the Draft Working Document on Sludge (European Commission, 2000); (Council Directive 86/278/EEC)

Elements	**Limit values (mg/kg dm)**			
	Directive 86/278/EEC 6<pH<7	5<=pH<6	6<=pH<7	pH=>7
Cd	1-3	0.5	1	1.5
Cr	-	30	60	100
Cu	50-140	20	50	100
Hg	1-1.5	0.1	0.5	1
Ni	30-75	15	50	70
Pb	50-300	70	70	100
Zn	150-300	60	150	200

The working document on sludge states that when the concentration value of an element in a specific land area is higher than the concentration limit set in Table 23 for soil, the competent authority may still allow the use of sludge on that land on a case-by-case basis and after evaluation of the following aspects (European Commission, 2000):

- Uptake of heavy metals by plants
- Intake of heavy metals by animals

- Groundwater contamination
- Long-term effects on bio-diversity and in particular on soil biota.

Furthermore, the working document on sludge suggests that the areas of land with higher heavy metal concentrations shall be monitored and the possibility of using sludge shall be subject to a periodical assessment by the competent authority. In addition, the use of sludge should not take place if the concentration of one or more heavy metals in sludge is higher than the concentration limits of Table 24 which are suggested by the sludge working document. Table 24 also provides a comparison of the limit values of Directive 86/278/EEC and those of the draft working document on sludge for heavy metal concentration in sludge.

Table 24: Limit Values for Concentration of Heavy Metals in Sludge for Use on Land (European Commission, 2000); (Council Directive 86/278/EEC)

Elements	**Limit values (mg/kg dm)**		**Limit values (mg/kg P)**
	Directive 86/278/EEC	Proposed in sludge working document	Proposed in sludge working document
Cd	20-40	10	250
Cr	-	1000	25000
Cu	1000-1750	1000	25000
Hg	16-25	10	250
Ni	300-400	300	7500
Pb	750-1200	750	18750
Zn	2500-4000	2500	62500

It must be noted that in Table 24 a supplementary method of measurement is being used in order to indicate the content of the heavy metals in relation to the phosphorus level. The sludge producer may choose to follow either the dry matter related or the phosphorus related limit values. The reason this method is introduced is that the measurement criterion of metal concentration in mg metal/kg dry matter has certain limitations as stated in paragraph 3.4 of the Opinion of the Economic and Social Committee on ‘The revision of Council Directive 86/278/EEC on the use of sewage sludge in agriculture’ (2001/C14/26) according to which (Opinion 2001/C14/26):

- *Metal concentration can be diluted by mixing sludge from treated sewage with lime, sand, peat, animal manure etc. thereby obtaining concentrations below the mg metal/kg dry matter limit value.*

- *The degree of decomposition/digestion plays a role; a more digested or composted material will have a higher metal concentration per kg dry matter;*
- *This measurement gives no indication of the element's origin. For instance, sludge and animal manure can have roughly the same metal concentration. In the former case, 95% of these metals will stem from technology-related environments and, in the latter, most metals will derive from feeding stuffs and the farmer's own land.*

The working document on sludge (3rd Draft) also proposes in Table 25 new maximum quantities of heavy metals that can be introduced in soil annually, based on a 10-year average. However, an exemption could be foreseen for land reclamation where a one-off large application of sludge is needed to raise the soil organic matter content and promote biological activity in the soil. In this particular occasion the limit values must still lay down in accordance with Tables 23, 24 and 28.

Table 25: Limit Values for Amounts of Heavy Metals which may be Added Annually to Soil Based on a 10-year Average (Council Directive 86/278/EEC); (European Commission, 2000)

Elements	**Limit values (g/ha/y)**	
	Directive 86/278/EEC	Proposed by Working Document of sludge
Cd	150	30
Cr	-	3000
Cu	12000	3000
Hg	100	30
Ni	3000	900
Pb	15000	2250
Zn	30000	7500

The competent authority may decide to allow an increase in the loading rate for copper and zinc on a case by case basis for those lands that are copper or zinc-deficient and if it has been proven by qualified expert advice that there is a specific agronomic need for the crops.

Member States have also set national regulations on the use of sludge in soil by specifying limit values for heavy metals introduced in soil which are in most cases similar or lower than the requirements set in Directive 86/278/EEC as it shown in Table 26. Some countries (Spain, Portugal, and the UK) have defined limit values for several categories of soil pH, while regulations in Latvia and Poland have distinguished several categories of soil based on their granulometric content. In addition, the legislation in several Member States includes limitations in terms of the maximum annual load of heavy metals to agricultural land, on a ten years basis (Finland, France, Luxembourg, Netherlands, Sweden, as well as Belgium-Flanders- and three Länder in Austria). In most countries, sludge cannot be used when these limit values are exceeded; however, the regulation in the United Kingdom specifies that when limits are exceeded, sludge can be used on "dedicated sites" which are defined as areas of agricultural land. Similarly, in Luxembourg, the regulation specifies that where the concentration of any heavy metals exceeds limit values, sludge may nevertheless be used on lands wit the aim of eliminating sludge and on which only commercial crops exclusively intended for animal food may be cultivated (Arthur Andersen, 2001b).

Pathogens

Directive 86/278/EEC does not set specific requirements for pathogen content in sludge used in agriculture. However, in order to reduce potential health risks related to pathogens, several national regulations have added limitations concerning the pathogen content for sludge applied to land. This is the case in France, Italy, Luxembourg and in two Länder in Austria (Burgenland and Lower Austria). According to legislation in Poland, sludge may not be used if it contains salmonella and other pathogenic elements. In Denmark, requirements on pathogens only concern sludge that has received advanced treatment, which must have no occurrence of salmonella, while faecal streptococci must be below 100 per g (SO/2000/49). The most common pathogens which are addressed by legislation are salmonella and enteroviruses. The limit values for pathogens are quite different among the Member States and are presented in Table 27 (Arthur Andersen, 2001b).

Table 26: Limit Values for Heavy Metals in Soil (mg/kg DM) - Shaded shells represent limit values below those required by Directive 86/278/EEC (Arthur Andersen, 2001b)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn	As	Mo	Co
Directive 86/278/EEC	1-3	-	50-140	1-1,5	30-75	50-300	130-300	-	-	-
Austria	1.5[a] 1[b] 2[c] 2[d] 2[e] 0,5-1,5[f]	100[a] 100[b] 100[c] 100[d] 100[e] 50-100[f]	60[a] 100[b] 100[c] 100[d] 100[e] 40-100[f]	1[a] 1[b] 1.5[c] 1[d] 1[e] 0,2-1[f]	50[a] 60[b] 60[c] 60[d] 60[e] 30-70[f]	100[a] 100[b] 100[c] 100[d] 100[e] 50-100[f]	200[a] 300[b] 300[c] 300[d] 300[e] 100-200[f]	-	10[e]	50[e]
Belgium (Flanders)	0.9	46	49	1.3	18	56	170	22	-	-
Belgium (Walloon)	2	100	50	1	50	100	200	-	-	-
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	1.5	100	60	1	50	100	200	-	-	-
Greece	1-3	-	50-140	1-1.5	30-75	50-300	150-300	-	-	-
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	-	-	-
Netherlands	0.8	100	36	0.3	35	85	140	-	-	-
Portugal								-	-	-
- soil pH<5.5	1	50	50	1	30	50	150			
- 5.5<soil pH<7	3	200	100	1.5	75	300	300			
- soil pH>7	4	300	200	2	110	450	450			
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	100-150	-	-	-
UK								-	-	-
- 5<soil pH<5.5	3	-	80	1	50	300	200			
- 5.5<soil pH<6	3	-	100	1	60	300	250			
- 6<=soil pH<=7	3	-	135	1	75	300	300			

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[a] Lower Austria (grade II)
[b] Upper Austria
[c] Burgenland
[d] Vorarlberg
[e] Steiermark
[f] Carinthia

- soil pH>7	3	-	200	1	110	300	450			
Estonia	3	100	50	1.5	50	100	300	-	-	-
Latvia	0.3-1	15-30	10-25	0.1-0.15	8-30	15-30	35-100	-	-	-
Poland	1-3	50-100	25-75	0.8-1.5	20-50	40-80	80-180	-	-	-

Table 27: National Limit Values for Pathogens Concentrations in Sludge (Arthur Andersen, 2001b)

	Salmonella	**Other pathogens**
France	8 MPN/10 g DM	Enterovirus: 3 MPCN/10 g of DM
		Helminths eggs: 3/10 g of DM
Italy	1000 MPN/g DM	
Luxembourg		Enterobacteria: 100/g
		No egg of worm likely to be contagious
Poland	Sludge cannot be used in agriculture if it contains salmonella	"Parasites": 10/ kg of DM
MPN: Most Probable Number		
MPCN: Most Probable Cytophatic Number		

Regulatory requirements on pathogen content in sewage sludge still remains quite limited in national legislations. This can be partly explained by the fact that national codes of practice are considered to sufficiently cover this issue, by providing recommendations on sludge treatment and sludge land spreading. For example, in the United Kingdom the Code of Practice for Agricultural Use of Sewage Sludge provides examples of the most effective sludge treatment processes so as to reduce the potential health hazard posed by pathogens.

Organics

It is difficult to set limits for organic micro-pollutants found in sewage sludge that is applied to land. The difficulty lies in the identification of the concentration of such pollutants, since expensive and laborious laboratory analyses are required to trace such organic micro-pollutants. To make matters more complicated, there are thousands of organic micro-pollutants and new substances are continuously being introduced in the market. This makes it difficult to agree on a certain list of micro-pollutants for which to set limit values. Consequently, Directive 86/278/EEC does not provide any limit values or requirements for organic compounds in sewage sludge. However, several national regulations related to use of sludge have added specifications on organic compounds. The 'Working paper on sludge' (3rd draft) introduces standards for concentrations of organic contaminants in sewage sludge. Furthermore, the Member States of Denmark, Sweden, Austria, Germany and France have set National Limit values for certain organics. In Table 28 the limits proposed by the sludge working document are compared with the limits set by National Regulations of certain Member States. It is observed that the limit values of National Regulations are stricter or at least similar to the ones proposed by the EU (Langenkamp & Part, 2001); (Arthur Andersen, 2001b).

The Danish Ministry of Environment and Energy identified organic chemical residues, for which limit values should be elaborated in order to guarantee that consumers of products grown on sludge-amended fields and consumers of groundwater from areas where sludge is applied as fertilizer will not be exposed to contaminants from sludge (Langenkamp & Part, 2001).

The German regulation sets limit values for AOX, PCB and PCDD/F for precautionary reasons based on the current concentrations of the respective compounds in German sewage sludge. Concentrations of AOX in sludge do not really provide information about the absence or presence of hazardous substances; it can be a measure of careful soil protection to prevent the input of high amounts of anthropogenic compounds into soil, some of which may be persistent pollutants (Langenkamp & Part, 2001).

Table 28: Standards for Concentrations of Organic Contaminants in Sewage Sludge in Different Countries of the EU (Langenkamp & Part, 2001); (Arthur Andersen, 2001b

	AOX mg/kg dm	**DEHP** mg/kg dm	**LAS** mg/ kg dm	**NP/NPE** mg/kg dm	**PAH** mg/kg dm	**PCB** mg/kg dm	**PCDD/F** ng TEq/kg dm
EU Recommendations 2000 (3rd Draft)	500	100	2600	50	6 [1]	0,8 [2]	100
Denmark (Danish Ministerial Order No. 823, 16 Sept. 1996)	-	50	1300	10	3 [1]	-	-
Sweden (LRF & SEPA & VAV; 1996)	-	-	-	50	3 [3]	0.4 [4]	-
Austria	500 [a, b, c]	-	-	-	6 [c]	0.2 [5, a] 0.2 [b, d] 1 [c]	100 [a, b, c] 50 [c]
France	-	-	-	-	2-5 [6] 1.5-4 [7]	0.8 [8]	-
Germany (Sauerbeck & Leschber 1992)	500	-	-	-	-	0.2 [5]	100

[a] Lower Austria
[b] Upper Austria
[c] Carinthia
[d] Vorarlberg

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[1] Sum of acenapthene, phenanthrene, fluorene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, enzo(a)pyrene, benzo(ghi)perylene, indeno(1, 2, 3-c,d)pyrene.

[2] Sum of 6 congeners PCB 28, 52, 101, 138,153, 180.

[3] Sum of 6 compounds

[4] Sum of 7 congeners

[5] Each of the six congeners PCB 28, 52, 101, 138, 153, 180.

[6] Fluoranthen, Benzo(b)fluoranthen, Benzo(a)pyren

[7] When used on pasture land

[8] Sum of 7 congeners PCB 28, 52, 101, 118, 138,153, 180.

In Sweden, the regulation contains no requirement on organic compounds in sludge; however, restrictions on the concentration of organic compounds in sewage sludge for use in agriculture have been introduced in the agreement between Swedish EPA, the Federation of Swedish Farmers and the Swedish Water and Waste Water Association signed in 1994. These agreements are based more on practical experience than on scientific data (Langenkamp & Part, 2001).

In case the case of France, apart from the limit values of PAH and PCB concentrations in sewage sludge (Table 29), guide values for PAH concentrations in sewage sludge have been introduced to be used in pasture land as well as PAH limit values for the maximum permissible sludge input over a period of 10 years.

Table 29: French Guide Values for PAH Concentrations in Sewage Sludge and Maximum Amounts in Soils of Pastures (Langenkamp & Part, 2001)

Compound	**concentrations in sludge to be used in agriculture at a rate of no more than 30 tonnes/ha/10a (mg/kg dw)**	**maximum permissible cumulated input on pasture soils per hectare in 10 years (g/ha dw)**
fluoranthene	4	60
benzo(b)fluoranthene	4	60
benzo(k)fluoranthene	4	60
benzo(ghi)perylene	4	60
benzo(a)pyrene	1.5	20
indeno(1, 2, 3-c,d)pyrene	60	60

3.2.2 Regulations for Sludge Treatment and Analyses Prior to Land Application

Directive 86/278/EEC includes several obligations for sludge treatment prior to its application to land. More specifically, in Article 6 it is stated that sludge shall be treated before it is used for agricultural purposes, unless it is injected or worked into the soil. As mentioned in Article 2, treated sludge is defined 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*". However, specific regulations are not provided concerning the utilization of specific sludge treatment technologies. Belgium, Denmark, Finland, Germany, Greece, Italy, the Netherlands, Portugal and Spain prohibit the use of untreated sludge, while other countries have no specific requirements. In the Flanders Region of Belgium the application of treated or untreated sludge to land is banned (Council Directive 86/278/EEC); (Arthur Andersen, 2001b).

Although the conditional application of untreated sludge in soil is acceptable, there are also certain rules which must be followed as mentioned in Article 8 of the Directive (Council Directive 86/278/EEC):

- *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*
- *where sludge is used on soils of which the pH is below 6, Member States shall take into account the increased mobility and availability to the crop of heavy metals and shall, if necessary, reduce the limit values they have laid down in accordance with Table 18*

The Directive requirements mentioned above concerning the application of untreated sludge to soil are followed by Member States such as France, Ireland, Luxembourg and Sweden in which their national legislation permits the use of untreated sludge (Arthur Andersen, 2001b).

The working document on sludge (3rd draft) recommends further standards for sludge management, and is more specific compared to Directive 86/278/EEC since it specifies the obligations concerning the sludge treatment in order to reduce the likelihood of pathogen spreading into the environment and in order to build-up consumer confidence. As opposed to the Directive, this working document mentions the type of treatment that sludge must receive prior to its land application. According to this document, sludge must be treated by one of the following processes before its application (European Commission, 2000):

a. Advanced treatment (hygienisation)

- Thermal drying ensuring that the temperature of the sludge particles is higher than 80°C with a reduction of water content to less than 10% and maintaining a water activity above 0.90 in the first hour of treatment
- Thermophilic aerobic stabilisation at a temperature of at least 55°C for 20 hours as a batch, without admixture or withdrawal during the treatment
- Thermophilic anaerobic digestion at a temperature of at least 53°C for 20 hours as a batch, without admixture or withdrawal during the treatment
- Thermal treatment of liquid sludge for a minimum of 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 lime reaching a pH of 12 or more and maintaining a temperature of at least 55°C for 2 hours
- Conditioning with lime reaching and maintaining a pH of 12 or more for three months

The process shall be initially validated through a 6 Log_{10} reduction of a test organism such as Salmonella Senftenberg W775. The treated sludge shall not contain Salmonella spp in 50 g (wet weight) and the treatment shall achieve at least a 6 Log_{10} reduction in Escherichia Coli to less than $5 \cdot 10^2$ CFU/g.

b. Conventional treatments

- Thermophilic aerobic stabilisation at a temperature of at least 55°C with a mean retention period of 20 days
- Thermophilic anaerobic digestion at a temperature of at least 53°C with a mean retention period of 20 days

- Conditioning with lime ensuring a homogenous mixture of lime and sludge. The mixture shall reach a pH of more than 12 directly after liming and keep a pH of at least 12 for 24 hours
- Mesophilic anaerobic digestion at a temperature of 35°C with a mean retention period of 15 days
- Extended aeration at ambient temperature as a batch, without admixture or withdrawal during the treatment period (*)
- Simultaneous aerobic stabilisation at ambient temperature (*)
- Storage in liquid form at ambient temperature as a batch, without admixture or
- Withdrawal during the storage period (*)

(*) The minimum time length of the treatment shall be laid down by the competent authority taking into consideration the prevailing climatic conditions in the area where the treatment plant is located.

The sludge treatment must achieve at least a 2 Log_{10} reduction in Escherichia Coli. The relevant process parameters must be monitored at least daily, and preferably continuously, if this practicable. Records shall be kept and made available upon request to the competent authority for inspection purposes. European standards for monitoring these treatment processes shall be developed. If CEN standards are not available and until they are developed, ISO, international or national standards shall apply. When the competent authority of the concerned Member State is sure that a treatment process that is not in the above list is capable of achieving the same results as the listed treatment options, it shall inform the Commission. The Commission, after evaluation of the provided information and after the positive reply of the relevant Committee can include it in the list (European Commission, 2000).

The working document proposes that sludge must not be used in land if it has not been treated with one of the above mentioned processes. Sludge from septic tanks, cesspools and similar installations shall be taken to a wastewater treatment plant for further treatment. In case of long distances, the competent authority may allow a derogation from the previous requirement on a case-by-case basis and as long as the provisions of Article 4 of Directive 75/442/EEC are fulfilled. The sludge shall be injected or worked into the soil as soon as it is spread (European Commission, 2000).

However, it must be emphasized that the working document on sludge serves only as recommendation as it has not been incorporated in any European legislation up to now.

Analyses foreseen

Directive 86/278/EEC covers both the analyses of treated sludge and of the soil to which it is applied as well as the methods for sampling of sludge and soil on which it is used, in order to observe and have a competent view of the sludge and soil quality. The Directive specifies the sampling frequency, the parameters to be analyzed and the means to perform the required measurements. However, the Directive leaves room for each Member State to decide on the frequency of sampling and on the analysis of heavy metals provided that certain conditions are met. More specifically, according to Annex IIA, Annex IIB and Annex IIC the following are specified (Council Directive 86/278/EEC):

Sludge must be analysed at least every 6 months. Where changes occur in the characteristics of the waste water being treated, the frequency of the analyses must be increased. If the results of the analyses do not vary significantly over a full year, the sludge must be analysed at least every 12 months.

The analysis of sludge should cover the following parameters:

- dry matter
- organic matter
- pH
- nitrogen
- phosphorus
- Heavy metals (cadmium, copper, nickel, lead, zinc, mercury, chromium)

In the case of copper, zinc and chromium, where it has been shown, to the satisfaction of the competent authority of the member state concerned that they are either not present at all or present only negligible quantities in the waste water treated by sewage plant, Member States shall decide on the frequency of the analysis to be carried out. Sludge must be sampled after processing, but before delivery to the user, and should be representative of the sludge production.

As far as the analyses of soil to which sludge is applied the following are specified by the Directive:

1 …. Member States must first ensure that the heavy metal content of the soil does not exceed the limit values laid down in accordance with Table 19. For this purpose, Member States shall decide what analyses to carry out, taking account of available scientific data on soil characteristics and homogeneity.

2. Member States shall decide on the frequency of further analyses, taking account of the metal content of the soil prior to the use of sludge, the quantity and composition of the sludge used and any other relevant factors.

The soil parameters that must be measured are the following:

- pH
- Heavy metals (cadmium, chromium, copper, mercury, nickel, lead and zinc).

Soil sampling: The representative soil samples for analysis should normally be made up by mixing together 25 core samples taken over an area not exceeding 5 hectares which is farmed for the same purpose. The samples must be taken to a depth of 25 cm unless the depth of the surface soil is less than that value; however, the sampling depth in the latter case must not be less than 10 cm.

Methods of analysis: Analysis for heavy metals must be carried out following strong acid digestion. The reference method of analysis must be that of atomic absorption spectrometry and the limit of detection for each metal should be no greater than 10 % of the appropriate limit value.

The national regulations in several Member States, concerning the frequency of analysis of sludge and soil on which it is used follow the same requirements as specified in the Directive 86/278/EEC which is at least once every 6 months. However, in Finland, France, Luxembourg, Italy and Sweden the frequency of analysis depends on the size of the sludge treatment plant. For instance in France the number of analyses per year is related to the tonnes of dry matter spread on land, reaching 48 the first year that land spreading is carried out. Table 30 compares the frequency of sampling specified by Directive 86/278/EEC and the one specified by National Legislation of the Member States

Table 30: Frequency of Sludge and Soil Sampling in EU Countries (Arthur Andersen, 2001b)

	Range of sampling frequencies		
	Sludge		**Soil**
Directive 86/278/EEC	**6 months**		**Before first application**
Austria	2 months – 10 years [a]	Every 2 years [b]	Before first application and at least every 5-10 years [a]
Belgium (Flanders)	6 months	6 months	Before first application and after having spread 20 tDM per hectare
Belgium (Walloon)	1 - 12 per year	–	Before first application and at least every 10 years
Denmark	3 months	12 months	Before first application
Finland	1 – 12 per year first year 1 – 4 per year later	-	Before first application
France	2 - 48 the first year [c] 2 – 24 per year later [c]	1 - 12 the first year [c] 1 – 12 per year later [c]	Before first application and at least every 10 years
Germany	6 months	6 months	Before first application and every 10 years.
Greece	6 months	-	Before first application
Ireland	6 months	-	Before first application and every 10 years.
Italy	> 100 000 p.e.: every 3 months < 5000 p.e.: once a year every 6 months for others	-	Every 3 years at most
Luxembourg	1 – 6 per year	-	Before use then depending on results, size of the WWTP, quantity of sludge
Netherlands	N/A	-	Before first application

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[a] according to the Länder
[b] for PCB and PCDD/PCDFs
[c] depending of the dry matter content of the sludge

Portugal	6 months	-	Before first application
Spain	6 months	-	Before first application
Sweden	1 – 12 per year	-	Before first application
UK	6 months	-	5 - 20 years
Estonia	depends on capacity	-	-
Latvia	N/A	-	Before first application
Poland	1-6 years	-	Metals and P_2O_5: 1 – 5 years

In order to improve the present situation of sludge utilization on land and to minimize its adverse effects, the working document on sludge suggests that sludge producers shall perform supplementary analysis on the characterization of the composition of sludge and its agronomic value as well as to the soil to which sludge will be applied. According to this document, the parameters which should be considered for sludge analysis are the following (European Commission, 2000):

- Dry matter, organic matter
  (should be evaluated from the measurements of dry residue and loss on ignition)
- pH
- Primary nutrients: nitrogen (N), phosphorus (P), potassium (K)
- Secondary nutrients: calcium (Ca), magnesium (Mg), sulphur (S) and
- Micro-nutrients (boron (B), cobalt (Co), iron (Fe), manganese (Mn), molybdenum (Mo))

As a minimum, the frequency of sludge analysis shall be carried out at regular intervals during the year as indicated in Table 31.

Table 31: Frequency of Sludge Analysis per Year as Specified in the Working Document on Sludge (European Commission, 2000)

Quantity of sludge produced per year and per plant (tones of dm)	Minimum number of analyses per year				
	Agronomic parameters	Heavy Metals	Organic Compounds	Dioxins	Microorganisms
<250	2	2	-	-	2
250-1000	4	4	1	-	4
1000-2500	8	4	2	-	8
2500-4000	12	8	4	1	12
>4000	12	12	6	1	12

The working document of the EU on sludge is much more detailed than the Directive itself as far as sampling and analyses of sludge and soil are concerned. The most important points are the following (European Commission, 2000):

- Sludge is assumed to be in accordance with the limit values for heavy metals, organic compounds and micro-organisms when the 90-percentile of the samples within a twelve-month period are at or below the threshold value and if the 10-percentile of the samples exceed only one threshold value and by less than 50%, for every pollutant individually.
- The competent authority can decide on a case-by-case basis to allow a reduction of the frequency of the analysis of any of the pollutants (heavy metals, organic compounds, micro-organisms) or agronomic parameters if in a two-year period it has been shown that each measured value of the pollutant parameter is consistently below 75% of the threshold limit or if any of the agronomic parameters, for the same period, deviates less than 20% from the average
- The analyses of soil on which sludge is applied shall take place before the first use of sludge on land and every ten years thereafter for the parameters specified in the Directive 86/278/EEC (pH, cadmium, chromium, copper, mercury, nickel, lead and zinc).

Tables 32 and 33 present methods for soil and sludge examination respectively.

Table 32: Methods for Soil Examination According to the working document on sludge (European Commission, 2000)

Parameter	**Title**	**Reference**
Sampling	Soil quality – Sampling – Part: 1: Guidance on the design of sampling programmes	ISO/DIS 10381-1
	Soil quality – Sampling – Part: 4: Guidance on the design of sampling programmes	ISO/DIS 10381-4
Soil texture – (clay and organic matter content)	Soil quality - Simplified soil description	ISO 11259
	Soil quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation	ISO 11277
	Soil quality – Determination of organic and total carbon after dry combustion (elementary analysis)	ISO 10694
PH	Soil quality – Determination of pH	ISO 10390
Heavy metals	Soil quality - Extraction of trace elements soluble in aqua regia	ISO 11466
	Soil quality – Determination of cadmium, chromium, cobalt, copper, lead, manganese, nickel and zinc – Flame and electrothermal atomic absorption spectrometric methods	ISO 11047
Nitrogen	Soil quality – Determination of nitrate nitrogen, ammonium nitrogen and total soluble nitrogen in air-dry soils using calcium chloride solution as extractant	ISO 14255
Phosphorus	Soil quality – Determination of phosphorus – Spectrometric determination of phosphorus soluble in sodium hydrogen carbonate solution	ISO 11263

Table 33: Methods for Sludge Examination According to the Working Document on Sludge (European Commission, 2000)

Parameter	**Title**	**Reference**
Sampling	Water quality – Sampling - Part 13 : Guidance on sampling of sludges from sewage and watertreatment works	EN/ISO 5667P13
Dry matter	Characterization of sludge - Determination of dry residue and water content	prEN 12880
Organic matter	Characterization of sludges - Determination of the loss on ignition of dry mass	prEN 12879
pH	Characterization of sludge - Determination of pH-value of sludges	EN 12176
Nitrogen	Characterisation of sludges - Determination of Kjeldahl nitrogen	prEN 13 342
Phosphorus	Determination of phosphorus compounds	prEN 13 346
Potassium		
Heavy metals	Characterisation of sludges Aqua regia extraction methods - Determination of trace elements and phosphorus	prEN 13 346
Secondary nutrients and micro-nutrients		(prEN 13 346)
Salmonella Seftenberg W775		
Salmonella spp		
Escherichia Coli		
AOX		[ISO 15009]
LAS		
NPE		
PAH		[ISO 13877]
PCB		[CD 10382]
PCDD/F		

3.2.3 Certification and Data Collection

According to Articles 6 and 10 of Directive 86/278/EEC each Member State is required to gather information and data related to the analyses of sludge and soil on which it is used. The sewage sludge producers must provide the end users with all the necessary data concerning (Council Directive 86/278/EEC):

- The quantities of sludge produced and used in agriculture
- The composition and parameters of sludge
- The type of sludge treatment that has been carried out (if any)
- The names and addresses of the recipients of sludge as well as the area where sludge is to be used

The aforementioned information must be collected by the relevant authorities of each Member State. Based on these records each Member State must prepare, every four years a consolidated report on the use of sludge for agricultural purposes by setting out the quantities used and the difficulties encountered. In some cases, sludge producers are also responsible for the conformity of sludge with the quality requirements set out in the regulation (Belgium - Walloon region), or responsible for ensuring that information on quality accompanies sludge data (Denmark). In France, national legislation obliges the producer to carry out a preliminary study before supplying sludge for use on land, in order to establish a land spreading plan each year and to produce a yearly report (ELODQ) on sludge spreading on land and on the resulting impacts on soil quality. At the moment, certification procedures concerning the use of sludge such as product or service quality certification are not specified in national legislation. However, the voluntary agreement on sludge in Sweden has led the main players to issue guidelines for quality assurance. In addition to these guidelines, consultative groups have been established at local level in order to conduct sewage sludge quality audits (Council Directive 86/278/EEC), (Arthur Anderson, 2001b).

Consequently, Directive 86/278/EEC obliges sludge producers to regularly inform the end users on the sludge properties and quality. The working document of sludge (3rd draft) also introduces some additional responsibilities which have not yet been incorporated into specific legislation. According to this document sludge producers are also responsible for the quality of sludge supplied (even when a contractor takes care of sludge marketing and spreading) and must guarantee the suitability of sludge usage. Sludge producers shall also perform a quality assurance assessment of sludge management which must include (Council Directive 86/278/EEC):

- The control of pollutants at source
- The process followed on sludge treatment
- The way that work is planned and land suitability is evaluated
- The sludge delivery
- The sludge application and
- The communication of information to the receiver of sludge

The working document on sludge also cites the information required for the stakeholders in order to promote sludge management. The sludge producer must provide the receiver with the (European Commission, 2000):

- Name and address of the producer
- Name and address of the treatment plant from which the sludge originates
- Assurance that the quality of supplied sludge fulfils all relevant and applicable requirements
- Copy of the auditor's certificate
- Type of treatment carried out and result of the analysis on Salmonella spp and Escherichia Coli, if applicable
- Composition and properties of sludge in relation to the agronomic parameters (secondary nutrients, micro-nutrients)
- Results of the analyses on sludge in relation to certain heavy metals and organic compounds

On the other hand the receiver of sludge shall keep records of and provide the producer with the following (European Commission, 2000):

- information about any other sludge, manure or other wastes that have been applied to land
- information about the land that is relevant to preventing water pollution
- records of fertilisers and agrochemicals used on the land

The producer must keep a copy of the information sent to the receiver along with the (European Commission, 2000):

- name and address of the receiver
- location of the land on which the sludge is used
- type of land use
- prior treatment, quantity and analysis of sludge supplied for use
- results of the analysis on the soil on which sludge is applied in relation to the heavy
- metals suggested
- details of the information supplied by the receivers

The producer has to keep the above mentioned information for at least ten years and has to report annually to the competent authority. This information, in an aggregated form, shall provide the basis for the consolidated report to be sent to the Commission by each Member State and shall be available upon request to the general public. Member States shall communicate to the Commission for the implementation and monitoring of these provisions on their territory. The Commission shall include this information in the consolidated report (European Commission, 2000).

Code of Practice

Apart from the obligatory requirements, it could be envisaged to set-up codes of good practice for the use of sludge in the different outlets. Most EU countries have not developed any codes of practice or guidelines concerning the use of sewage sludge (EC, 2001). In order to overcome this problem the working document on sludge (3rd Draft) sets the basic structure for the implementation of codes practice and guidelines for sludge use in order to prevent any negative environmental impacts. Producers should, on a voluntary basis, implement such codes which should contain certain provisions covering as a minimum the following items (European Commission, 2000):

For all outlets:

- measures to be taken for not impairing the quality of groundwater
- measures and precautions to be taken in order to prevent the leaching from sludge which is stored prior to its use
- periods in which the use of sludge is not suitable because of adverse weather conditions

For sludge use in agriculture and silviculture:

- the sludge shall be used when there is an agronomic interest for growing of crops or for the improvement of soil
- the sludge nutrient load, especially with regards to nitrogen and phosphorous, shall be taken into account when the amount of fertilisers needed by crops is calculated
- periods in which spreading of sludge is not suitable because crops would not benefit from the supplied organic matter or nutrients will be specified

3.3 Specific Requirements for the Use of Sludge for other Recycling Outlets

Apart from agricultural land there are other potential recycling outlets for sewage sludge, including forestry, silviculture and reclaimed land (European Commission Joint Research Centre, 2001). In order to maintain or improve the present rate of recycling of nutrients and organic matter contained in sludge the working document on sludge suggests that the scope of the existing regulations must be broadened to include the management of sludge in outlets such as silviculture, green areas and reclaimed areas.

3.3.1 Forestry and Silviculture

Forestry and silviculture refer to different kinds of tree plantation and use. The term forestry is mainly used when considering amenity forests, or mature forest exploitation. On the contrary, silviculture is more specifically used when referring to intensive production. From the agricultural and environmental point of view, differences exist in terms of the impact of land spreading of sludge in factors such as the plant species grown, the fauna and flora involved and the soil types. The agronomic benefits from sludge application include increased tree growth and the provision of nutrients to the soil. However, competition with weeds, especially in young plantations may be observed. Excessive rates of sludge application may also lead to degradation of the upper layer of the soil and the humus, as well as nitrogen leaching to groundwater. The use of sludge in a forest environment may cause an alteration in the characteristics of the ecosystem and, in the case of a mature forest where there is no need to have an additional input of nutrients, may disturb the natural biotopes. More research is however needed on this issue. When considering the risks to humans associated with the presence of heavy metals in sludge, it is assumed that these are lower than those associated with spreading on agricultural land, as forest products represent only a very small part of the human diet. However, some risks may still exist due to the transfer of heavy metals to edible mushroom species and in a general manner to wild fauna and flora (Marmo, 2002).

Use of sewage sludge in land reclamation and revegetation aims to restore derelict land or protect soil from erosion through soil provision and increased vegetal covering. In the case of industrial sites, topsoil may often be absent or if present, damaged by storage or handling. Soil or soil forming materials on site may be deficient in nutrients and organic matter. Other problems may exist, such as toxicity, or adverse pH levels. All these problems create a hostile environment for the development of vegetation. Possible solutions include the use of inorganic fertilisers or imported topsoil, which can be very expensive depending on location and availability. An alternative solution is the use of organic wastes such as sewage sludge, which is already performed in Sweden, Finland, Germany and the United Kingdom. Sludge application takes place using the same machinery as in recycling for agriculture. Some specific machinery for sludge projection may be needed when applying sludge in areas where access is difficult. It is assumed that risks are lower than in the case of spreading on agricultural land, when its use is not related to food production. However, no data is available concerning the potential impacts on wild fauna and flora (Marmo, 2002).

It is not always possible, without carrying out an in-depth analysis for each country, to establish whether certain uses of sludge are covered by regulation. In addition, it is even more difficult to estimate whether uses for which there are no specific regulations are prohibited, authorised or simply tolerated. The review of relevant legislation reveals that very few elements in the regulations specifically address the use of sludge in routes other than the recycling in agriculture such as use in silviculture, on natural forest, green areas, and in land reclamation. However, use of sludge on forestry is mentioned by the regulation on sludge use in Belgium-Flanders, Denmark, France, and Luxembourg. In addition, some national regulations have prohibited the use of sludge on silviculture (Germany, Netherlands) on natural forest (Walloon region, Germany), and in green areas (Germany, Netherlands). The regulation in Poland includes limit values for heavy metals concentrations in sludge for use in land reclamation and on "non-agricultural soil" (Arthur Andersen, 2001b).

A limited number of national legislations exist on sewage sludge application in silviculture. Moreover, in several cases the term "forest" or "forest soil" is mentioned without specifying whether it covers silviculture, natural forest and reforested areas. For example, in Flanders, the use of waste in forests is not permitted without making a distinction between natural and cultivated forests. National regulations for several EU member states concerning the sludge usage in silviculture are the following (Arthur Andersen, 2001b):

- In Denmark, according to the Danish Statutory Order No. 49, the application of sludge in cultivated forests can be allowed when fertilisation is needed. Nevertheless, specific restrictions can be established.
- In Germany, land spreading of sludge for silvicultural purposes is prohibited by paragraph 4 of the German Sludge Ordinance.
- In the Netherlands, land for silviculture is either considered as agricultural land (and therefore the regulations for agricultural land apply) or as miscellaneous land (use of sludge being prohibited on these areas).
- In Sweden, no specific elements address these aspects in the regulation, but the General Guidelines 1990/13 from the SEPA (sludge from municipal sewage treatment plants), contain recommended maximum values when sludge is used in silviculture.

Regulations on sewage sludge in Greece, Finland, Ireland, Italy, Netherlands, Portugal, Spain and Sweden do not address the use of sludge on natural forests. The Countries or regions which explicitly prohibit the use of sludge on forest are Austria, Belgium (Flanders and Walloon regions) and Germany. In Austria, although the regulation on the use of sludge does not mention use on forests, section 16 of the Forest Law prohibits the use of sludge on forests. However, this prohibition does not apply to "forest gardens", forest seed plantations and Christmas tree plantations. In the cases listed below, the use of sludge on forest areas is authorised, under certain conditions (Arthur Andersen, 2001b):

- In France, the Government Decree of December 8, 1997 specifies in Article 16 that the requirements defined for the use of sewage sludge on agriculture also apply to natural forest areas, whether public or private, provided that risks for humans as well as for the fauna are minimised.
- In Luxembourg, according to the Grand Ducal Regulation of 14th April 1990, the use of sludge on forest soil is subject to licensing. Moreover, licensing is also necessary

before spreading on agricultural land at a distance of less than 30 meters of a forest boundary.

- In the United Kingdom, the use of sludge in natural forest and reforested areas is not addressed by the regulation, but a "Manual of Good Practice for the Use of Sewage Sludge in Forestry" has been published by the Forest Authority.

3.3.2 Land reclamation

There are almost no specific requirements for the use of sludge in land reclamation in most national regulations. The only exceptions to this are Austria (Vorarlberg), Belgium (Flanders), France and Poland. In Austria, the regulation in Vorarlberg specifies that recultivation using sludge as a fertilizer (defined in this regulation as composted or heat-dried sewage sludge), for areas where the soil has been ‘considerably damaged by human intervention’ is permissible, provided that heavy metals limits are respected. In Belgium (Flanders), the use of sludge, in conformity with the limit values defined by the regulation, as covering layer for landfills falls under "black soil" applications. This latter entails the sludge being mixed with other materials such as sand. In practice, the use of sludge in black soil is limited. In France, it is stated in Article 17 of the Decree of the 8th of December 1997 that the use of sewage sludge for land reclamation must be adapted to the particularities of the soil (considering other substances which may have been introduced in the soil). In addition, the use of sludge is prohibited in mines or quarries. In Poland the Decree of August 11th 1999 established specific limit values for heavy metals in sludge when sludge is used for land reclamation. Other elements relating to land reclamation in the Member States are the following (Arthur Andersen, 2001b):

- Sweden: the regulation does not address these aspects, but the General Guidelines 1990/13 provide recommendations on sludge use in land reclamation.
- United Kingdom: a manual of good practice for the use of sewage sludge in land reclamation is available.

3.3.3 Green areas

The national regulations on sewage sludge do not address the use of sewage sludge on green areas, except in few cases which either explicitly prohibit the use of sludge on green areas (Germany and Netherlands) or provide additional requirements (in Denmark, where sludge used on green areas must be pasteurised). In Sweden, the regulation does not address these aspects, but the "General Guidelines 1990/13 provide recommendations on use of sludge on green areas. The Decision of the Ministry of Agriculture and Forestry (46/1994) in Finland requires that "soil improving agents" used for landscaping purposes are exempt from requirements on heavy metals concentrations. Regulations on sludge in Poland and in Estonia cover the use of sludge on green areas (Arthur Andersen, 2001b):

- In Estonia, use of sludge in green areas is covered by the same regulation as for use in agriculture; this is the 1999 regulation on "instructions for use of wastewater sludge in agriculture, green area creation and recultivation’
- In Poland, the Decree of August 11, 1999 defines specific limit values for heavy metals in sludge for use on non-agricultural soil including green areas

3.4 Protection of Waters Against Pollution when Sewage Sludge is Used in Agriculture

As it has been previously mentioned, EU legislation encourages the use of sludge in agriculture as soil conditioner, provided it does not pose a threat to human health and it does not contaminate the environment. In this Section, the legislation related to the protection of groundwater and surface water from nitrates is analyzed.

Directive 91/676/EEC of the 12th December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (known as the nitrates’ Directive) sets the foundations for the prevention and the confrontation of water pollution. Water pollution by nitrates has increased due to more intensive farming practices, the increasing use of fertilizers and due to the larger number of animals concentrated in smaller areas. The aim of this Directive is to ensure that waters are protected against nitrate pollution. According to the Directive requirements Member States must identify, on their territory (Council Directive 91/676/EEC):

- surface waters and groundwater affected or which could be affected by pollution
- vulnerable zones which contribute to pollution

The Member States must establish codes of good agricultural practice to be implemented by farmers on a voluntary basis. Furthermore, the Member States must establish and implement action programmes within the vulnerable zones. These action programmes must include guidelines, rules, recommendations and measures prescribed in the codes of good agricultural practice in order to (i) limit the spreading of fertilizers containing nitrogen on land, (ii) set limits for the spreading of livestock effluent and (iii) ensure ‘correct’ agricultural activities that will provide a certain protection level to waters. The action plans take into consideration the prevailing environmental conditions in each Member State as well as the available scientific and technological data based on the presence of nitrogen that originates from agricultural activities. The action plans of the Nitrates’ Directive also include dissemination programmes for the farmers for the use of approved fertilizers (Council Directive 91/676/EEC).

The action plans are designated for the regions of the EU where the agricultural activities pollute or pose a danger for pollution of waters. The determination of these aquatic regions is based on the following criteria (Council Directive 91/676/EEC):

- Surface freshwaters which are used or intended to be used as a source of drinking water and contain or could contain more than the concentration of nitrate as indicated in Table 34.
- Groundwaters which contain, or could contain more than 50mg/L of nitrates
- Natural freshwater lakes, other freshwater bodies, estuaries, coastal waters and marine waters which are found to be eutrophic or tend to be eutrophic in the near future.

Table 34: Classification of Surface Water (Council Directive 91/676/EEC):

	A1 (G)	A1 (I)	A2 (G)	A2 (I)	A3 (G)	A3 (I)
Nitrates mg/L NO_3	25	50 (O)	-	50 (O)	-	50 (O)

I= mandatory, G= guide, O=exceptional climatic or geographic conditions

Table 34 derives from Directive 75/440/EEC, which classifies surface water into three categories A1, A2 and A3 of drinking water according to the standard methods of treatment.

- A1: Simple physical treatment and disinfection (e.g. rapid filtration and disinfection)

- A2: Normal physical treatment, chemical treatment and disinfection (e.g. pre-chlorination, coagulation, flocculation, decantation, filtration, disinfection (final chlorination))
- A3: Intensive physical and chemical treatment, extended treatment and disinfection (e.g. chlorination to break point, coagulation, flocculation, decantation, filtration, adsorption (activated carbon), disinfection (ozone, final chlorination))

According to Article 2 of the same Directive (Council Directive 91/676/EEC):

Groundwater means all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.

Freshwater means naturally occurring water having a low concentration of salts, which is often acceptable as suitable for abstraction and treatment to produce drinking water.

Eutrophication means the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned.

Finally, Directive 91/676/EEC outlines in Article 6, the revision of the areas which are most likely to be affected by the agricultural practice by performing methodical examinations of nitrates concentration and the trophic condition of fresh surface waters, estuarial and coastal waters.

It is evident that the implementation of the nitrates' Directive limits the use of fertilizers that contain nitrogen and can favour the application of treated sludge on land.

3.5 Sludge Incineration

Incineration of waste with energy recovery can be a preferable process of waste management, especially when economical or technical reasons restrain other routes. Waste incineration is a way of utilizing the energy content in waste and at the same time reducing its initial volume and weight and minimizing the capacity needed for landfilling. The main restriction on the incineration of waste is the flue gas emissions produced during the process, which usually contain various hazardous substances. However, the different treatment processes for flue gas cleaning in modern incineration plants ensure that such hazarsdous substances are not released in the atmosphere. Another problem associated with incineration plants concerns the disposal of the produced ash which is problematic as it is considered a toxic substance (European Environmental Agency, 2002a).

Directive 2000/76/EEC on the incineration of waste (including sludge) aims to prevent or reduce, as far as possible, air, water and soil pollution caused by the incineration or co-incineration of waste, as well as the resulting risk to human health. Directive 2000/76/EEC on the incineration of waste (including sludge) lays down stringent limit values for air emissions and emissions for discharges of waste water from the cleaning process of exhaust gases. This Directive aims to complement Directives 89/369/EEC and 89/429/EEC concerning the operation of existing incineration facilities for municipal waste as well as Directive 94/67/EEC concerning the incineration of hazardous waste. Directive 2000/76/EEC requires (i) the attainment of a certain efficiency level for the incineration process (ii) the attainment of temperatures around 850°C for the air emissions for at least 2 seconds in order to ensure the completion of the combustion process (iii) heat recovery and (iv) the operation of an automated feeding system for the input waste (Council Directive 2000/76/EC).

Article 6 of the Directive specifies the operation conditions according to which the incineration and co-incineration plants should be designed, equipped and operated. In particular (Council Directive 2000/76/EC):

- The content of Total Organic Carbon (TOC) in bottom ash and slag must be less than 3% or the loss of ignition less than 5% of the dry weight of the material.
- The temperature of the gas resulting from the process must be 850°C and if the hazardous wastes contain more than 1% of halogenated organic substances, expressed in chlorine, the temperature must be raised to 1100°C.
- Each line of the incineration plant must be equipped with an auxiliary burner in order to sustain the temperature at desirable levels, as the case may be.
- An automatic system which will regulate the waste feed must be installed and operated

whenever temperature is not maintained as the Directive indicates, whenever any emission limit is exceeded and at the initiation of the process until temperature reaches the specific values.

Directive 2000/76/EEC determines the following:

- The required details for the procedure of application submission and for the license issue, concerning the construction of a waste incineration plant
- The required precautions during the delivery and acceptance of waste, for the prevention or the reduction of negative effects on the environment
- The operation conditions. The incineration plants operate in a manner which ensures such a degree of incineration that the atmospheric emissions should not cause significant atmospheric pollution
- The limit values of atmospheric pollutants. The exhaust gases from the plants should not exceed specific limit values which are stringent
- The procedure of rejection of the wastewaters that are generated from the treatment process of exhaust gases
- The residue management
- The procedure of control and monitoring of the installation
- The measurements of atmospheric pollutants that are required
- The ways of accessing to the information and participation of the public
- The tackling of unusual operational conditions
- The cases of re-examination
- The procedure of report submission
- The ways of future re-adaptation of the Directive
- The penalties applied in case of non-conformance to the Directive’s requirements

In order to comply with the requirements of the Directive (and particularly with the strict air-emission limit values) the cost for installing and operating modern incineration and co-incineration facilities is generally high and can be prohibitive for countries that have narrow budgetary constraints (European Environmental Agency, 2002a). Incineration is an expensive treatment option for sludge and has the problem of how to dispose the residues, which constitutes approximately 30% of the input mass. These residues can be regarded as hazardous waste due to contamination by heavy metals – especially if sludge is incinerated along with municipal waste (Langenkamp & Marmo, 2000).

An important factor, which must be taken into consideration when it comes to the incineration of sludge, is the balance of carbon in the ecosystem. When sludge is incinerated the organic matter is decomposed mainly to carbon dioxide. This majority of the emitted carbon dioxide accumulates in the atmosphere, since the time needed for vegetal and animal biomass to absorb it and form organic carbon is hundreds of years. Thus, sludge incineration results in an increase of the atmospheric carbon dioxide level in the short to medium term and can have a negative impact on the climate. The correct strategy would then be to lock as much organic carbon as possible in vegetal and animal biomass in soils so as to decrease the stock of carbon in the atmosphere (Langenkamp & Marmo, 2000). However, it must be mentioned that the negative effect of carbon dioxide release is very small compared to the release of methane that results due to the decomposition of organic matter in landfills.

3.6 Sludge Disposal

According to the Directive 1999/31/EC of the 26th of April 1999 on the landfill of waste, "*landfill is a waste disposal site for the deposit of the waste onto or into land*. The aim of this Directive is to define measures, directions and guidance in order to prevent or reduce, as far as possible, the adverse effects of the landfill of waste on the environment, in particular on surface water, groundwater, soil, air and human health, by providing stringent operational and technical requirements concerning the waste and landfills.

The Council Directive 1999/31/EC on the landfill of waste does not apply for the spreading of sludge on the soil, including sewage sludge and sludge resulting from dredging operations as well as similar matter for the purposes of fertilisation or improvement. Furthermore, Directive 1999/31/EC does not apply for the application of non-hazardous dredging sludge alongside small waterways and for non-hazardous sludge in surface water, including the bed and its subsoil (Council Directive 1999/31/EC).

Although not directly related to sewage sludge, Directive 1999/31/EC impacts on sewage sludge management since the Directive prohibits the disposal of liquid waste (e.g. sewage sludge) to landfills. Therefore, the landfill Directive has resulted in the reduction of the quantities of sludge that are disposed to landfills in the Member States. The final aim is to eliminate the quantities of sludge that are disposed to landfills. Certain Member States such as Germany have already achieved this target.

Sludge annual production in the EU is about 9 million tonnes of dry matter. It is also essential to compare this amount with the 200 million tonnes of municipal waste which is annually generated within the EU. By preventing sludge disposal to landfill sites the available landfill capacity can be used over a longer period of time. This capacity can be used for materials for which treatment or reuse is not possible. It must be also mentioned that landfilling spaces are decreasing and according to EUROSTAT service, the current average available capacity in eight Member State countries is less than 10 years (European Environmental Agency, 2002a).

When organic matter, including sewage sludge, decomposes in landfills, their nutrients' content are lost and they are not recycled and do not contribute to plant growth. Furthermore, landfilled organic matter enhances landfill gas production, and consequently aggravates the greenhouse effect. In fact landfill gas is mainly composed of methane, which is twenty times more powerful than carbon dioxide in terms of climate change effects. The landfilling of organic material is problematic and can cause negative effects in the environment and particularly in the pollution of groundwater in occasions where landfill sites are not equipped with appropriate leachate collection systems (Marmo, 2002). Consequently, the diversion of organic matter (including sludge) away from landfills is a major objective of the European Legislative Framework

4 Existing Situation in the EU

The EU Council Directive concerning urban wastewater treatment (91/271/EEC) required by the end of 2005 to apply at least secondary treatment to the wastewater discharged from every agglomeration having a population equivalent of more than 2,000 discharging to surface fresh water and estuaries, and of more than 10,000 population equivalent discharging to coastal waters. To comply with this Directive, most municipalities select the well-known activated sludge technology, on the basis of three main reasons: compactness, reliability and efficiency (if properly operated and maintained). However, this technology has the drawback of producing large amounts of sludge

In 2003, the total amount of sewage sludge produced annually in the 15 old EU member countries was approximately 7.5 million tonnes of dry solids, presenting an increase of 44% since year 1992. Currently, it is estimated that approximately 8.3 million tonnes of dry solids of sewage sludge are produced annually in the 15 old Member States. It must be mentioned that these values correspond to the dry weight of sludge. To determine the actual quantities of produced sludge the wet weight of sludge must be considered. By considering an average sludge solids concentration of 10% the generated sludge in the 15 old EU Member States is 83 million tonnes per year. However, it is important to notice that this is only an approximate estimation of sludge quantity, since the solids concentration varies and greatly depends on the type of treatment sludge has received (Arthur Andersen, 20001a-c). It is expected that the annual quantities of produced sludge will reach 15 to 20 million tonnes of dry solids when the Directive 91/271/EC is fully implemented by all Member States. This means increases in EU Member States ranging from 20% to 300% with respect to current production levels.

There is an ongoing debate in the majority of European countries and the in the EU regarding sludge recycling and disposal. The constant increase of the amount of sewage sludge produced has created the need to find ways to handle and use/dispose the generated sludge.

The use of sludge in agriculture is one of the most common routes for sewage sludge disposal. It is also a controversial issue because of some uncertainty regarding environmental effects and the uncertainties of the risks that it may have to human health, if the pollutants of sludge are transferred to the food chain. Debates between stakeholders have been initiated in many European countries. The most serious concern regards food safety and consequently the potential impacts on human health. On the other hand, sewage sludge contains fertilizers and materials that are beneficial to many soil types, including agricultural soil. Incineration, use in forestry and silviculture, or other developing management routes such as mineralization to construction products, pyrolysis and gasification, could play a crucial role in the future as alternative routes for sewage sludge management.

Data on sewage sludge utilisation and disposal changes rapidly, and needs to be updated regularly. The situation regarding sludge management has changed in the last 10 years due to, on the one hand, a ban on sea disposal in 1998, and on the other hand, the pressures from consumer organisations and large food retailer industries on farmers to restrict land spreading. This pressure is due to their concerns over its microbiological quality and the risk to contamination of food crops.

In 1999, the recycling of sludge to agriculture land accounted for about 40% of the overall sludge production in the EU15. In some countries, there have been heated debates between the farming community, the retail food industry and the water companies, which have driven the water industry to adopt new guidelines on the use of sludge in agriculture (in the UK and in France for example). Some countries have even introduced plans and policies to end the disposal of sewage sludge to land (i.e. Switzerland, Netherlands and Badden Wurttemberg in Germany). In Switzerland, in 2001, 40% of the sludge (80,000 tonnes of Total Solids - TS) was spread on farmland. The country ended this practice in 2005 and diverts these quantities to incineration and co-incineration in cement industry.

Most of the data that is presented is based on Eurostat data and on data found in relevant reports of the European Commission and of the European Environmental Agency.

4.1 Sludge Generation

The increase in the production of sludge in each Member State is directly related to the progress each country has achieved in the field of wastewater treatment. Tables 35 & 36 show sludge production in the European Union for the years of 1992, 1995, 1998, 2000 and 2005 in tonnes of dry weight and in kg per capita respectively. It is observed that the fluctuations of sludge production per capita in the member countries are significant. Denmark, Finland, Germany and Luxembourg produce more than 30kg of dry mass of sludge per capita. The differences in sludge production per capita reflect the degree of implementation of the Urban Wastewater Treatment Directive, the variety of wastewater treatment systems used by each country, the differences in the type and extent of the sewerage system, the effect of the qualitative and quantitative characteristics of wastewater input, as well as the differences in the quality, availability and type of sludge taken into consideration in the statistical data.

Table 35: Sludge Production in the European Union (1000 tonnes of dry weight) (Arthur Andersen, 2001c); (European Commission, 2003)

Country	**Year**				
	1992	**1995**	**1998**	**2000**	**2005**[e]
Austria	190	190	196	402	-
Belgium	59	78	113	98.7[f]	159
France	643	764	878	855	1.172
Germany	2.208	2.512	2.661	2297	2.787
Denmark	175	185	200	159	200
Greece	66	66	86	90	99
UK	998	1.158	1.193	1066	1.583
Ireland	37	40	43	40	113
Spain	528	751	787	853	1.088
Italy	-	-	-	729	-
Luxemburg	9	10	13	-	14
Norway	-	76	93	-	-
Netherlands	324	366	381	-	401
Portugal	126	147	246	238	359
Sweden	243	236	-	220	-
Finland	150	158	150	160	160

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[e] Estimation

[f] This value is only for the Wallonia and the Flemish Region

Table 36: Sludge Production of Sludge in the EU Member States (kg per capita) (Arthur Andersen, 2001c); (European Commission, 2003)

Country	Year			
	1992	**1995**	**1998**	**2005[g]**
Austria	23,6	23,6	26,4	-
Belgium	5,8	7,7	11,2	15,7
France	11,1	13,1	15,1	20,2
Germany	27,1	30,8	32,6	34,2
Denmark	33,5	35,4	38,3	38,3
Greece	6,3	6,3	8,2	9,5
UK	17,2	19,9	20,5	25,3
Ireland	10,4	11,3	12,1	31,9
Spain	13,3	19,0	19,9	27,5
Italy	-	-	-	-
Luxemburg	21,8	24,2	31,5	33,9
Norway	16,2	17,5	21,4	-
Netherlands	20,9	23,4	22,5	25,9
Portugal	12,8	15,0	25,1	36,6
Sweden	27,7	26,9	-	-
Finland	29,4	30,9	30,6	31,3

In Figures 3-6, recent data on the production of sewage sludge for the 15 Old Member States as well as for the 10 New Member States are given. The data are for the year 2000. As seen in Figure 3, Germany is the largest producer of sludge in the EU followed by the United Kingdom, France, Italy and Spain, all producing more than 500,000 tonnes of dry matter (DM) of sludge in a year. These 5 countries generate altogether nearly 75 % of the sludge generated by the 15 Member States. The 10 new Member States produce altogether less than 250,000 tonnes DM. In the new Member States the situation roughly reflects the demography of each country. Sludge generation is more difficult to estimate than in the old Member States because of the heterogeneous statistical systems and the low reliability of data. Figure 5 shows the amount of sludge produced in the 10 new Member States. The values are between 400 tonnes in Malta and 330,000 tonnes in Poland (assuming a dry matter level of 10 %). From the 10 new Member States, Poland is the country with the largest population and the largest production of sewage sludge.

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[g] This value is a future estimation

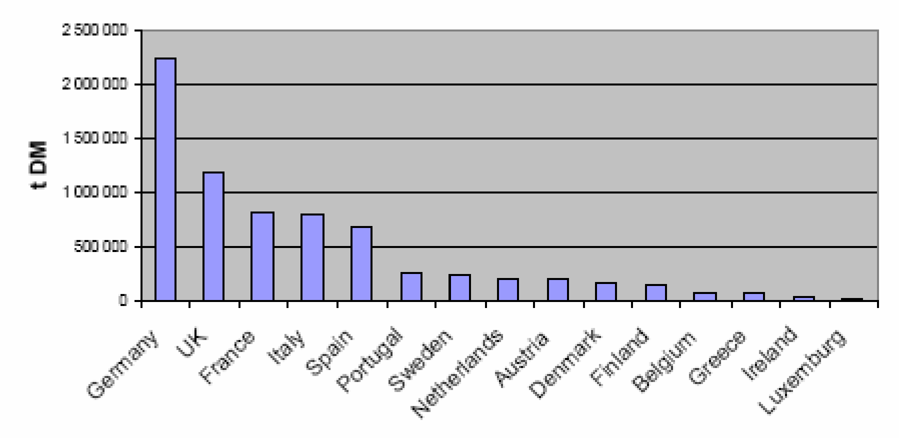

Figure 3: Sludge Production in the 15 Member States in tonnes DM = dry mass

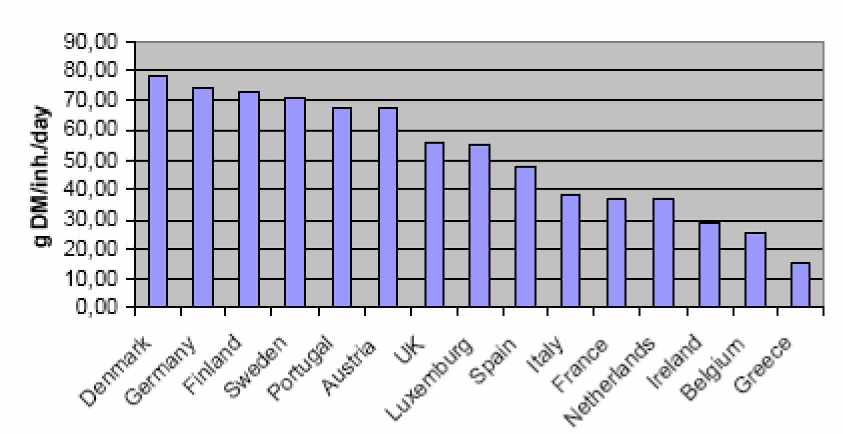

Figure 4: Sludge production per capita per day in the 15 Old Member States (units: gr DM per capita per day)

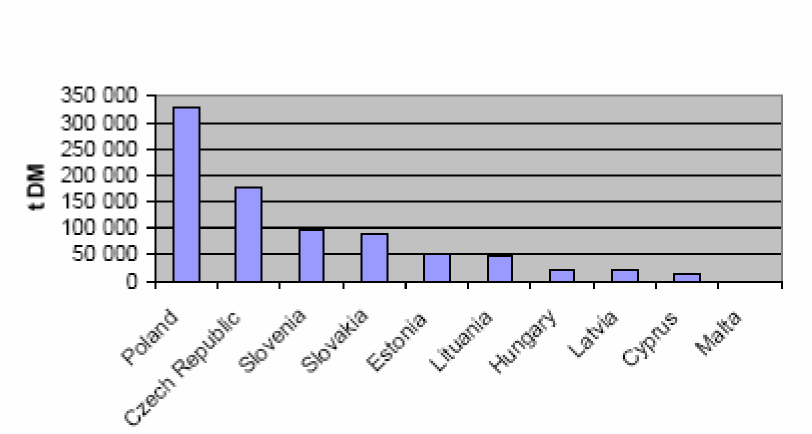

Figure 5: Sludge Production in the 10 New Member States in tonnes DM

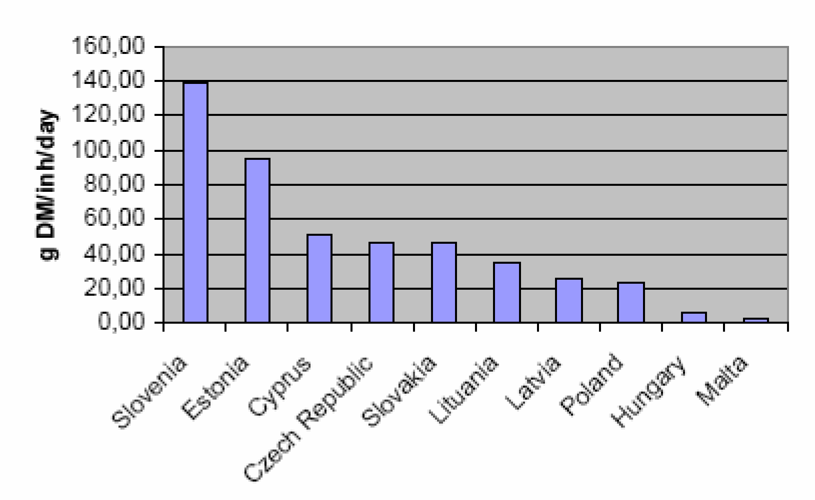

Figure 6: Sludge Production per Capita per Day in the 10 New Member States (units: gr dry mass per capita per day)

4.2 Sludge Management in the EU

Figure 7 shows the alternative sludge treatment and disposal routes for sewage sludge in the 15 old Member States. These sludge management options include disposal to landfills, agricultural reuse, incineration and other methods. Figure 8 shows the management routes for the 10 new Member States. The data are estimations for the year 2005. The data show that agricultural use of sewage sludge is the dominant forms of sludge management. In countries such as Ireland and Finland more than 65% of produced sludge is applied to land. Even in countries that have invested heavily on thermal treatment methods (mainly incineration) for the treatment of sludge (e.g. Austria and Netherlands), some proportion of sewage sludge is applied to agricultural.

In the 10 New Member States the situation concerning sludge management is diverse and it is difficult to draw specific conclusions. In certain countries such as the Czech Republic, Hungary and the Slovak Republic agricultural use of sludge is the dominant management route. Several countries dispose the majority of sludge to landfills (i.e. Poland, Slovenia and Estonia). Energy recovery is usually not employed in the New Member States as incineration is an expensive option.

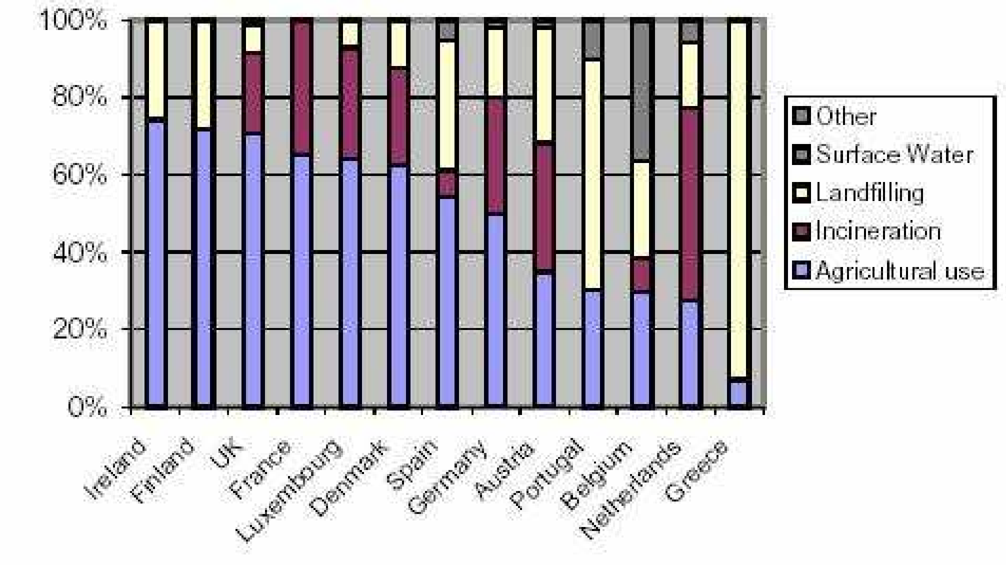

Figure 7: Sludge Management in the 15 Old Member States (Arthur Andersen, 2001c)

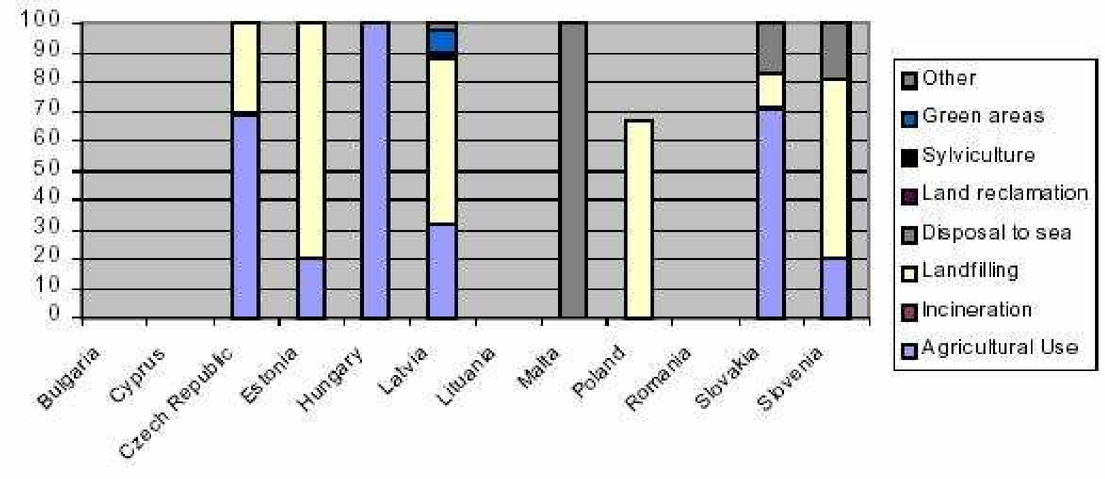

Figure 8: Sludge Management in the 10 New Member States (Arthur Andersen, 2001c)

4.2.1 Austria

Figure 9 and Table 37 show the production of sewage sludge as well as the management routes employed for the years 1997-2002 in Austria. Sludge production has increased during these years. Incineration has been the main method employed to treat sludge. Austria has invested heavily in thermal treatment of sludge. In the year 2002, approximately 50% of the generated sludge was incinerated. The use of sludge in agriculture has not been a priority. Only 12% of sludge is used in agriculture. At the year 2002, 11.5% of the produced sludge was disposed in landfills and this figure has recently been eliminated. However, the management of sewage sludge varies form region to region For example, in the provinces Burgenland and Vorarlberg more than 70% of produced sludge is used for agricultural purposes, while in Tyrol and Carinthia agricultural use is comparatively low (Scharf et al., 1998). The use of sludge in natural forests or in reforested areas has been banned. The use of sludge for soil rehabilitation is only allowed if the heavy metal concentration limits are met.

Since 2004 disposal to landfills is allowed only for waste (the law refers to waste in general) containing a maximum of 5% of organic matter or for waste which has undergone mechanical biological treatment. This evolution has affected the quantities of sludge disposed to landfills. With these constraints, the only possible ways for future sewage sludge management are incineration and agricultural application, which are expected to increase (Arthur Andersen, 2001c).

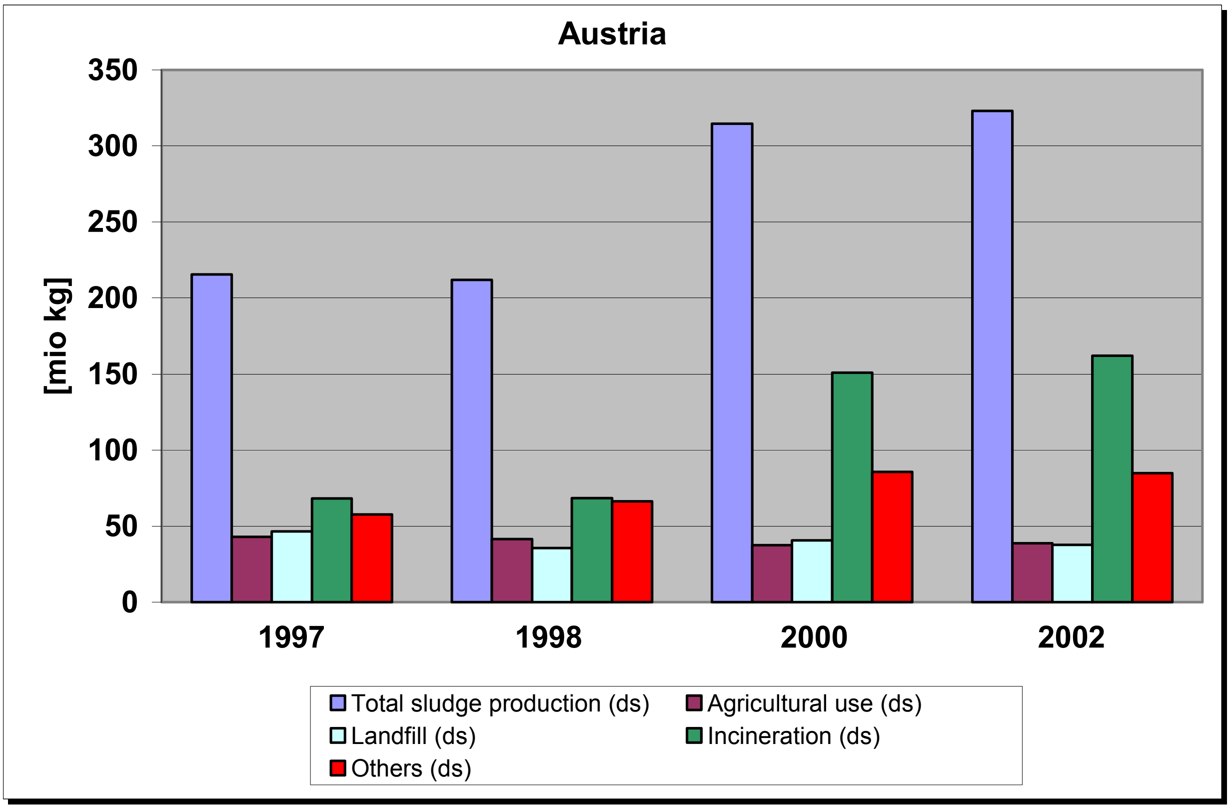

Figure 9: Sludge Production and Management in Austria (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 37: Sludge Production and Management in Austria (Million Kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Austria	1997	1998	2000	2002
Total sludge production	215.5	211.9	314.8	323.1
Agricultural use	43	41.6	37.3	38.7
Compost and other applications	-	-	-	-
Landfill	46.7	35.4	40.8	37.5
Incineration	68.2	68.4	151	162.1
Others	57.7	66.4	85.6	84.8

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.2 Belgium

Belgium is divided into three administrative regions: Flanders, Walloon and the region of Brussels. The authorities, on a national level, are responsible for the action and establishment of a legislative framework concerning the environment, while individual administrative regions are responsible for the national legislation transfer to the local level as well as for its implementation.

In the region of Flanders, the Decree of April 16, 1998 permits only the land spreading of sewage sludge that has been treated to reduce its content of hydrosoluble forms of N and P by at least 85% compared to untreated sludge. Only a very small quantity (approximately 5%) of the sewage sludge produced can fulfil this regulatory requirement; consequently the use of the majority of sludge in agriculture is indirectly banned. The limits concerning heavy metals are much stricter than the equivalent ones specified in Directive 86/278/EEC. In addition, the use of sludge is restricted to 4 tons per two years for cultivated land and 2 tons per two years for non cultivated land. In 1999, the majority of the produced sewage sludge (60%) was disposed to landfills. However, over the last years this is changing as more sludge is incinerated (Arthur Andersen, 2001c).

In the Walloon and Brussels Region of Belgium, landfill disposal of organics will be fully prohibited by 2010 due to the Government Order of 23 July 1987. More focus is given on the agricultural use of sewage sludge since the majority of the generated sewage sludge is applied to land. However, sludge incineration is also expected to increase. Farmers are not against sludge use, however, it seems their priority is with animal fertilizers. Apart from agricultural use, a small increase in sludge incineration is also expected (Arthur Andersen, 2001c).

4.2.3 Czech Republic

Figure 10 and Table 38 show the total production of sewage sludge and the various disposal-reuse practices in the Czech Republic for the period 1997–2002. As a result of the implementation of the Urban Wastewater Treatment Directive (91/271/EC), sludge production has increased during this period. Furthermore, since 2002, the composting method has been promoted among others management routes. At the year 2002, approximately 56% of sewage sludge was composted and used in agriculture (Eurostat, 2006); (European Environmental Agency, 2002b); (European Commission, 2001).

Direct land application is not anymore an acceptable option due to stricter hygienic requirements. The government supports the agricultural use of sewage sludge and it is therefore making great efforts to implement Directive 86/278/EEC. Its overall aim is to create such conditions so as to encourage interest for use of sewage sludge in agriculture and to support technological process of sewage sludge processing so as to improve its quality. Furthermore, another option that may play a crucial role in the future, in the case of Czech Republic, is the incineration of sludge, especially in large cities. It is expected that the total generation of sewage sludge in the country will continue to increase, as the Czech Republic fully implements Directive 91/271/EEC.

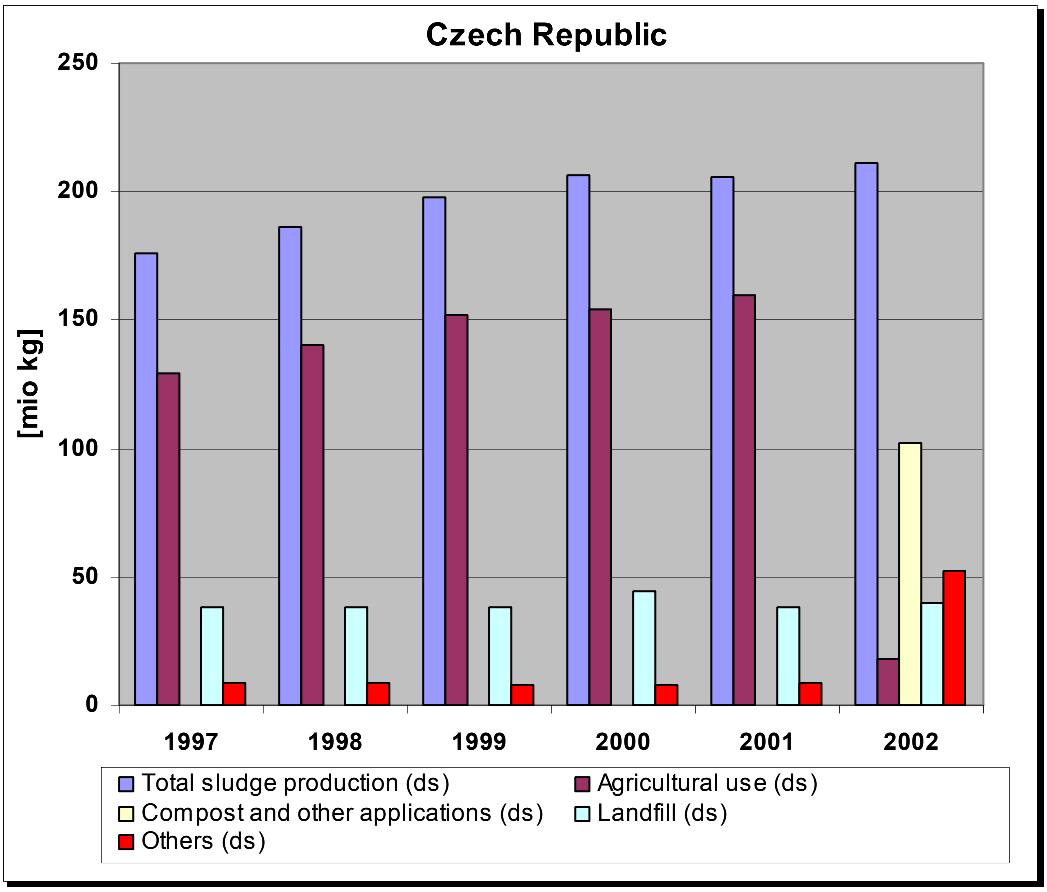

Figure 10: Sludge Production and Management in the Czech Republic (Eurostat, 2006)

Table 38: Sludge Production and Management in the Czech Republic (Million Kg DM) (Eurostat, 2006)

Czech Republic	1997	1998	1999	2000	2001	2002
Total sludge production	175.9	186.2	198.2	206.7	205.6	211.4
Agricultural use	129.1	140.2	152.2	154.4	159.3	17.6
Compost and other applications	-	-	-	-	-	101.8
Landfill	38.2	37.8	38.1	44.3	37.9	39.7
Incineration	-	-	-	-	-	0.3
Others	8.6	8.2	7.9	8.1	8.4	52.1

-: No data available
DM = Dry Mass
http://epp.eurostat.ec.europa.eu/

4.2.4 Denmark

As shown in Figure 11 and in Table 39, Denmark produced in 1997 and 1998 more than 150 million kg of sludge each year. The estimations for year 2005 show a significant increase in sewage sludge generation. Denmark relies heavily on agricultural use of the produced sludge; the country also incinerates a significant portion of sludge (around 50 million kg of sludge per year). According to the estimated data for the year 2005, 62% of the produced sludge is applied to land, 25% is incinerated and only 12% is disposed to landfill sites (European Environmental Agency, 2002b).

The national legislation is one of the strictest in force today with respect to the limit values for heavy metal concentration. New regulations that came into force in 2003 are very stringent, thus aiming at reducing risks to an acceptable level. Although farmers were initially negative to the use of sludge in agriculture, their attitude has changed as a result of the implementation of stricter legislation. Some farmers consider that legislation is strict enough to reduce risks. On the other hand, food industry is in favour of the use of sludge in silviculture or for land reclamation for economic and sanitary reasons (Arthur Andersen, 2001a).

Farmer unions consider that it is difficult to have guarantees for the quality of sludge and that is the reason why they often prefer to use manure produced by their own livestock. Food industries are skeptical about the use of sludge in agriculture and propose its use in forest and reforested areas. It is worth mentioning that other methods of sludge treatment-disposal are studied, such as the stabilization in cement and in building materials. Small towns support the agricultural use of sewage sludge, while bigger towns seem more reluctant, due to poorer sludge quality and large distances (and costs) to agricultural land (Duvaud et al., 1999); (Arthur Andersen, 2001a).

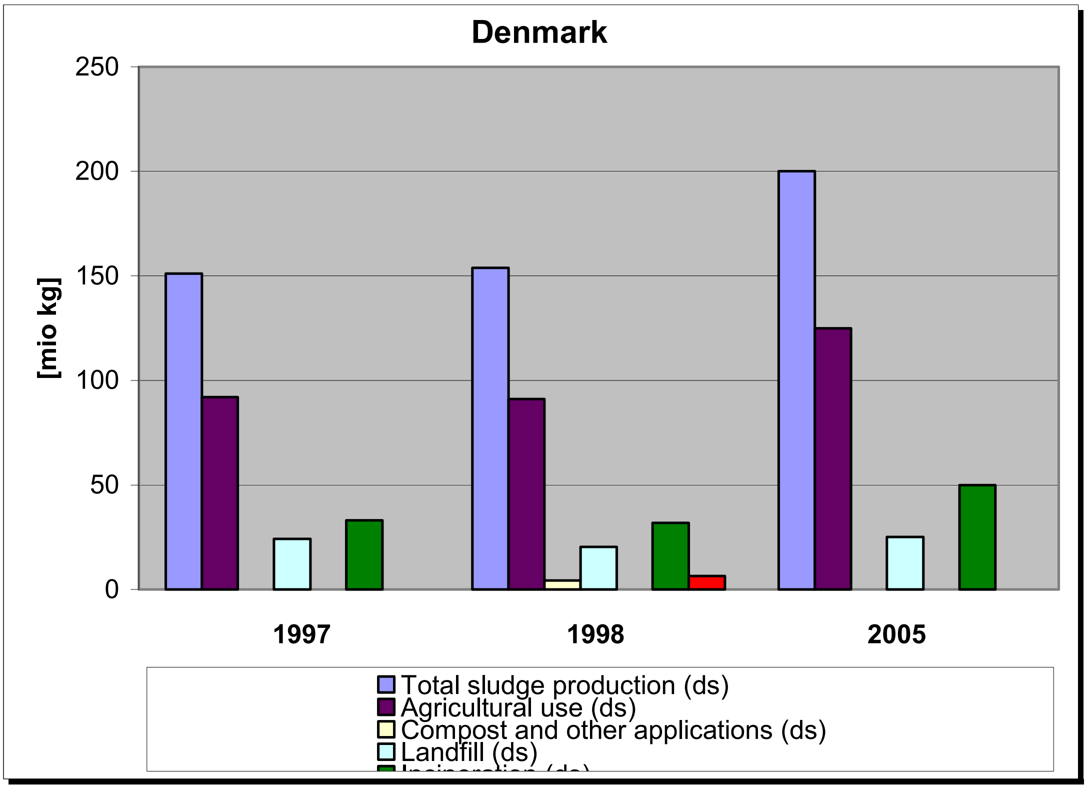

Figure 11: Sludge Production and Management in Denmark (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 39: Sludge Production and Management in Denmark (Million Kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Denmark	**1997**	**1998**	**2005**[h]
Total sludge production	151	153.8	200
Agricultural use	92.1	91	125
Compost and other applications	-	4.2	-
Landfill	24.2	20.3	25
Incineration	33.2	31.9	50
Others	-	6.4	-

-: No data available
DM = Dry Mass
http://epp.eurostat.ec.europa.eu/

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[h] Estimations

4.2.5 Finland

Figure 12 and Table 40 present the various management methods used for sewage sludge in Finland for years 1997-2000 and estimations for year 2005. The majority of sludge in Finland is composted. Compost is preferred to landfill disposal and incineration. The end compost is mainly used in agriculture (around 30%) and is also allocated to tree planting along the highways and to park renovation (around 30%). Sludge is neither incinerated nor used in forest areas.

Despite the legislation implemented in 1994, which is one of the strictest at a European level as far as the limit values of heavy metals contained in sewage sludge are concerned, the farmers' attitude remains negative. Moreover, the lack of suitable land for spreading of urban sewage sludge makes this disposal route difficult to follow. Under these circumstances, the public authorities and the sewage sludge producers are forced to find alternative routes for the disposal of sewage sludge. Therefore there might be a reduction to the quantities of sewage sludge used in land spreading and an increase of the quantities of composted sewage sludge used for land reclamation (Arthur Andresen, 2001a); (Duvaud et al., 1999).

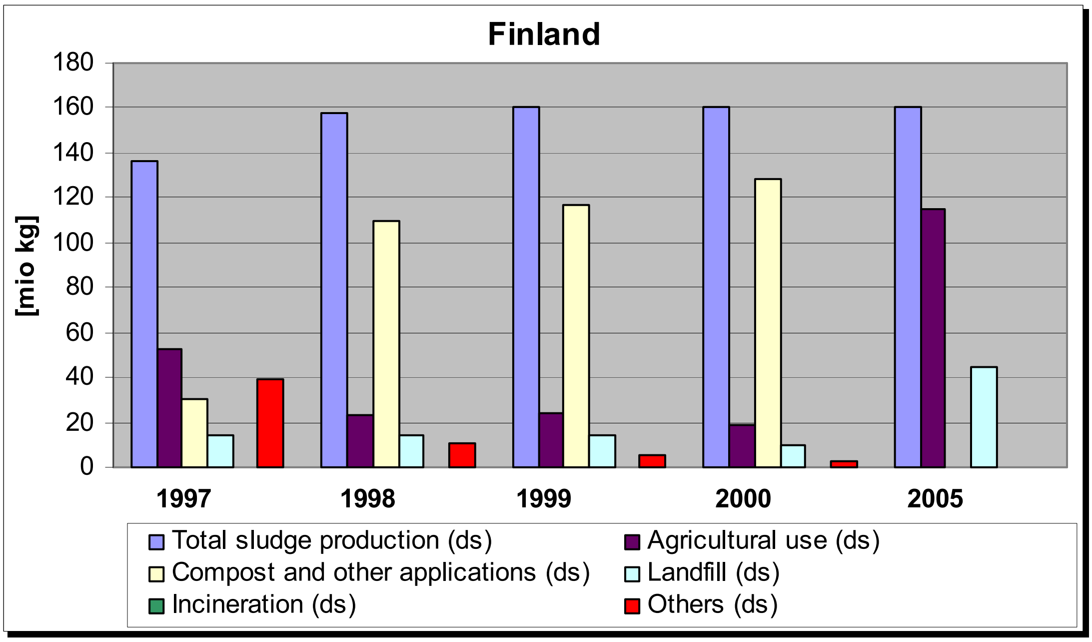

Figure 12: Sludge Production and Management in Finland (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 40: Total Sludge Production in Finland (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Finland	1997	1998	1999	2000	2005
Total sludge production	136	158	160	160	160
Agricultural use	53	23	24	19	115
Compost and other applications	30	110	117	128	-
Landfill	14	14	14	10	45
Incineration	-	-	-	-	-
Others	39	11	5	3	-

-: No data available
DM = Dry Mass
http://epp.eurostat.ec.europa.eu/

4.2.6 France

Figure 13 and Table 41 show the sludge production for years 1997, 1998 and 2001 and the applied management practices for the years 1998 and 2001. Furthermore, estimations are made for year 2005. The majority of produced sludge is applied to land. Also, a significant proportion of generated sludge is incinerated. At 2001, approximately 55% of the produced sludge was applied to land, with a small proportion of sludge being composted (approximately 5%). During the same year, 17% of generated sludge was incinerated and 24% was disposed to landfills (Eurostat, 2006).

Due to the continuous increase in the quantities of produced sludge and due to the cost of incineration, an increase is expected in the future in the use of sludge in agriculture. A small increase will be noticed, in parallel, in the quantities which are incinerated. Farmers, worried about possible negative effects, are against the agricultural use of sludge, having the view that the existing restrictions, with respect to sludge disposal, do not safeguard public health. On the other hand, local authorities and specialists in wastewater treatment support sludge application to the soil since it is an economical recycling route. As far as food industries are concerned, they are, in general terms, in favour of the agricultural use of sludge since adverse effect on the food chain are excluded. A great problem that France confronted the last years was the fact that farmers and the public were not well informed of the benefits arising from the land application of sludge (Arthur Andresen, 2001c).

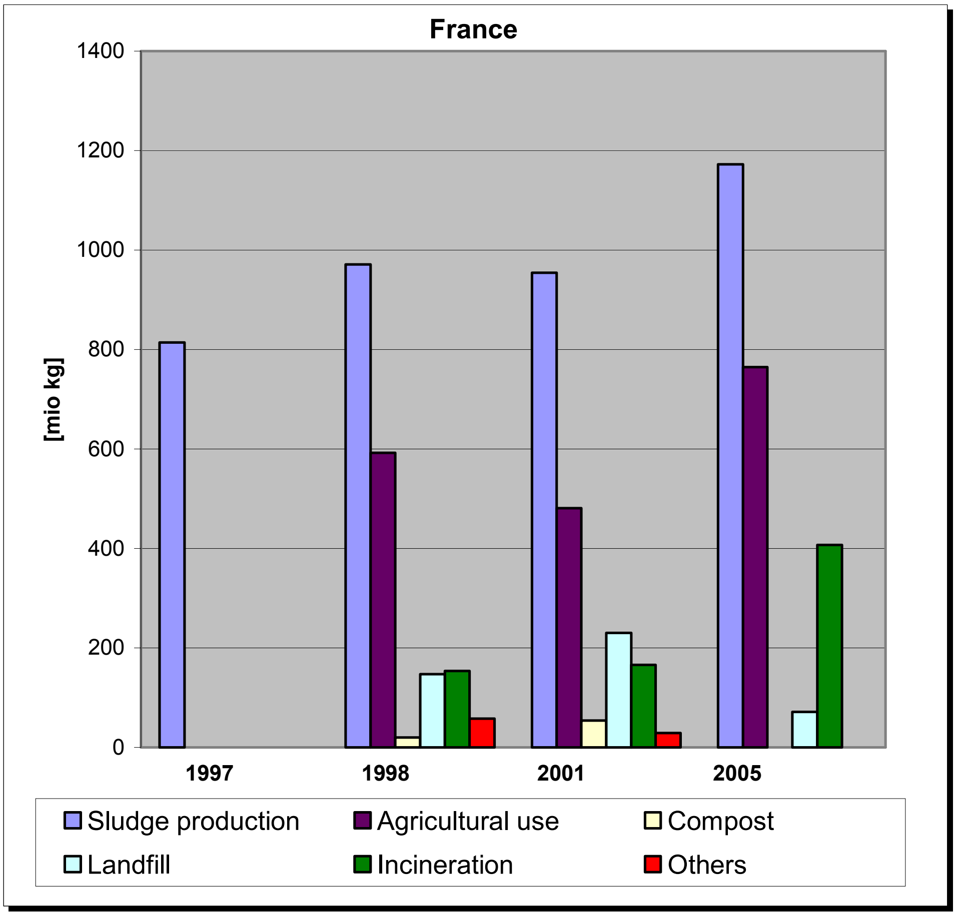

Figure 13: Sludge Production and Management in France (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 41: Sludge Production and Management in France (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

France	1997	1998	2001	2005[i]
Sludge production	814	971.4	954	1172
Agricultural use	-	592.5	481.3	765
Compost & other applications	-	19.8	54.1	-
Landfill	-	147.1	230.1	-
Incineration	-	154.1	166.4	407
Others	-	58	28.6	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.7 Germany

Figure 14 and Table 42 show data on production and management routes of sewage sludge in Germany for years 1998, 2001 and estimations for 2005. Incineration and composting are employed in order to treat sewage sludge. In addition, a significant proportion of sludge is reused in agriculture. Efforts have concentrated on eliminating the organics (including sludge) that are disposed to landfills. According to German Legislation, since June 2005 only wastes containing less than 5% of organic matter is accepted in landfills. In Germany, most of the produced sludge is either incinerated or used in agriculture. According to estimations of 2005, 50% of the produced sludge is reused in agriculture while 40% is incinerated (Arthur Andersen, 2001a).

The German state has adopted stricter limit values for heavy metal concentrations than those set in the European Directive 86/278/EEC. In addition, a compensation policy has been implemented for farmers who face problems with their crops due to sludge application. German National Legislation bans the use of sludge in forest and reforested areas. As a result, the proportion of sewage sludge that is incinerated has increased over the last years and is expected to rise further. Until recently, the use of sewage sludge in agriculture was common practice since it is the most economical option. Nevertheless, according to the German Technical Association for Wastewater there is not enough sludge that meets the quality criteria for agricultural use. Landowners, support land spreading provided that the sludge is of good quality and the regulatory constraints are respected. On the other hand, food companies are generally against this option and seem reluctant to purchase products that have been grown with sludge fertilizers. Consumer associations have adopted a firmer attitude and they are clearly against the use of sewage sludge in agriculture, since they find that there is a great risk involved. These associations support the incineration of sewage sludge and this is reflected by an increase of the quantities of sludge that is

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[i] Estimations

incinerated (Arthur Andersen, 2001a).

Since the use of sewage sludge in silviculture, in natural forest and reforested areas and in green areas is prohibited and since only waste containing less than 5% of organic matter is accepted in landfills, the amounts of sewage sludge that will be either incinerated or used in agriculture will increase. Recently, incineration is preferred to agricultural reuse due to increasing fears about the effects of land spreading of sewage sludge on soils and crops (Ministry of Environment of Baden-Württemberg, 2003); (Arthur Andersen, 2001a).

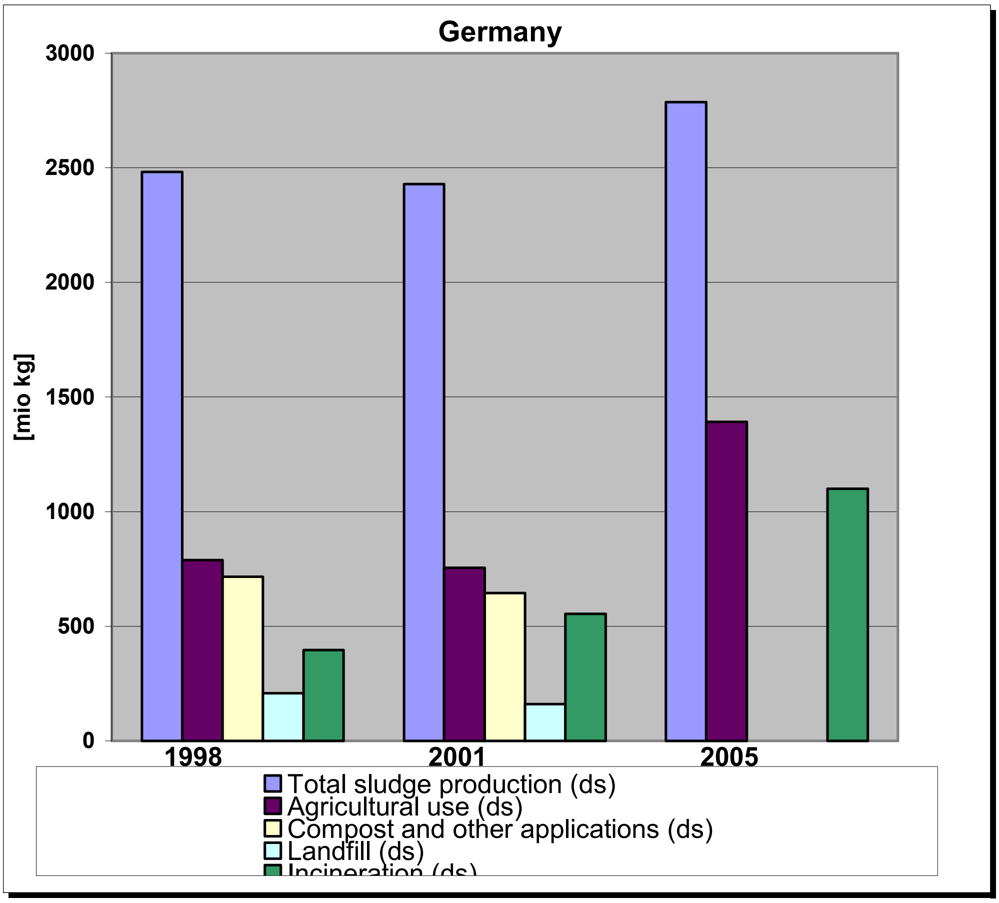

Figure 14: Sludge Production and Management in Germany (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 42: Sludge Production and Management in Germany (Million Kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Germany	1998	2001	2005[j]
Total sludge production	2482	2429.4	2787
Agricultural use	788	754.8	1391
Compost and other applications	716	644.6	-
Landfill	207	159.7	-
Incineration	396	554.9	1102,1
Others	-	-	58

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.8 Greece

Table 43 shows the production of sludge in Greece for the years 1993-2005, while Table 44 shows the quantities of different types (primary, secondary & tertiary) of sludge are shown for the years of 1993, 1995 and 1997. Agricultural use of sludge amounts to only 10% of the total quantity produced. The remaining quantity is disposed in landfills. In the urban centres of Athens and Salonika the atmospheric pollution problem is already acute and for this reason incineration is not promoted by the state as a solution to the problem. The use of sludge in forest and reforested areas has not yet been applied. The composting plant in Ano-Liosia of Athens receives approximately 300 tonnes/day of wet, dewatered sludge. However, this plant does not have the capacity to treat the whole of sludge that is produced in Athens. Consequently, much of the produced sludge ends-up in landfills.

In order to investigate the suitability of sewage sludge that has undergone some kind of treatment for agricultural use, several pilot studies have been carried out. In the city of Volos for example, field experiments showed that sludge quality complied with the limits set by EU and that its application to soil significantly improved its properties, thus increasing cotton yield. Similar experiments in the city of Larissa proved an

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[j] Estimations

increase in the wheat and corn yields. Nevertheless, sewage sludge produced in the largest wastewater treatment plant in Psyttalia is only marginally suitable for agricultural reuse, according to the existing legislation, due to significant industrial contributions. An extensive industrial wastewater control is needed if the anticipated stricter limits for heavy metals concentrations are to be met (Sanitary Engineering Laboratory, 2000; Christoulas, 1999). An investigation, involving sludge from 15 medium-large treatment plants has shown that heavy metals concentrations were well below the limits of the existing EU legislation. With the exemption of the large treatment plants of Athens and Thessaloniki, in most of the other cases the sludge characteristics favour agricultural reuse (Sanitary Engineering Laboratory, 2000).

The small proportion of agricultural application of sludge in Greece (only 10%) has not been an issue of debate in Greek society. Consequently, all stakeholders (farmer unions, consumer associations, food industries and environmental organizations) have not yet taken a stand on the problem. Another management option that may be considered in the future is the use of sewage sludge as a fuel substitute in the cement industry.

Table 43: Sludge Production in Greece (tonnes DM/year)

Year	**Produced Sludge (tn DM)**
1993	46,864
1995	51,624
1996	52,137
1997	58,993
1998	68,325
2000	79,211
2002[k]	86,875
2004[j]	92,500
2005[j]	95,156

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[k] Estimated value

Table 44: Quantities of Different Types of Sludge Produced in Greece (tonnes DM/year) (Tsagarakis, 1999)

Sludge Type	**Year**		
	1993	1995	1997
Primary	24.896	24.942	27.044
Secondary	16.894	18.341	20.783
Tertiary	5.074	8.341	11.166
Total	**46.864**	**51.624**	**58.993**

4.2.9 Hungary

Figure 15 and Table 45 show the amount of sludge generated and the management practices applied in Hungary for the years 1997–2002. The data show that agricultural reuse, composting and landfill disposal are the dominant practices. Composting and landfill disposal have increased since 1997, while agricultural reuse of sludge has remained constant.

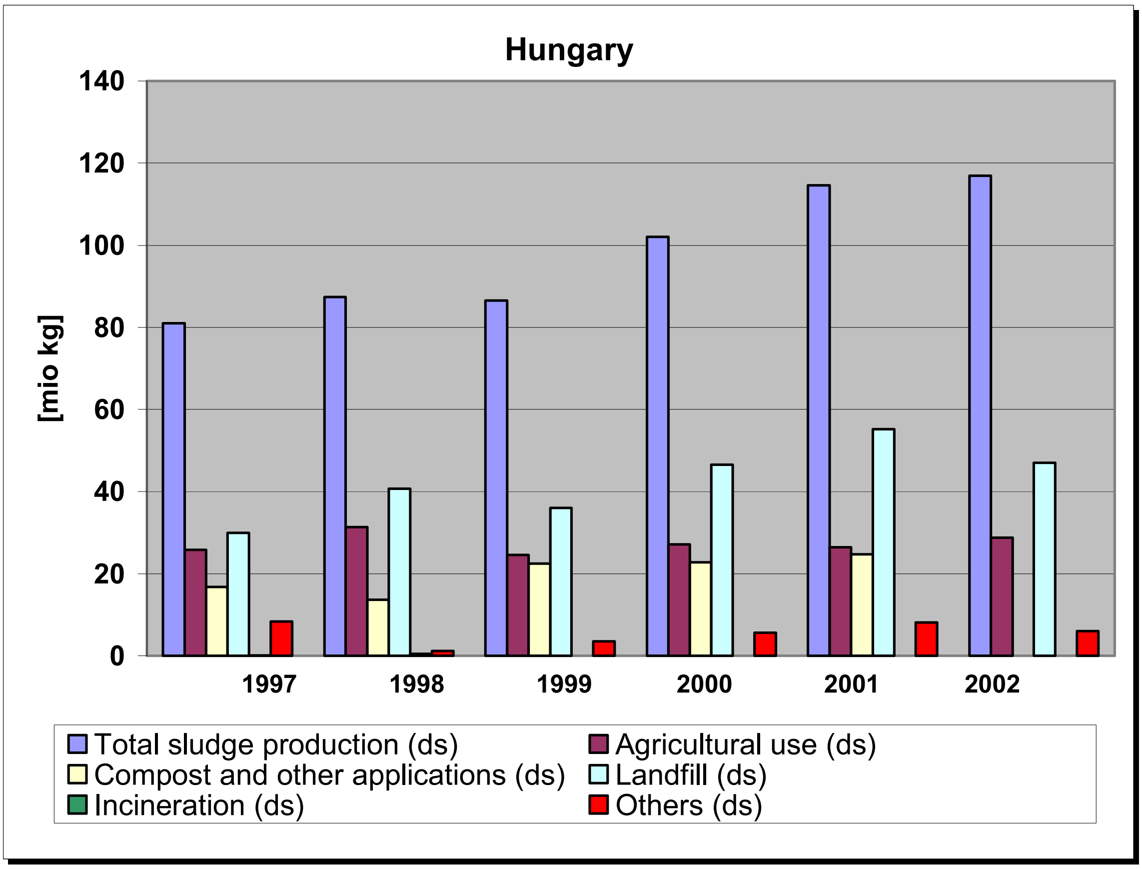

Figure 15: Sludge Production and Management in Hungary (Eurostat, 2006);

Table 45: Sludge Production and Management in Hungary (Million kg DM) (Eurostat, 2006)

Hungary	1997	1998	1999	2000	2001	2002
Total sludge production	81	87.4	86.5	102.1	114.6	116.9
Agricultural use	25.8	31.3	24.6	27.1	26.4	28.8
Compost and other applications	16.8	13.7	22.5	22.8	24.7	35.1
Landfill	29.9	40.7	36	46.6	55.2	47
Incineration	0.1	0.5	-	-	-	-
Others	8.4	1.2	3.5	5.6	8.2	6

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.10 Ireland

Figure 16 and table 46 present the sludge production and treatment-disposal options for years 1997–2001 as well as estimations for year 2005 in Ireland. Agricultural use and landfill disposal of sludge are the dominant treatment-disposal options and are continuously rising. During the year 2001 landfill disposal of sludge was the main sludge management method (54%), followed by agricultural use (45%). Over the last years, agricultural application of sludge has increased significantly. It is worth mentioning that sea disposal, a method used to manage 30% of sludge in Ireland, has stopped, since 1998. The capacity of existing landfills is small, while site restrictions make it difficult to find new sites. Furthermore, there is a negative public opinion about incineration. Agricultural application is strongly supported by the national authorities, since the general public is opposed to incineration. In the future, it is expected that the quantities of the sludge produced will increase and this will lead to a consequent increase in the amount of sludge that is applied in agriculture. The majority of farmers see the use of sludge positively, although there are those who prefer the use of manure which is abundant. Food industries have not yet expressed their view on the matter (Arthur Andersen, 2001a; Duvaud et al., 1999).

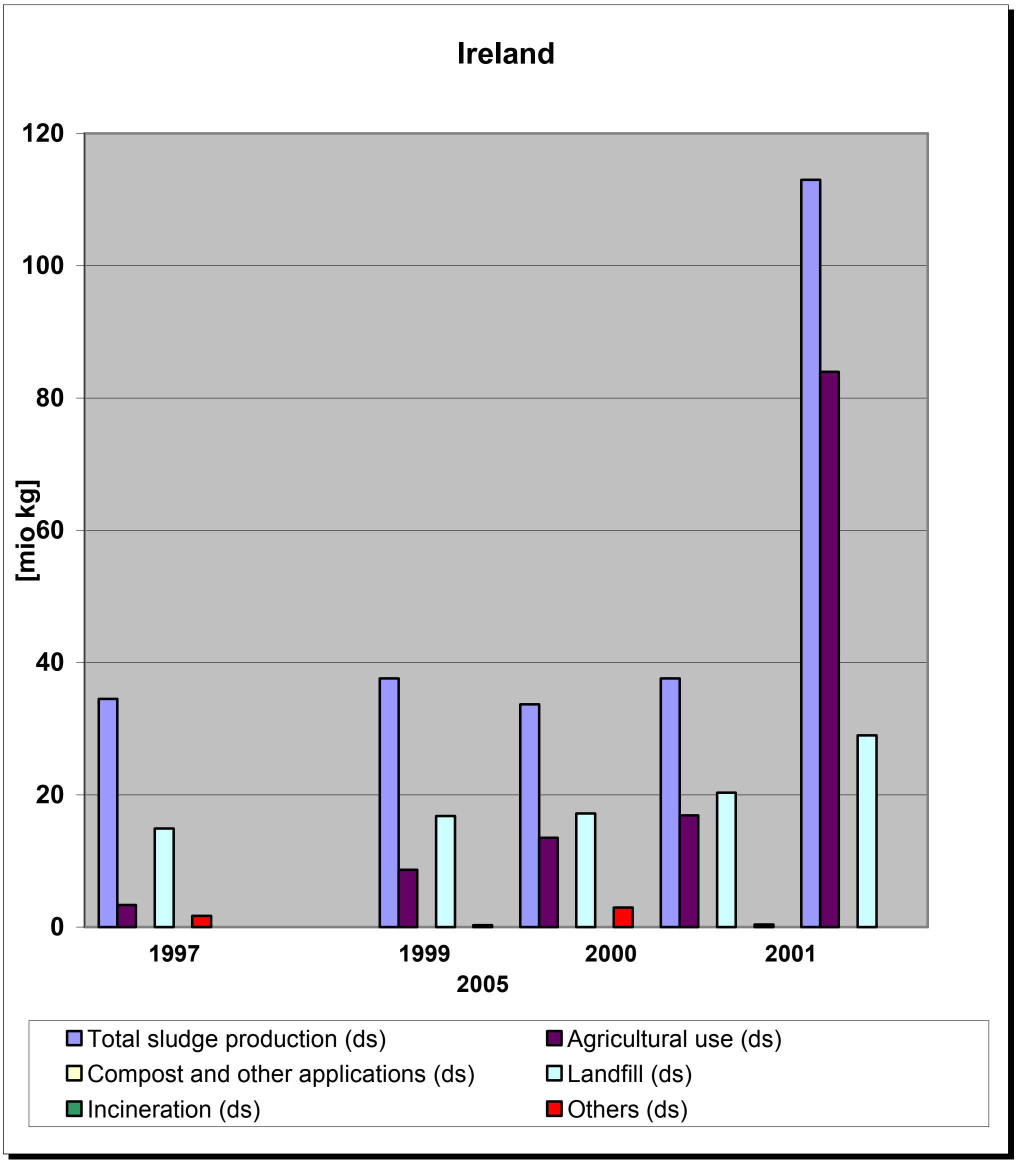

Figure 16: Sludge Production and Management in Ireland (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 46: Sludge Production and Management in Ireland (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Ireland	1997	1998	1999	2000	2001	2005[1]
Total sludge production	34.5	-	37.6	33.7	37.6	113
Agricultural use	3.4	-	8.7	13.5	16.9	8
Compost and other applications	-	-	-	-	-	-
Landfill	14.9	-	16.8	17.2	20.3	29
Incineration	-	-	-	-	-	-
Others	1.7	-	0.3	3	0.4	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.11 Italy

In Italy, according to data of year 2000, agricultural use of sludge is limited: only 18% of the total sludge produced is used in agriculture and that almost entirely in the northern and central part of the country. During the same year 80% of the produced sludge was disposed to landfills. Due to the strong opposition of public opinion against incineration, only 1% of the sludge produced is consumed by this method. It is expected that landfill disposal will be greatly reduced with agricultural recycling of sewage sludge being the most viable alternative (Arthur Andersen, 2001a).

4.2.12 Latvia

Prior to 2000, a large proportion of sludge (about 60%) was disposed to landfills, while 30% was used in agriculture and around 7% was composted for further use. However, data of Figure 17 and Table 47 show that this situation has radically changed. In particular, no sludge is disposed to landfills. The two main practices applied are agricultural reuse and composting and other applications. More specifically, during the year 2003, 31% of the generated sludge was applied in agriculture, 13% was composted, while 48% was managed in other ways (Latvian

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[1] Estimations

Environmental Agency, 2002); (Eurostat, 2006).

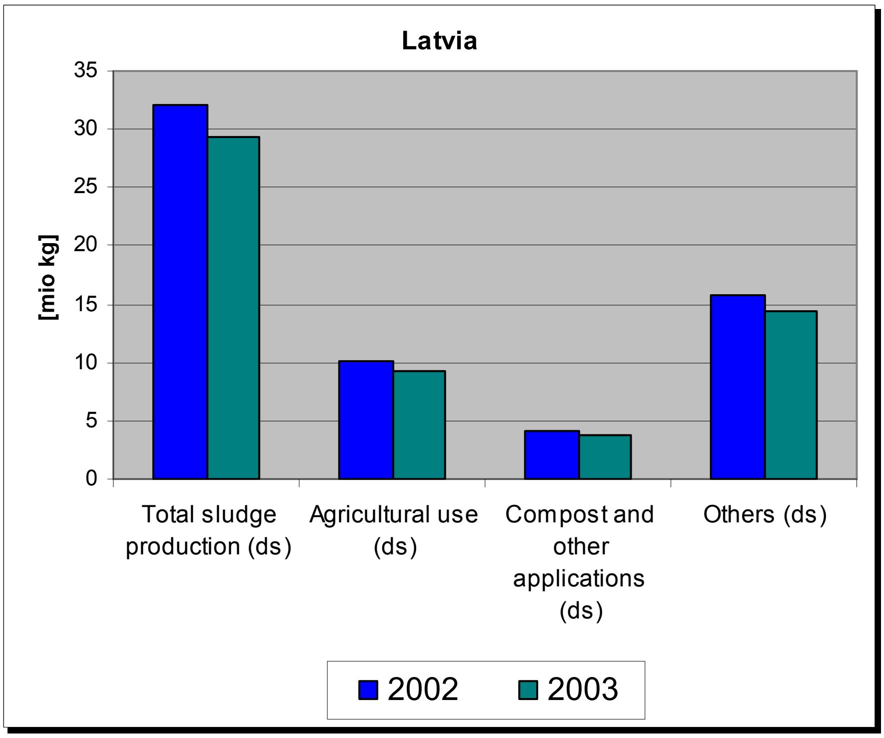

Figure 17: Sludge Production and Management in Latvia (Eurostat, 2006);

Table 47: Sludge Production and Management in Latvia (Million kg DM) (Eurostat, 2006)

Latvia	2002	2003
Total sludge production	32.1	29.3
Agricultural use	10.1	9.2
Compost and other applications	4.2	3.8
Landfill	0	0
Incineration	0	0
Others	15.8	14.4

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.13 Lithuania

Figure 18 and Table 48 present the total sludge produced for the years 1997 to 2001 in Lithuania. There are no data available for the disposal methods used for sewage sludge in Lithuania for these years.

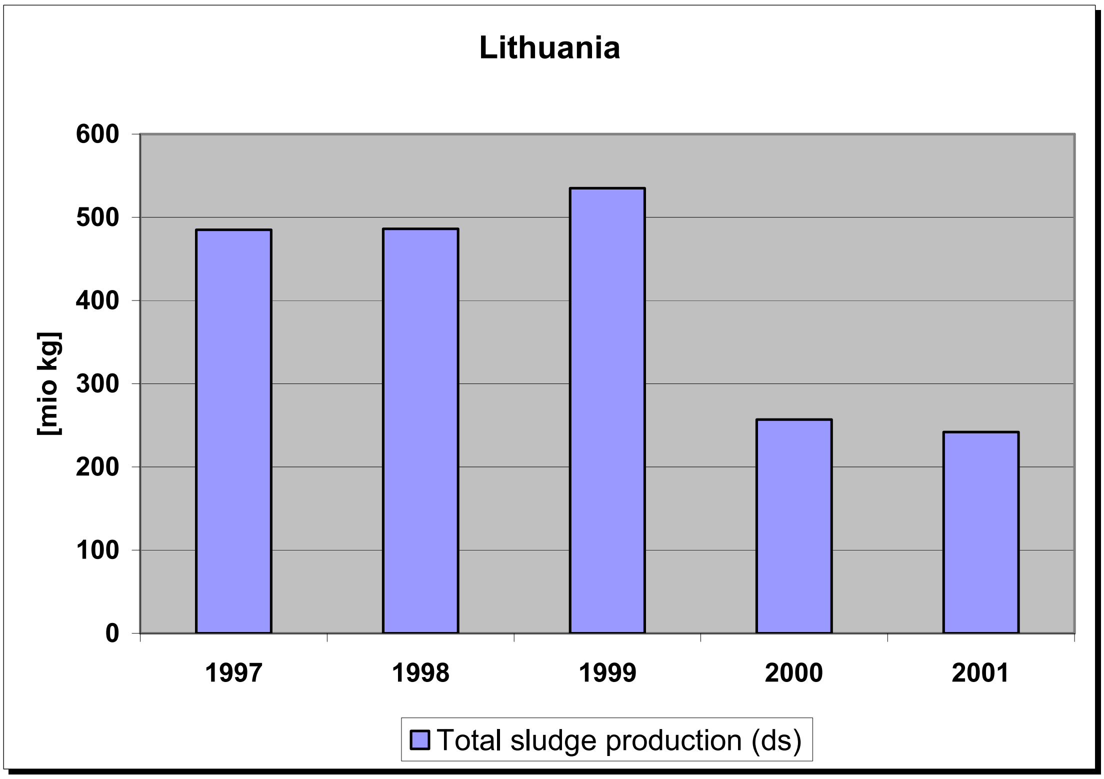

Figure 18: Sludge Production in Lithuania (Eurostat, 2006)

Table 48: Sludge Production in Lithuania (million kg DM) (Eurostat, 2006)

Lithuania	**1997**	**1998**	**1999**	**2000**	**2001**
Total sludge production	485	486	535	257	242

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.14 Luxemburg

Figure 19 and Table 49 present the sludge production and treatment-disposal patterns for the years 1999 and 2003 in Luxembourg and estimations for year 2005. Agricultural reuse is mainly employed, while a significant proportion is directed to landfills. During the year 2003 composting was employed to treat around 15% of the generated sludge, 50% was applied to agricultural land and around 33% was disposed to landfills (Eurostat, 2006). During the last decade high amounts of metals were traced in sludge and that is why the method was strongly disputed. Furthermore, farmers already use animal manure and in addition they face objective difficulties which forces them to limit the use of sewage sludge. Consequently, a turn of farmers is noticed towards the use of animal fertilizers. According to estimations for the year 2005, 20% of the sludge produced is incinerated. For use in forest areas, a special license by the state is required (Arthur Andersen, 2001a).

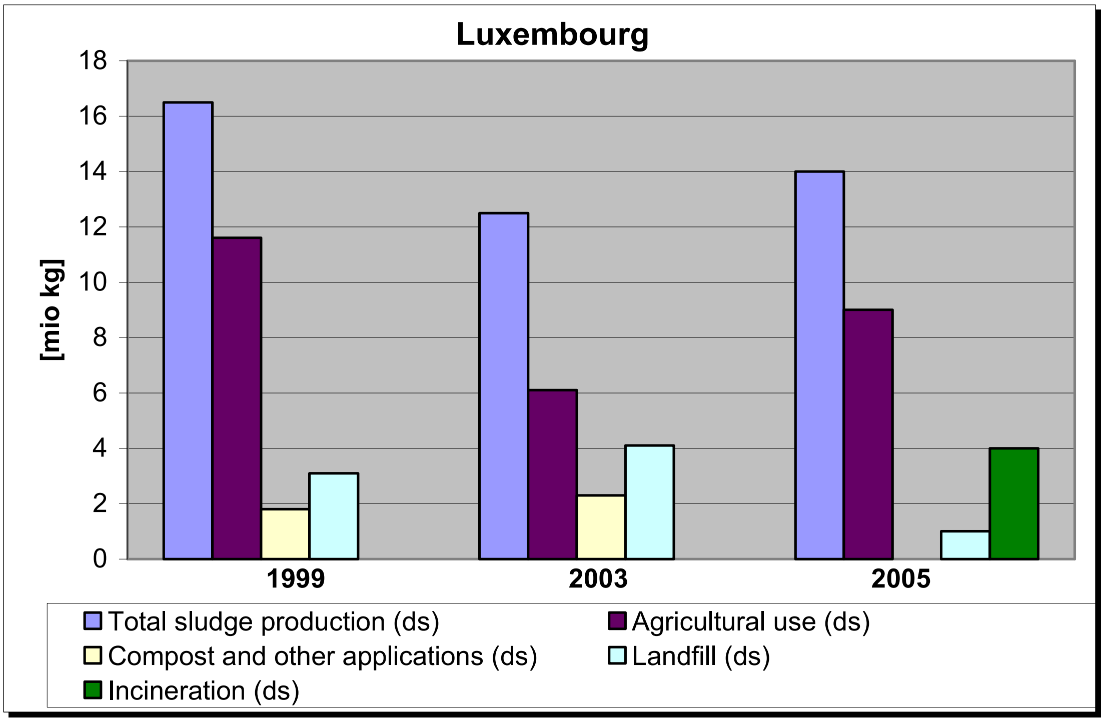

Figure 19: Sludge Production and Management in Luxembourg (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 49: Sludge Production and Management in Luxembourg (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Luxembourg (Grand-Duché)	**1999**	**2003**	**2005**
Total sludge production	16.5	12.5	14
Agricultural use	11.6	6.1	9
Compost and other applications	1.8	2.3	-
Landfill	3.1	4.1	1
Incineration	0	0	4
Others	0	0	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.15 Netherlands

Figure 20 and Table 50 show data on sludge production and management-disposal routes for years 1997–2002 in the Netherlands. Incineration has shown an increase during the last years, while disposal to landfills has decreased significantly. Incineration is used to treat approximately 50% of the produced sludge. Composting is also employed for the treatment of sewage sludge. During year 2002, 56% of sludge was incinerated, 14% was composted and 10% was disposed to landfills (Eurostat, 2006).

The state has established very strict limit values regarding the agricultural use of sludge. Consequently, only a small proportion of generated sludge is composted. The strict specifications governing sludge application to land aim to promote the use of animal manure as fertilizer. The use of sludge in green areas is not allowed, while use in silviculture is regulated by the strict Dutch Decree applied for the use of sludge in agriculture (Arthur Andersen, 2001b). Given these conditions, it is expected that sludge incineration will grow in the future.

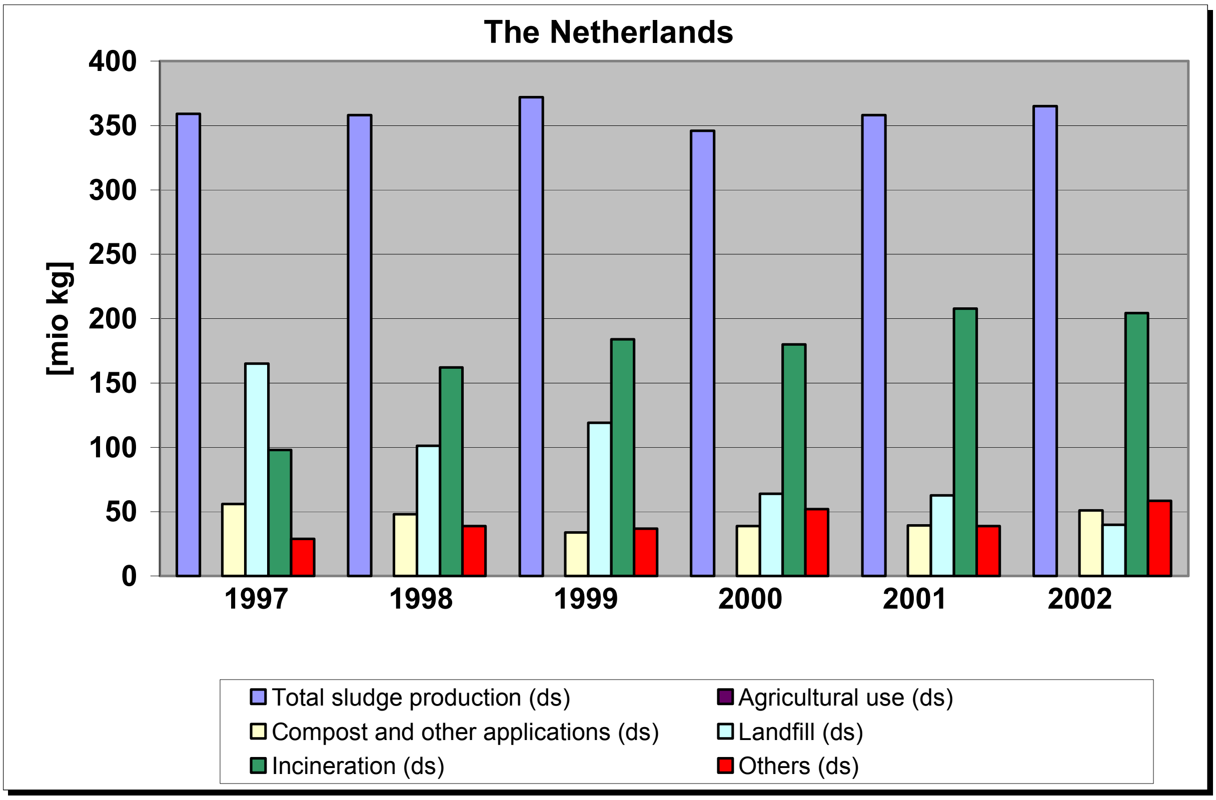

Figure 20: Sludge Production and Management in Netherlands (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 50: Sludge Production and Management in Netherlands (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Netherlands	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Total sludge production	359	358	372	346	358	365
Agricultural use	0	0	0	0	0	0
Compost and other applications	56	48	34	39	39.4	51.1
Landfill	165	101	119	64	62.8	39.8
Incineration	98	162	184	180	207.6	204.3
Others	29	39	37	52	39	58.6

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.16 Poland

Figure 21 and Table 51 show the production of sewage sludge in Poland for the years 1997-2003. During this period total sludge production has increased. Poland mainly employs landfill for the treatment and disposal of sludge. It must be stressed that Poland produces the greatest amounts of sludge from the 10 new Member States. During year 2003, 37% of the produced sludge was disposed to landfills, 4.5% was composted, 1.5% was incinerated and the remaining 45% was managed through other ways (Eurostat, 2006). The use of sludge in agriculture is regulated by the Decree of August 11, 1999 which states that sewage sludge can be used for land reclamation, in agriculture, in green areas and for the production of compost. The limit values as far as heavy metals are concerned are more stringent than the ones defined by the Sludge Directive 86/278/EEC. The most probable route to be followed in the future is the use of sewage sludge in agriculture. It is expected that the quantities of produced sludge will rise in the future as the country fully implements Directive 91/271/EEC.

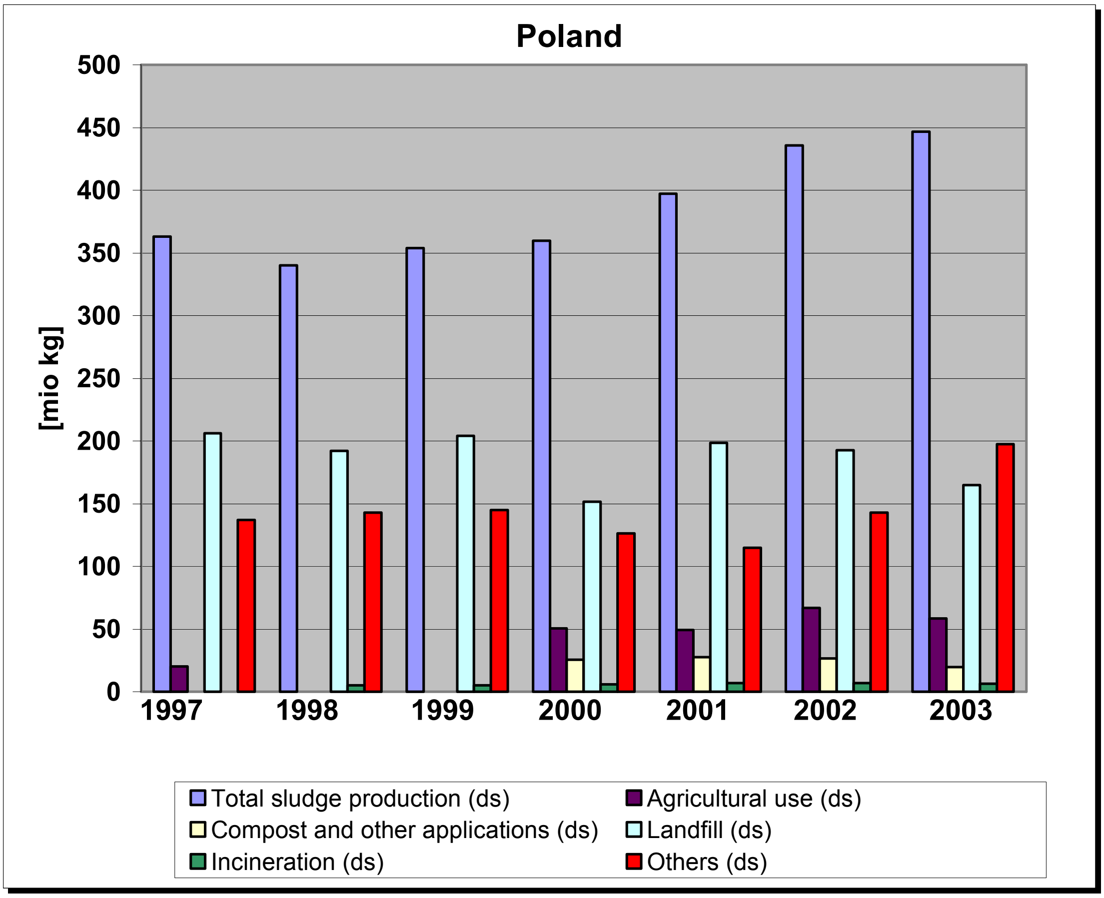

Figure 21: Sludge Production and Management in Poland (Eurostat, 2006)

Table 51: Sludge Production and Management in Poland (Million kg DM) (Eurostat, 2006)

Poland	1997	1998	1999	2000	2001	2002	2003
Total sludge production	363	340	354	359.8	397.2	435.7	446.5
Agricultural use	20			50.6	49.3	67	58.4
Compost and other applications	-	-	-	25.5	27.6	26.5	19.7
Landfill	206	192	204	151.6	198.6	192.5	164.9
Incineration	-	5	5	5.9	6.9	6.8	6.3
Others	137	143	145	126.1	114.8	142.9	197.4

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.17 Portugal

Figure 22 and Table 52 show data on sludge production in Portugal for the years 1995, 1997 and 1998 and provide estimations for the year 2005. Agricultural reuse is mainly employed in Portugal for the management of sludge. The data show that approximately 30% of the generated sludge is applied to land for agricultural purposes. Farmers support the use of sewage sludge due to its fertilizing value and its organic matter content and this will increase the quantities of sewage sludge that are being used. According to statistical studies, there are periods in the year when sludge demand by farmers is greater than the offer by waste water treatment plants due to the low price of compost. The allowed quantity of sludge added to cultivated soils reaches annually 6 tons per acre. Given that incineration is not developed, it is anticipated that the amount of sludge that is used in agriculture will rise in the following years (Arthur Andersen, 2001a).

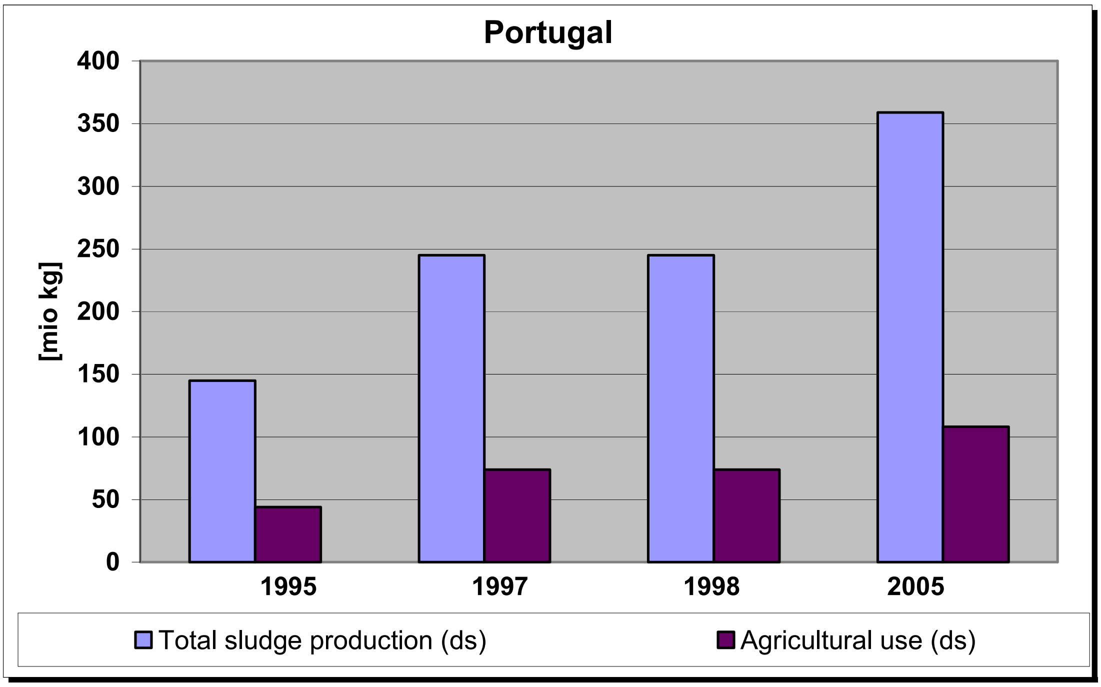

Figure 22: Sludge Production and Management in Portugal (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 52: Sludge Production and Management in Portugal (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Portugal	**1995**	**1997**	**1998**	**2005**
Total sludge production	145	245	245	359
Agricultural use	44	74	74	108

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.18 Slovak Republic

Figure 23 and Table 53 show the quantities of sludge produced in the Slovak Republic as well as the employed management routes. The quantities of produced sludge have risen significantly from 1997 to 2002 due to the implementation of the Urban Wastewater Treatment Directive. Agricultural use of sludge is the preferred option. During year 2002, 64% of the produced sludge was used for agricultural purposes, 20% was composted and only about 10% was disposed to landfills.

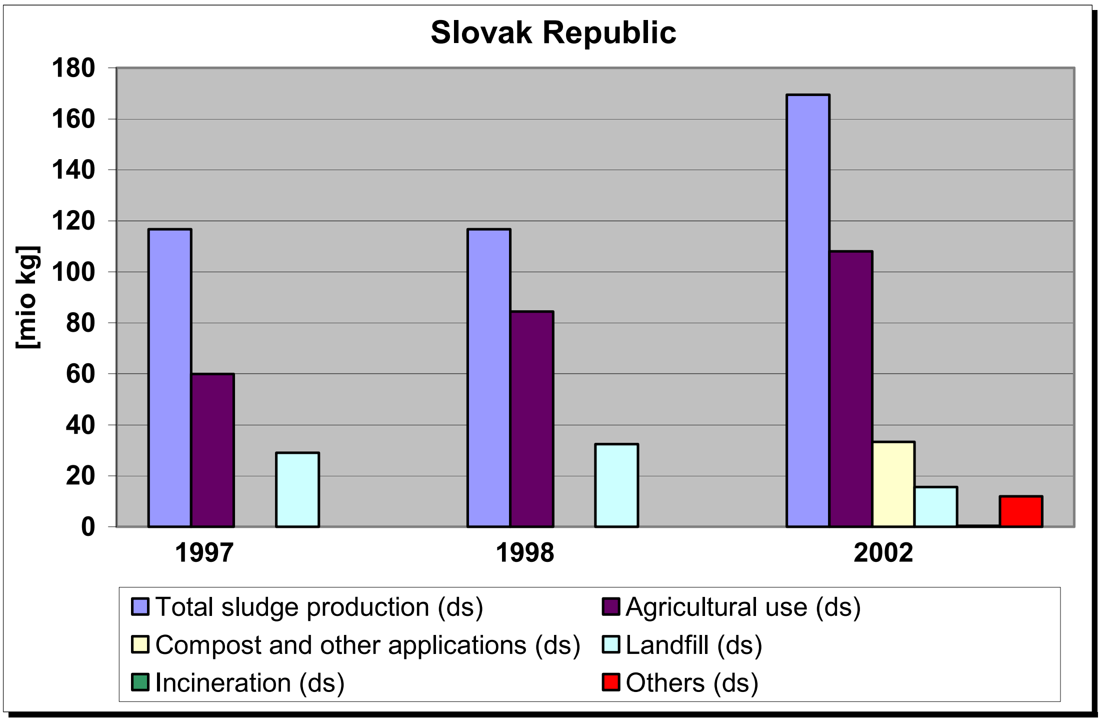

Figure 23: Sludge Production and Management in the Slovak Republic (Eurostat, 2006)

Table 53: Sludge Production and Management in the Slovak Republic (Million kg DM) (Eurostat, 2006)

Slovakia	1997	1998	2002
Total sludge production	88.9	116.8	169.5
Agricultural use	59.9	84.4	108
Compost and other applications	-	-	33.3
Landfill	29	32.4	15.7
Incineration	-	-	0.4
Others	-	-	12

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.19 Slovenia

Figure 24 and Table 54 provide data on the sludge generated in Slovenia and illustrate the various management methods employed. The data are for the years of 1998, 2000, 2001 and 2002. Landfill disposal is the preferred method. Some sludge is composted and reused in agriculture. More specifically, during the year 2002, 16% of the produced sludge was used in agriculture, 71% was disposed to landfills and approximately 13% was composted (Eurostat, 2006).

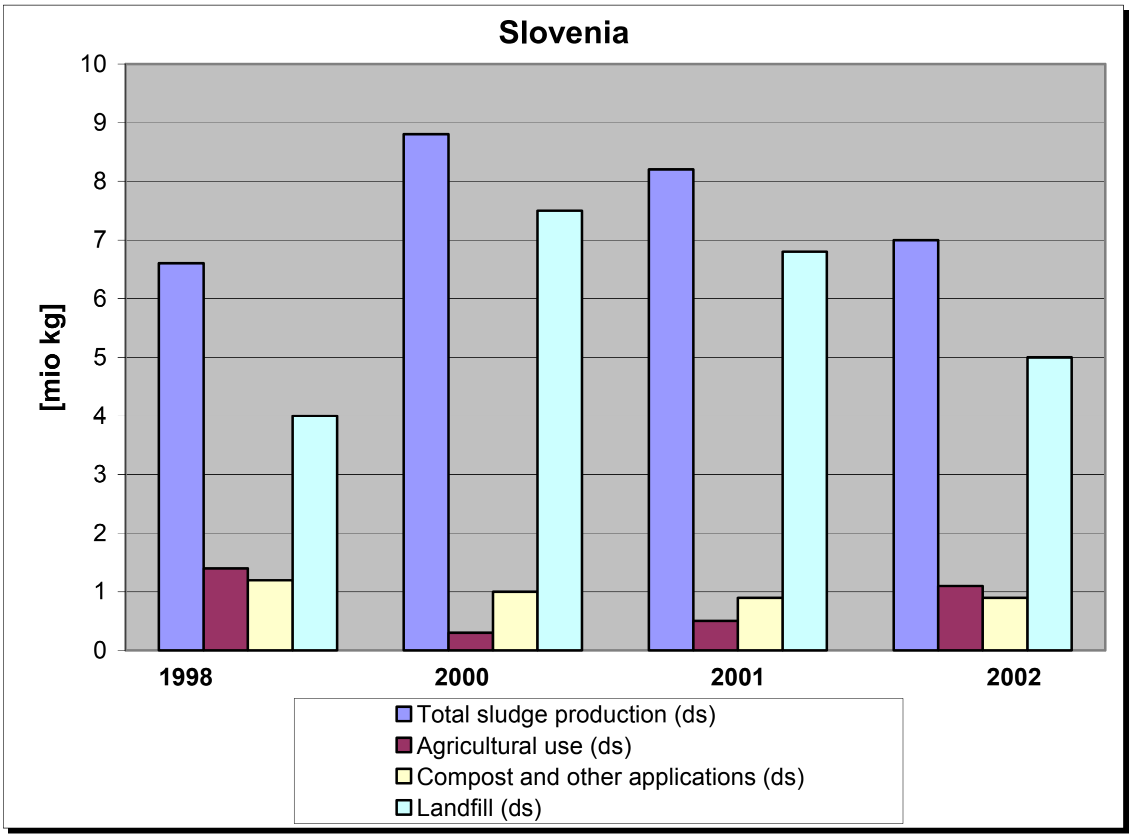

Figure 24: Sludge Production and Management in Slovenia (Eurostat, 2006)

Table 54: Sludge Production and Management in Slovenia (Million kg DM) (Eurostat, 2006)

Slovenia	**1998**	**2000**	**2001**	**2002**
Total sludge production	6.6	8.8	8.2	7
Agricultural use	1.4	0.3	0.5	1.1
Compost and other applications	1.2	1	0.9	0.9
Landfill	4	7.5	6.8	5
Incineration	-	-	-	-
Others	-	-	-	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.20 Spain

Figure 25 and Table 55 provide data on the various management routes employed for sewage sludge in Spain during the years 1997-2000 and estimations for year 2005. Agricultural use is the preferred option and has shown a significant increase during the period 1997-2000. For the same period landfill disposal is constant, while incineration increased slightly but steadily. Estimations for the year 2005 show that the generation of sewage sludge is increasing significantly due to the full application of the Urban Wastewater Treatment Directive. During the year 2000, approximately 53% of the generated sludge was applied to land, 8% was incinerated and 18% was disposed in landfills. The state supports the agricultural use of sludge and considers it as a method that will solve the problem of sludge increase. In 1995 the Spanish Plan for the purification and treatment of sewage sludge was created. This plan aims at improving the quality of sewage sludge used in agriculture and at preventing it from being polluted as well as ensuring its safe final disposal. Farmers seem to accept the use of sewage sludge, whereas public has some reservations to its use, mainly due to lack of information (Arthur Andersen, 2001a). The public is particularly negative towards sludge incineration. This, combined with the absence of sludge use in forest areas and barren soil, promotes the agricultural use of sludge as a solution to the problem (Calleja et al., 2000).

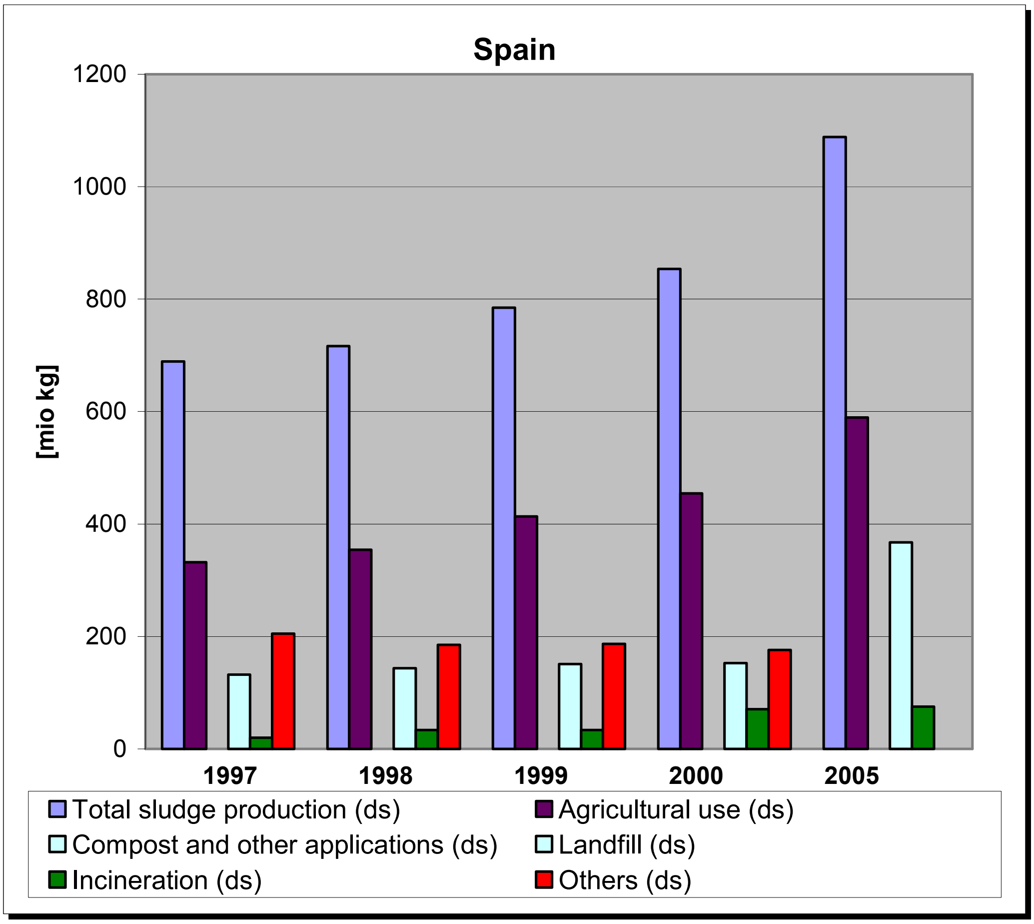

Figure 25: Sludge Production and Management in Spain (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 55: Sludge Production and Management in Spain (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Spain	1997	1998	1999	2000	2005^{m}
Total sludge production	689	716.2	784.9	853.5	1088
Agricultural use	332	354	413.7	454.3	589
Compost and other applications	-	-	-	-	-
Landfill	131.6	143.6	150.9	153.1	367
Dumping at sea	-	-	-	-	-
Incineration	20	33.5	33.5	70.2	75
Others	205.2	185	186.7	176	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.21 Sweden

Figure 26 and Table 56 present data on sludge generation and management methods employed in Sweden for the years 1998, 2000 and 2002. Within this period sludge disposal to landfills has decreased dramatically. Sweden mainly employs composting to treat sludge as well as other treatment technologies. During year 2002, 31% of the produced sludge was composted, 10% was disposed to landfills, while only 6% was applied in agriculture.

The agricultural use of sewage sludge was a very controversial issue in the early 90s. In 1994, a voluntary agreement concerning quality assurances related to the use of sludge in agriculture was reached among the Swedish Environmental Protection Agency (SEPA), the Swedish Federation of Farmers (LRF) and the Swedish Water and Waste Water Association (VAV). The agreement lasted until 1999, when the publication of reports that mentioned the presence of traces of chemicals in sludge resulted in the farmers' unions suggesting to ban the agricultural use of sewage sludge (Arthur Andersen, 2001a). The Swedish Federation of Farmers - LRF - supported this suggestion, which led to the current limited use of sewage sludge for land spreading (approximately 20% of sewage sludge is currently used in agriculture). Only farmers that do not belong to the LRF still use sludge in their land. Neither the food industry nor consumer and environment protection associations support the use of sludge in agriculture (Arthur Andersen, 2001a). Swedish regulations have banned since 2005 the disposal of organics to landfills. Consequently, sludge incineration and sludge use for reclamation or revegetation is expected to increase significantly

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[m] Estimation

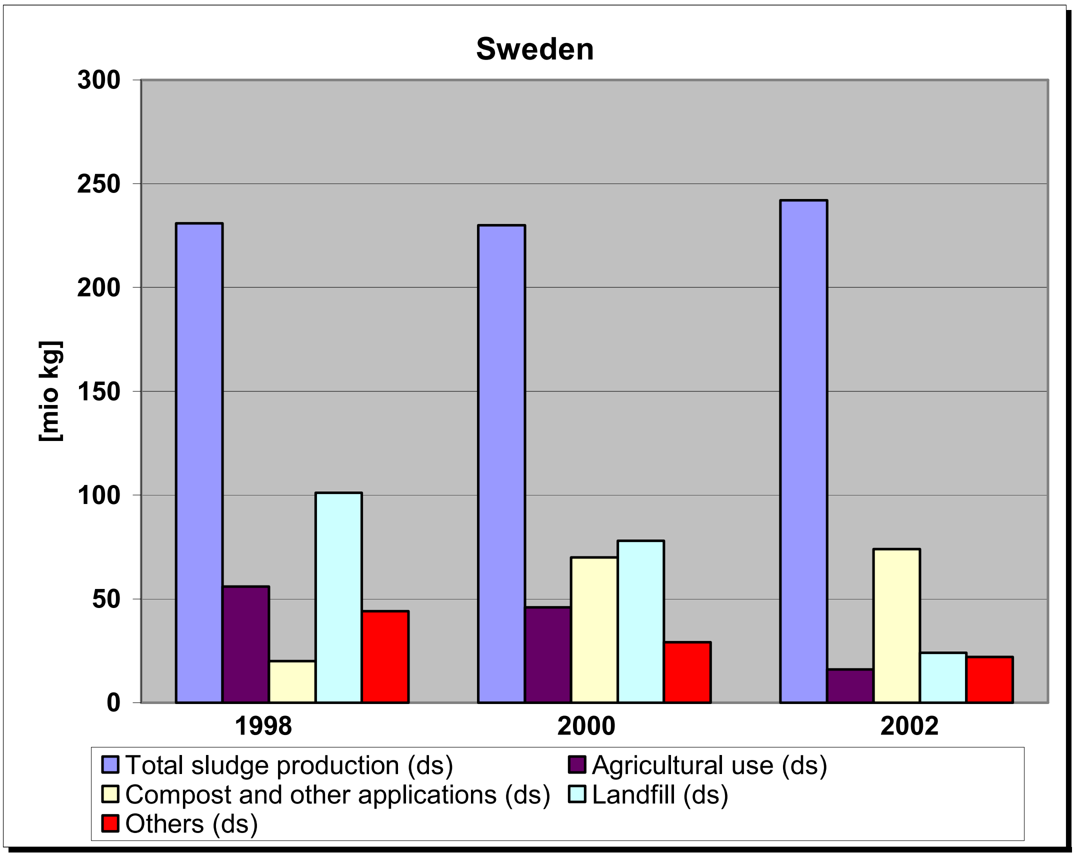

Figure 26: Sludge Production and Management in Sweden (Eurostat, 2006); (European Environmental Agency, 2002b)

Table 56: Sludge Production and Management in Sweden (Million kg DM) (Eurostat, 2006); (European Environmental Agency, 2002b)

Sweden	**1998**	**2000**	**2002**
Total sludge production	231	230	242
Agricultural use	56	46	16
Compost and other applications	20	70	74
Landfill	101	78	24
Incineration	-	-	-
Others	44	29	22

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

4.2.22 United Kingdom

UK is one of the largest producers of sludge in the EU with quantities that exceed 1,500,000 tonnes per year. Figure 27 and Table 57 present the sludge generation and management routes in the UK for the years 1997, 1998, 2001 and 2002. It can be seen that agricultural reuses of sludge, followed by incineration are the dominant schemes. According to year 2002, about 55% of the total sludge generated is used in agriculture, while approximately 20% of the produced sludge is incinerated. A small percentage of generated sludge is disposed to landfills. There is an agreement between the responsible Ministry, the farmers' union and the wastewater treatment plants so that the produced sludge fulfils the specifications for use in agriculture.

In addition to legislative regulations, a voluntary agreement which was reached in 1998 between the main sludge producers and the main food retailers led to the common adoption of a "Safe Sludge Matrix". The matrix establishes restrictions for the use of sewage sludge in agriculture, as well as categories of crops on which sludge may not be used. This agreement prohibits the use of untreated sludge. It is expected that agricultural use of sludge will continue to be the dominant form of sludge management followed by incineration. An alternative method that seems to be attractive is the use of sludge in forest areas (Arthur Andersen, 2001a).

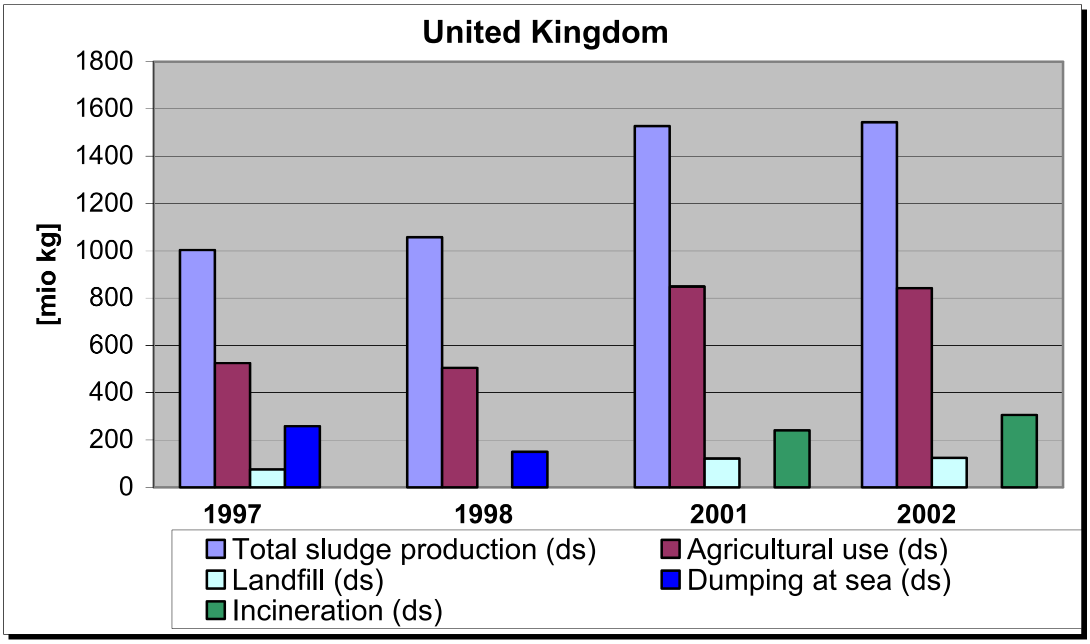

Figure 27: Sludge Production and Management in UK (Eurostat, 2006)

Table 57: Sludge Production and Management in UK (Million kg DM) (Eurostat, 2006)

United Kingdom	**1997**	**1998**	**2001**	**2002**
Total sludge production	1004	1058	1527,5	1543,8
Agricultural use	525	504	849,8	842,5
Compost and other applications	-	-	-	-
Landfill	75	0	122	124
Dumping at sea	258	150	0	0
Incineration	-	-	241,2	305,8
Others	-	-	-	-

-: No data available

DM = Dry Mass

http://epp.eurostat.ec.europa.eu/

5 Conclusion and Future Prospects in the EU

The quantities of sludge produced in the European Union are increasing due to the implementation of the Urban Wastewater Directive (91/271/EEC). Currently, it is estimated that approximately 8.3 million tonnes of dry solids of sewage sludge are produced annually in the 15 Old Member States and another 1 million tonnes from the 10 New Member States. This figure will rise as the New Member States fully conform to Directive 91/271/EEC. The analysis of data shows that land application for agricultural purposes is the dominant management scheme employed in the EU. Few Member States countries have focused more on incineration processes (e.g. Netherlands, Austria). Such countries have imposed very stringent limit values on heavy metals for sludge which cannot be attained by most of the produced sludge. However, most Member State countries have focused on agricultural use of sludge, since incineration is seen as an expensive investment option.

As far as EU legislation is concerned, depending on the treatment and disposal practices that take place, different Directives are applicable. Directive 86/278/EEC is important when sludge is applied to land. Consequently, it is important when treatment processes such as composting and drying of sludge take place. This Directive sets limit values for specific heavy metal concentrations in sludge and in soil where sludge is applied, but it does not specify limit values for pathogens or for organic contaminants. It is currently believed that these organic micro-pollutants are unlikely to cause adverse health effects, but in spite of increased investigation efforts, the ecotoxicological profile of organic contaminants is still not clear. Some Member States have adopted the Directive’s limit values while other Member States have set more stringent limitations.

The European Council declared in the Directive 86/278/EEC that the preferred routes for the handling of sludge are those where materials are utilised (e.g. the application in agriculture, which allows making use of its agronomic value). However, there are some barriers that may hinder the use of sewage sludge in agriculture at high proportions. These barriers are the following:

- Problems of public acceptance
- Quality of sludge
- Availability of agricultural soil
- Cost of alternative disposal routes for sewage sludge

There is a general agreement that agricultural use can be a safe and viable option for sludge disposal (Bontoux et al, 1999). However, there is also public concern, not yet scientifically justified, of the safety of food products deriving from cultivation on land where sewage sludge has been applied. In addition, there are reservations from landowners and farmers based on concerns such as liability and land value (Arthur Andersen, 2001a). Consumer pressure to the agricultural sector and the food industry has lead to policies based on tightening of the pollutant threshold values in sludge applied to land. However, these policies have failed to increase the acceptance of sludge, which is rather based on cultural perceptions (Arthur Andersen, 2001a). Under the current level of scientific lack of knowledge of the uncertainties and possible risks, some countries have adopted total bans on the agricultural use of sewage sludge (e.g. Switzerland). Some of the ways to overcome public acceptance hurdles is to enhance communication of the results of the scientific research in the field and to promote the creation of labels at European level that guarantee the quality of sludge with low contaminant level (Arthur Andersen, 2001a-c).

In some countries such as Netherlands, Germany and Denmark, sewage sludge competes for available land with other sources of nutrients and fertilisers such as farm manure, commercial lime, commercial fertilisers and industrial residues (Jepsen, 2003). In these conditions, residues that can be supplied to land at low cost and which can guarantee a low content of pollutants are likely to be preferred. Sewage sludge does not fulfil in some cases these criteria. The market is also influenced by internal agreements (e.g. among landowners and manure producers), which favour the use of manure, which otherwise has to be disposed of (e.g. landfilled) at high cost.

If sludge is to be incinerated Directive 2000/76/EEC on the incineration of waste has to be considered; this Directive sets stringent limits for air emissions and sets ways of handling the produced ash.

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