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

Draft Summary Report 1
Assessment of Existing Knowledge

milieu ENVIRONMENTAL LAW & POLICY

WRc

RPA

This report has been prepared by Milieu Ltd and WRc for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Anne Gendebien. Additional expertise was provided by Bob Davis, John Hobson, Rod Palfrey, Robert Pitchers, Paul Rumsby, Colin Carlton-Smith and Judith Middleton.

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EXECUTIVE SUMMARY

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

The aim of the study is to provide the Commission with the necessary elements for assessing the environmental, economic and social impacts, including health impacts, of present practices of sewage sludge use on land and prospective risks/opportunities and policy options related to the use of sewage sludge on land. This could lay the basis for the possible revision of Community legislation. This report summarises information on sludge recycling to land. It is the first deliverable of the study on "Environmental, economic and social impacts of the use of sewage sludge on land" for the European Commission (DG Environment). The report focuses on work reported since 2000 but taking account of important earlier studies. The aim of the report is to identify key information that would be relevant for updating the Directive 86/278/EEC (hereinafter, the "Sewage Sludge Directive") which is the principal legislation underpinning the control of sludge recycling to land in the EU.

Topics covered in this report include: sludge production, legislation, economics and some social considerations but the emphasis is on environmental factors. In this way, the report has identified, from the very extensive literature on sludge recycling to land, the key factors on which the review of Directive 86/278/EEC needs to focus. The topics covered are:

- Current sludge Production and Disposal in the EU
- EU and Related Legislation on the Use of Sludge on Land
- Economics of sludge Treatment and Disposal
- Agricultural Value
- Contaminants and Pathogens
- Water and Air Pollution
- Greenhouse Gas Emissions and Carbon Footprint
- Stakeholder Interests and Public Perception
- Future Trends
- Monitoring, Record Keeping and Reporting
- Summary of Areas of Uncertainty and Knowledge Gaps

1 Introduction

The Sewage Sludge Directive 86/278/EEC was set up to encourage the use of sewage sludge in agriculture and to regulate its use in such a way as to prevent harmful effects on soil, vegetation, animals and man. To this end, it prohibited the use of untreated sludge on agricultural land unless it is injected or incorporated into the soil. The Directive also required that sludge should be used in such a way that account is taken of the nutrient requirements of plants and that the quality of the soil and of the surface and groundwater is not impaired.

Directive 86/278/EC on sewage sludge was based on the knowledge available at the time, including the evaluation of the risks provided by the COST 68 programme during the early 1980's. Since its adoption, many Member States have, on the basis of new scientific insight in the effects of sludge use on land, enacted and implemented stricter limit values for heavy metals as well as for contaminants which are not addressed in the Directive.

The most recent estimates reported to the Commission by the Member States suggest that more than 10 millions tons DS were produced in 26 EU Member States (no estimate for Malta), of which approximately 36%, almost 3.7 million tons DS, was recycled in agriculture. In the last 10 years, the total amount of sludge produced has increased in most of the 15 EU Member States, due primarily to the implementation of the Urban Waste Water Treatment Directive 91/271/EEC. The quality of the sludge has also improved quite substantially in the EU 15. The proportion of waste recycled to land has also changed dramatically. For example, in Finland, Slovenia and Flanders quantities going to land has decreased significantly in recent years while they have increased in countries like Bulgaria.

2 Current Sludge Production and Management in the EU

This section reviews recent information on the production and disposal of sewage sludge in the EU. In particular, it presents information that can be used in the next stage of the study to develop a baseline scenario for future production and disposal.

2.1 Sludge quantity and disposal

According to the figures provided to the European Commission for the period 2003-2006 (personal communication, 2009) (Table 1), about 10 million tons DM of sewage sludge were produced in the EU; 8.7 million t DM in the EU-15 and an additional 1.2 million t DM for the 12 new Member States. This is probably underestimating the total quantities produced as not all of the Member States had provided up to date figures for the latest Commission survey (2003-2006) and figures from the previous survey (1999-2002) (EC, 2006) or from other sources were included in the Table. No data was reported for Malta.

According to the same sources of information, 37%, about 3.6 million t DM, was recycled in agriculture (Table 1). However, the proportion of sludge recycled in agriculture varies widely between different Member States and regions. In the Walloon Region (Belgium), Denmark, Spain, France, Ireland, and the UK, 50% or more of the sludge generated is applied to agricultural land while in other Member states there is less than 5% (i.e. Finland, Flemish Region of Belgium) or no application

(Greece, Netherlands, Romania, Slovenia, Slovakia) of sewage sludge to land (EC, 2006; Alabaster and LeBlanc, 2008).

Compared with figures (Table 2) provided in the previous Commission surveys for 1995-1997 and 1998-2000 (EC, 2006), sludge production has steadily increased between 1995 and 2006 in most Member States. This can be attributed mainly to the implementation of the Urban Waste Water Treatment Directive 91/271/EEC (CEC, 1991) and also, in some cases (i.e. Italy and Portugal), to better reporting. However, in some Member States (i.e. Germany, Denmark, Finland, Sweden), although sludge quantities had increased since the 1980's, sludge production appears to have stabilised or even slightly decreased over the last 5 years. This has been attributed to a reduced consumption of water and an increased treatment of sludge (Jensen 2008). In 2004 and 2007, there was also the enlargement of the EU with the accession of 10, then 2, more new Member States, which added another 12% to the total sludge production in the EU. For the next 5 years this trend should continue with further investment in sewer connection and wastewater treatment capacity, especially in the new Member States.

The proportion of waste recycled to land has also changed dramatically in recent years (Tables 1 and 2). While in some Member States, such as France, Portugal, Spain and the UK, quantities recycled to agriculture have continued to increase, agricultural application has effectively been banned in some countries, e.g. the Netherlands and some regions of Belgium (Flanders), of Austria and of Germany, due to growing public concerns about the safety of the outlet and competition with other organic materials going to land such as animal manure. The Global Atlas (Alabaster and LeGrand 2008), however, estimates that there is more than a 50% chance that the benchmark sludge in a European city would be treated and recycled to land.

Incineration and landfilling are the main alternative methods to agricultural recycling for sludge management. Most Member States treat a proportion of their sludge by incineration and the residual ash is usually disposed of to landfill. The amount of sludge that is incinerated significantly increases when recycling is discouraged or banned. In Flanders (Belgium), for instance, more than 70 % of sludge production is now incinerated (Table 3). In the Netherlands, about 60% of sewage sludge is incinerated (Smith 2008) and in Austria, Denmark and Germany approximately 40 % of sludge is incinerated. Slovenia dries and then sends 50% out of the country to be incinerated.

The total amount of sludge destined for landfills is relatively small overall, and as the Landfill Directive 99/31/EC (CEC, 1999) sets mandatory targets for the reduction of biodegradable waste to landfill, landfilling of sewage sludge will be effectively banned. Some countries (mainly in the new Member States), however, still depend heavily, or entirely on this outlet as a means of sludge disposal (e.g. Greece, Hungary, Poland – see Table 3).

Table 1 Recent sewage sludge production and quantities recycled to agriculture in the 27 EU Member States (Doujak 2007, EC, 2006, EC, personal communication, 2009, IRGT 2005)

Member State	**Year**	**Sludge production**	**Agriculture**	
		(t DS)	**(t DS)**	**(%)**
Austria (a)	2005	266,100	47,190	18
Belgium				
• Flemish region	2006	76,254 (b)	1,981	3
• Walloon region	2003	23,520	11,787	50
• Brussels region (c)	2002	2,792	878	31
Denmark	2002	140,021	82,029	59
Finland	2005	147,000	4,200	3
France	2002	910,255	524,290	58
Germany	2006	2,059,351	613,476	30

Greece	2006	125,977	56.4	0
Ireland	2003	42,147	26,743	63
Italy	2006	1,070,080	189,554	18
Luxembourg	2003	7,750	3,300	43
Netherlands	2003	550,000	34	<0
Portugal	2002	408,710	189,758	46
Spain	2006	1,064,972	687,037	65
Sweden (e)	2006	210,000	30,000	14
United Kingdom	2006	1,544,919	1,050,526	68
Sub-total EU 15		***8,649,848***	***3,462,839***	***40***
Bulgaria	2006	29,987	11,856	40
Cyprus	2006	7,586	3,116	41
Czech republic	2006	22,0700	8,300- 25,400	4- 12
Estonia (d)	2005	nd	3,316	?
Hungary	2006	128,380	32,813	26
Latvia	2006	23,942	8,936	37
Lithuania	2006	71,252	16,376	23
Malta		nd	nd	nd
Poland	2006	523,674	88,501	17
Romania	2006	137,145	0	0
Slovakia	2006	54,780	0	0
Slovenia	2006	19,434	27	< 0
Sub-total for EU 12		***1,216,880***	***190,341(f)***	***17***
Total		**9,866,728**	**3,653,180**	**37**

a) Austria has not submitted figures to the Commission for the last two surveys. Figures presented above are from Doujak (2007) from UBA: total sludge production amounts to 420,000 t DM in 2005. This includes 238,100 t DM municipal sewage sludge + 28,000 t DM exported and 155,000 t DM of industrial sludge (mainly from cellulose and paper industry.
b) Figure for previous year (2005) as for total sludge produced no figure was provided for 2006.
c) No figures submitted to the Commission. Figures from IRGT 2005. In the Brussels Region, there are now 2 STEs; wastewater treatment started in one STW in 2000 for 360,000 pe and a second STW was commissioned for 1.1 M pe and started operating in 2008. In 2002, sludge production in the Brussels Region amounted to 2800 t DM.; 66% was incinerated, 32% recycled to agriculture and 2% was sent to landfill.
d) No figures reported for total sludge production.
e) Estimates
f) Taking into account the highest figure for the Czech Republic.

Table 2 Past (1995 and 2000) Sludge production in the EU-15 (EC 2006)

Year	**1995**		**2000**	
Member State	**Sludge production (t DS)**	**Sludge used in agriculture (%)**	**Sludge production (t DS)**	**Sludge used in agriculture (%)**
Austria (a)	390,000	12	401,867	10
Belgium				
• Flemish region	73,325	13	80,708	0 (b)
• Walloon region	14,311	75	18,228	59
Denmark (c)	166,584	67	155,621 (1999)	61 (1999)
Finland	141,000	33	160,000	12
France	750,000	66	855,000 (1999)	65 (1999)
Germany	2,248,647	42	2,297,460	37
Greece	51,624	0	66,335	0
Ireland	38,290 (1997)	11 (1997)	35,039	40
Italy	609,256	26	850,504 (d)	26
Luxembourg	nd	nd	7,000 (1999)	80 (1999)

Netherlands (f)	nd	0	nd	0
Portugal (e)	145,855	30	238,680	16
Spain	685,669 (1997)	46 (1997)	853,482	53
Sweden (e)	230,000	29	220,000	16
United Kingdom	1,120,00 (e)	49	1,066,176	55
Total EU-15	**6,664,781**	**42**	**7,306,342**	**40**

a) Includes sludge from municipal treatment plants (60%) and commercial/industrial treatment plants (40%) (especially from cellulose and paper industry)
b) Since December 1999, municipal sewage sludge is no longer used in agriculture.
c) Since 1994, annual sludge production in Denmark has been between 150,000 – 160,000 t DM with a drop to 140,000 t DM in 2002.
d) Data not complete for all regions
e) Estimates
f) Figures reported to the Commission in 1995 and 1999 only covered sludge produced by private treatment plants (220 t DM and 242 t DM respectively as since 1995), as since 1995 municipal sewage sludge was no longer used in agriculture in the Netherlands

Nd no data

Table 3 Disposal methods for sewage sludge in EU Member States as percentage (AMF 2007, Doujak 2007, Eureau 2006 reported by Smith 2008, IRGT 2005, Leonard 2008, COM personal communication, 2009)

Member State	Year of data	Agriculture	Landfill	Incineration	Other
Austria (a)	2005	18	1	47	34
Belgium					
• Flemish Region (b)	2005	9		76	14
• Walloon Region (c)	2005	32	6	62	
• Brussels region (d)	2002	32	2	66	
Denmark (e)	2002	55	2	43	
Finland	2000	12	6		80 (f)
France (g)	2002	62	16	20	3
Germany (h)	2003	30	3	38	29 (i)
Greece (j)			>90%		
Ireland	2003	63	35		3
Italy		32	37	8	22 (k)
Luxembourg	2004	47		20	33 (l)
Netherlands (m)	2006	0		60	40
Sweden		10-15		2	90-85 (n)
UK	2004	64	1	19.5	15.5 (o)
Bulgaria (p)	2006	40	60		
Czech republic (q)	2004	45	28		26
Hungary (r)	2006	26	74		
Poland (s)	2000	14	87		7
Romania (t)		0			
Slovenia (u)	2006	>1	50		49
Slovakia (v)	2006		17		83

a Figures from Doujak (2007) from UBA. In 2005, municipal sewage sludge production amounted to 238,100 t DM + 28,000 t DM exported. Sludge used in agriculture has to meet specific legal requirements which differ from federal state to federal state. In several federal states, there is a ban on sewage sludge application in agriculture. The legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are much less stringent; therefore an increasing part of sewage sludge is used for this purpose. Since 2001, thermal treatment has increased from about 30% to nearly 50% . While in 2001, 11% of municipal sewage sludge was sent to landfill, by 2005, this outlet represented only 1%. Sludge disposal to landfill was basically banned in 2004 as new legislation required that only material meeting the following criteria be allowed for landfill disposal: ≤ 5 % TOC related to total dry solids and ≤6000 MJ/kg dry solids. These criteria cannot be met by conventional sludge treatment. Only the ashes after incineration are meeting these requirements. Out of 91,700 t DM disposed of by others routes - 77% are composted, 12.3% used in landscaping, 2.4% in temporary storage and 8.2% in unknown outlets.

b The Flemish Region has discouraged the recycling of sewage sludge to land through stricter limit values due to the large volume of animal manure produced in the region. While in 2005, 31% of 76,250 t DS were still used in agriculture, land spreading of sludge in agriculture was stopped in 2006 due to increasing costs of complying with the recent regional restrictions. Other means landfill cover.

c While landspreading in agriculture (82% in 1998, 56% in 2001) and landfilling (18% in 1998 and 37% in 2001) have been the preferred options for years, these outlets have now been supplanted by incineration which was first used in 1999 (2% , 7% in 2001) (IRGT 2005, Leonard 2008).

d According to IRGT (2005), in 2002, 66% of sludge in the Brussels region was incinerated, 32% recycled to agriculture and 2% was sent to landfill.

e Denmark has a target for 2008 to sent 50% of sewage sludge to agriculture, 45% to incineration corresponding to 25% incineration with recycling of ashes in industrial processes and 20% “normal” incineration. Agriculture includes sludge mineralisation plants, composting, long time-storage. Incineration includes recovery, e.g. cement or sand blasting agents (58% of incinerated sludge is recovered by alternative methods). Sludge recycling to agricultural land has been encouraged as a way of recycling nutrients. From 1995 to 2002, however, the relative fraction of sludge recycled to land has decreased from 70% down to 60%. Since 1994, the relative proportion of sludge incinerated has stayed fairly constant at around 20%, while landfilling has decreased to less than 5% (Jensen, 2004).

f While in 2004, there was still 9% of sludge recycled to agriculture, it was down to 3% in 2005. In 2000, other outlets include 27% as landfill cover and 53% for landscaping

g From AMF 2007 (Data from Agences de l’Eau for 2002/2003)

h Three of 16 federal states intend to stop agricultural sludge use.

i 26% as landscaping and 3 % as other

j No recycled to agriculture. Stated that most goes to landfill due to joint ownership of WWTP and landfills by municipalities.

k Includes 19% as composting, no final outlet given.

l As composting no final outlet given

m Since 1995, in the Netherlands, municipal sewage sludge is no longer used in agriculture. In 1996, the majority of municipal sewage sludge was sent to landfill (82%). Now, most sewage sludge goes to incineration in the Netherlands or in Germany, some of it after composting or heat drying.

n Including 60-65% as construction soil and 10% as vegetation material.

o Including 11% for land reclamation and 4% as compost and industrial crops

p While there was no recycling to agriculture in previous years (in 2004 and 2005), 40% of sludge was reported to be used in agriculture in 2006.

q In the Czech Republic, in 2001, 42-48% of sludge was recycled to agriculture, in 2002 and 2003, there was no sludge sent to agriculture and in 2004, 16% of 206,000 t DM was again recycled to land.

r Recent legislation regarding maximum water content of landfilled sludge (at least 25% DM) could limit this outlet. No incineration of sludge.

s Data from Twardowska 2005

t From the literature review (Crac 2004) although Romania does not yet recycled sludge to agriculture, is intending to do so in the near future as well as other recovery methods such as co-incineration in cement kilns

u In the past, the majority of sewage sludge was disposed of in landfills; however, following the adoption of a Decree on landfilling of waste, the volume should slowly be reduced as the landfilling of sludge from 2008 is only authorised for waste with TOC < 18% d.m. and calorific value < 6 MJ/kg d.m. In 2001, 2002 and 2003, Slovenia recycled 6%, 16% and 9% respectively to agriculture. Since 2003, the quantities of sludge recycled into compost and on agricultural land have been reduced down to about one per cent due to concerns about the content in hazardous substances when produced from combined wastewater treatment plants in urban and industrial areas. The remaining sludge is exported for the preparation of artificial soil and other recovery methods (not specified but could include co-incineration).

v Figures reported are estimates. In Slovakia, in 2004, 23% of sludge was directly spread on land, 54% was composted and another 3% was used in land reclamation, 9% was landfilled and 11% were placed in temporary storage. In 2006 there was no direct land spreading in agriculture but 61% was composted (no final outlet mentioned) and 10% was used in land reclamation, 17% landfilled and 11% placed in temporary storage. No suitable incineration capacity for sewage sludge, but potential co-incineration in cement plants.

2.2 Sludge quality

Member States have to provide information to the Commission on the average quality of sludge recycled to agriculture regarding PTEs (Potentially Toxic Elements) and nutrients (Total nitrogen and total phosphorus). The information submitted during the latest survey for period 2004- 2006 is presented in the Table 4 below. The following comments can be made:

- The three highest values for each metallic elements have been highlighted;
- There are some large differences in quality between 18 Member States which have provided information depending on the elements;
- Cyprus, Italy, Latvia, Poland have the sludge containing the highest concentrations for at least 3 elements.

Sewage sludge contains potentially toxic elements (PTEs), including heavy metals, which are from domestic (i.e. plumbing, body care products, etc.), surface run-off and/or commercial and industrial origins (see chapter 6 below). It has been confirmed by several studies (Smith 2008) that since the mid 80’s concentrations of heavy metals in sewage sludge has steadily declined in the EU due to regulatory controls on the use and discharge of dangerous substances, voluntary agreements and improved industrial practices; all measures leading to the cessation or phasing out of discharges, emissions and losses of these PTEs to the environment.

Table 4 Quality of sewage sludge (on dry solids) recycled to agriculture (2006) (CEC, personnel communication 2009)

Parameter	**BE a,b)**	**DE**	**ES**	**FI b)**	**IT**	**PT a)**	**SE**	**UK**	**BG**	**CY**	**CZ**	**EE b)**	**HU**	**LT**	**LV**	**PT**	**SI**	**SK b)**
Zinc	337	713	744	332	879	341	481	574	465	**1188**	809	783	824	534	**1232**	996	410	**1235**
Copper	72	**300**	252	244	283	12	**349**	295	136	180	173	127	185	204	**356**	153	190	221
Lead	93	37	68	8.9	**101**	27	24	**112**	55	23	40	41	36	21	**114**	51	29	57
Nickel	11	25	30	30	**66**	15	15	30	13	21	29	19	26	25	**47**	**32**	29	26
Chromium	20	37	72	18	**86**	20	26	61	20	37	53	14	57	34	**105**	**127**	37	73
Mercury	0.2	0.4	0.8	0.4	1.4	<1	0.6	1.2	1.2	**3.1**	1.7	0.6	1.7	0.5	**4.2**	**4.6**	0.8	2.7
Cadmium	1	1	2.1	0.6	1.3	<0.4	0.9	1.3	1.6	**6.9**	1.5	2.8	1.4	1.3	**3.6**	**4**	0.7	2.5
Total Nitrogen	3.9	4.3	4.5	3.4	4.1	1.7	4.5	2.8	7.2	4.1	3.6	4.9	3	2.3	3.9	0.9	3.2	3.8
Total Phosphorus	6.7	3.7	3.6	2.4	2.1	2	2.7	2.2	4.3	4.9	1.9	3.4	1.4	0.9	1.3	0.6	3.9	1.8

a) Data from the Flemish Region
b) data for 2005 as no values available for 2006

2.3 Sludge Treatment and current practice in EU Member States

Directive 86/278/EEC requires that sewage sludge be treated before it is used in agriculture (Member States may authorise the injection or working of untreated sludge in soil in certain conditions, including that human and animal health are not at risk). The Directive specifies that for sludge to be defined as treated it should have undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as to significantly reduce its fermentability and the health hazards associated with its use.

These overall requirements have been interpreted and implemented within individual Member States differently, in part based on specific local conditions and circumstances. Detailed descriptions of sewage sludge management for each Member States can be found in the latest available Commission's implementation report (EC 2006). In general, untreated sludge is no longer applied. In the Czech Republic, Denmark, Spain, Finland, Germany, Hungary, Italy, Luxembourg, the Netherlands, Slovakia, Slovenia, and in the UK it is prohibited to spread any untreated sludge on land (EC 2006).

Where sludge is to be used on land, it is usually stabilised by mesophilic anaerobic digestion, or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting.

In the UK, land spreading of raw, untreated sludge to food crops was banned by the Safe Sludge Matrix from December 1999, and on land used to grow non-food crops from December 2005 (ADAS, 2001).

In the UK, most sludge is stabilised by anaerobic digestion and must meet other management restrictions. A site permit is not required but regulations, notably the Code of Good Practices (CoGP) and Safe Sludge Matrix (SSM), must be followed. Treatment processes for sludge in the UK are managed according to the principles of HACCP (Hazard Analysis and Critical Control Point management) (Water UK, 2004). HACCP applies risk management and control procedures to manage and reduce potential risks to human health and the environment. The approach has been adopted and applied to sludge treatment for agricultural application to provide assurance that the microbiological requirements set out in the Safe Sludge Matrix are met and that risk management and reduction combined with appropriate quality assurance procedures are in place, thus preventing the use on farmland of sludge that does not comply with the microbiological standards.

The periods of prohibition between sludge spreading and grazing or harvesting vary according to the Member State (EC 2006). In Ireland, Spain, Luxembourg, the Netherlands, Portugal and the United Kingdom, the provisions of the Directive apply: i.e. sludge must be spread at least three weeks before grazing or harvesting and on soil in which fruit and vegetable crops are growing, or at least ten months for soils where fruit and vegetable crops that are eaten raw are cultivated in direct contact with soil. In the other Member States the rules are generally stricter than those provided for by the Directive. For more detailed information, please refer to the Commission report (EC 2006).

3 EU Legislation, other EU Acquis and Member State Controls on the Use of Sludge on Land

3.1 EC legislation

The recycling of sewage sludge in agriculture has been regulated by Directive 86/278/EEC since 1986. The Directive both addresses pathogen reduction and the potential for accumulation of persistent pollutants in soils. The Directive sets maximum limit values for Potentially Toxic Elements (PTEs) in sludge (Table 6) or sludge-treated soil (Table 5) and specifies general land use, harvesting, and grazing restrictions, to provide protection against health risks from residual pathogens. The Directive allows untreated sludge to be used on agricultural land if it is injected or worked into the soil. Otherwise sludge shall be treated before being used in agriculture; however, the Directive does not specify treatment processes but rather defines "treated sludge" as "sludge which has undergone biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use" (Art. 2(b)).

The Commission now plans to undertake a comprehensive review of the provisions contained in the Directive. There have been previous reviews of this Directive, which produced draft proposals that included limit values for Organic Compounds (OCs) (Table 8).

When considering a review of the Directive 86/278/EEC, it is also necessary to consider other (especially more recent) directives and how they might regulate or otherwise affect the production and use of sludge on land as well as restrict other outlets for sludge.

- **Directive 91/271/EEC Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment**

The Urban Waste Water Treatment Directive 91/271/EEC concerns the collection, treatment and discharge of urban waste water and the treatment and discharge of waste water from certain industrial sectors. The Urban Waste Water Treatment Directive 91/271/EEC sets the following targets for secondary treatment of waste waters coming from agglomerations:

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

Since the implementation of these requirements quantities of sewage sludge requiring disposal have increased dramatically in Member States. Foreseeing such issue, the Urban Waste Water Treatment Directive 91/271/EEC encourages the recycling of sludge arising from waste water treatment. It states that sludge arising from waste water treatment shall be re-used whenever appropriate. Under the Directive, Member States authorities must also publish situation reports on the disposal of urban waste water and sludge in their areas.

- **Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources**

This Directive has the objective of reducing water pollution caused or induced by nitrates from agricultural sources and preventing such pollution. To that aim the Directive requires Member States to designate vulnerable zones that contribute to the pollution of water by nitrates. Within these vulnerable zones, a code of good agricultural practice should be applied by farmers. Such a code could for example provide periods when the land application of fertilizer is inappropriate ban the land application of fertilizer to steeply sloping ground or to water-saturated, flooded, frozen or snow-covered ground. Since the Directive considers that sewage sludge falls within the definition of fertilizers, such code of agricultural practice should also apply to the spreading of sewage sludge.

- **Directive 99/31/EC Council Directive 99/31/EC pf 26 April 1999 on the landfill of waste (Landfill Directive)**

EU policy for waste management (CEC 1999) aims to encourage the recovery of value from waste products and to reduce the disposal of biodegradable wastes in landfill. The Landfill Directive (99/31/EC) implements by obliging Member States to reduce the amount of biodegradable waste that they send to landfills to 35% of 1995 levels by 2016. This implies that land filling is not considered a sustainable approach to sludge management in the long-term.

- **Directive 2000/76/EC of the European Parliament and the Council of 4 December 2000 on the incineration of waste**

Dry sewage sludge can be incinerated to produce energy. Sewage sludge falls within the category of waste and thus falls under the scope of Directive 2000/76/EC on the incineration of waste. This Directive sets several standards and technical requirements (air emissions, water discharges contamination, plant designs) that have to be respected by the operators of the plants which incinerate dry sewage sludge.

- **Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive (WFD))**

Cadmium, lead and mercury are designated Priority Hazardous Substances under the Water Framework Directive 2000/60/EC, and thus are subject to further measures leading to the cessation or phasing out of discharges, emissions and losses of these substances to the environment as far as possible. Directive 2008/105/EC implements these provisions in the Water Framework Directive. The Water Framework Directive is discussed further in section 9.

- **Directive 2008/105 on environmental quality standards in the field of water policy**

This Directive lays down environmental quality standards (EQS) for priority substances and certain other pollutants with the aim of achieving good surface water chemical status and in accordance with the provisions and objectives of Article 4 of Directive 2000/60/EC. The environmental quality standards set in Annex I, part A, of Directive 2008/105 are to be applied by Member States for bodies of surface water. Member States have also the option to apply environmental quality standards for sediment and/or biota. Member States might thus apply stricter measures to sewage sludge in order to respect these environmental quality standards.

- **Directive 2006/118/EC on the protection of groundwater against pollution and deterioration**

This directive complements the Water Framework Directive with additional rules to protect groundwater. It establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater. It establishes quality criteria that take into account local characteristics and allows for further improvements to be made based on monitoring data and new scientific knowledge. This Directive might have an impact on the practise of the spreading of sludge since it provides that the protection of groundwater may in some areas require a change in farming or forestry practices. Annex 1 of the Directive sets some groundwater quality standards; the spreading of sewage sludge will need to ensure that contaminants do not contaminate groundwater.

- **Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives**

Directive 2008/98/EC[1] is the new Waste framework Directive that lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste and by reducing the overall impacts of resource use and improving the efficiency of such use. Directive 2008/98/EC does not mention sewage sludge. However, it provides that waste waters are excluded from its scope to the extent that they are covered by other Community legislation (Article 2(2(a).).

Since Directive 2008/98/EC entered into force recently, the ECJ has not yet ruled whether sewage sludge falls within the scope of this Directive as waste or was excluded from it as waste waters. However, the Directives that refer to "sewage sludge" as well as the commission working papers it is

[1] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance)

not mentioned that "sewage sludge" is defined as waste waters. For example the report from the commission on the implementation of the "community waste legislation", which dates back to the 19^{th} of July 2006, only provides that waste oils, sewage sludge, and packaging waste are specific waste streams each with different characteristics and management issues.

Furthermore the European Court of Justice in the "Lahti Energia"[2] judgment, defined sewage sludge as a "residue" from the treatment of waste water, thus making a distinction between waste waters and the products that are generated from its treatment.

Finally, in case sewage sludge is considered as waste waters, a preliminary ruling of the ECJ[3] mentioned that waste waters were to be excluded from Directive 75/442/EC (the former waste framework Directive) only if such waste waters were covered by other legislation (national or European) that guarantee at least the same level of environmental protection as Directive 75/442/EC. For example, the Court mentioned that the Urban Waste Water Treatment Directive did not say anything about disposal of waste or decontamination of soils and therefore couldn't guarantee a level of environmental protection as high as Directive 75/442/EC. This interpretation of the ECJ was partially taken into consideration by Directive 2008/98/EC which provides that waste waters are excluded from its scope to the extent that they are covered by other Community legislation.

Thus, it is probable that sewage sludge when discarded or intended to be discarded is waste that falls within the scope of the Directive 2008/98/EC because as the ECJ stressed, it is not waste water but a residue of it. In case sewage sludge is included into the definition of waste waters it might anyway be covered by the new framework Directive if other Community legislation dealing with waste waters do not guarantee at least the same level of environmental protection as this Directive.

Requirements that must be applied to sewage sludge if sewage sludge falls within the scope of Directive 2008/98/EC as waste:

First of all, under Article 6 of Directive 2008/98/EC certain specified waste shall cease to be waste when it has undergone a recovery, including recycling, operation and complies with specific criteria to be developed in accordance with the following conditions: the substance or object is commonly used for specific purposes; a market or demand exists for such a substance or object; the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and the use of the substance or object will not lead to overall adverse environmental or human health impacts. The criteria shall include limit values for pollutants where necessary and shall take into account any possible adverse environmental effects of the substance or object.Thus, sewage sludge that fulfils these criteria might not be considered waste anymore under Directive 2008/98/EC.

Secondly, under articles 10 and 11 Member States shall take the necessary measures as to ensure that waste is recycled or re-used. When it is not possible to do so, under article 12, waste must undergo safe disposal operations, which meet a certain number of conditions regarding human health and the environment (article 13). These disposal operations must occur without risk to water, soil, plants or animals, must not cause noise or odour nuisances, and must not adversely affect the countryside or places of special interest. Their costs lie with the producer of the waste. Under Article 16, disposal of waste must answer to the principles of self-sufficiency and proximity, meaning that MS shall cooperate to set up a network of waste disposal installations.If sewage sludge falls within the scope of this directive, all these measures will have to be taken into account when dealing with its disposal.

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[2] http://eur-lex.europa.eu/Result.do?arg0=Lahti+Energia&arg1=&arg2=&titre=titre&chlang=en&RechType=RECH_mot&idRoot=10&refinecode=JUR*T1%3DV100%3BT2%3D%3BT3%3DV1&Submit=Search

[3] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:62005J0252:EN:HTML

Thirdly, article 15 deals with management responsibility. Member States must ensure that any original waste producer or other holder carries out the treatment of waste himself or has the treatment handled by a dealer or an establishment. Member states may specify the conditions of responsibility for the whole treatment chain and decide that it is to be borne partly or wholly by the producer of the product.

Fourthly, Member States must require any establishment intending to carry out waste treatment to obtain a permit from the competent authority, which shall specify the types and quantities of waste that may be treated, the technical requirements relevant to the site concerned, the safety and precautionary measures to be taken, etc. MS may exempt from these requirements establishments intending to carry out recovery of waste. Under article 34, establishments which carry out waste treatment operations, or collect or transport waste on a professional basis or produce hazardous waste, shall be subject to appropriate periodic inspections by the competent authorities. Establishments that treat sewage sludge will have to fulfil these requirements if sewage sludge falls into the scope of the directive.

Finally it is worth mentioning that Directive 2008/98/EC defines 'bio-waste' as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants. Thus, sewage sludge cannot fall within the definition of bio-waste. Under Article 22 of Directive 2008/98/EC, member States shall take measures to encourage, the separate collection of bio-waste with a view to the composting and digestion of bio-waste, the treatment of bio-waste in a way that fulfils a high level of environmental protection; the use of environmentally safe materials produced from bio-waste. The Commission shall also carry out an assessment on the management of bio-waste with a view to submitting a proposal if appropriate. The Commission has come up with a Green paper on the management of bio-waste in the European Union[4].

The current measures on bio-waste under Directive 2008/98/EC and the probable future EC legislation on bio-waste will increase the treatment of bio-waste into compost that can be spread on agricultural fields. Compost from bio-waste might conflict with sewage sludge since compost from bio-waste might have a better environmental reputation. Indeed there are fewer probabilities that it contains hazardous substances compared to sewage sludge.

- **EC Regulation 1907/2006, concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)**

The purpose of REACH is to ensure a high level of protection of human health and the environment, including the promotion of alternative methods for assessment of hazards of chemical substances, as well as the free circulation of the substances on the internal market while enhancing competitiveness and innovation. The Regulation applies to the manufacture, placing on the market or use of such substances on their own, in preparations or in articles and to the placing on the market of preparations.

Under the REACH Regulation, waste does not fall within the definition of a chemical substance, preparation or article. Thus, sludge sewages producers are not directly affected by the REACH Regulation. However REACH will have an indirect impact on the sewage sludge composition, as it may lead to a reduction in the levels of chemicals contained.

- **Commission Regulation (EC) No 466/2001**

This regulation sets maximum levels for certain contaminants in foodstuffs set limits for Cd in foodstuffs 'as low as reasonably achievable' following the precautionary principle. The limits are close to background levels which occur naturally in foodstuffs from uncontaminated sources. The spreading of sewage sludge thus needs to respect these requirements (see section 6).

[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0811:FIN:EN:PDF

- **Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No2092/91**

Regulation No 834/2007 provides the basis for the sustainable development of organic production while ensuring the effective functioning of the internal market, guaranteeing fair competition, ensuring consumer confidence and protecting consumer interests. It establishes common objectives and principles concerning all stages of production, preparation and distribution of organic products and their control, and the use of indications referring to organic production in labelling and advertising.

This Regulation does not directly refer to sewage sludge. However, on the requirements for soil, article 12 of this Regulation provides that 'the fertility and biological activity of the soil shall be maintained and increased by multiannual crop rotation including legumes and other green manure crops, and by the application of livestock manure or organic material, both preferably composted, from organic production.' It is clear from this provision that the application of material coming from non-organic production, including sewage sludge, is not allowed for organic production.

- **Decision 2006/799 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to soil improvers**

Decision 2006/799 defines soil improvers as 'materials to be added to the soil in situ primarily to maintain or improve its physical properties, and which may improve its chemical and/or biological properties or activity.' In order to be awarded the Community Eco label, soil improvers shall comply with the criteria set in out in the Annex to Decision 2000/799.
1.1 of the Annex mentions that soils improvers containing sewage sludge shall not be awarded an eco-label.

- **Decision 2007/64 establishing revised ecological criteria and the related assessment and verification requirements for the award of the Community eco-label to growing media**

Decision 2007/799 defines growing media as 'material other than soils in situ, in which plants are grown.' In order to be awarded the Community Eco label, growing media shall comply with the criteria set in out in the Annex of this Decision. 1.2 of the Annex mentions that growing media containing sewage sludge shall not be awarded an eco-label.

- **Proposal for a Directive establishing a framework for the protection of soil and amending Directive 2004/35/EC [5]**

The Commission adopted a Soil Thematic Strategy (COM(2006) 231) and a proposal for a Soil Framework Directive (COM(2006) 232) on 22 September 2006 with the objective to protect soils across the EU. Sewage sludge contains organic matters which reduce soil degradation but can also contain pollutants that affect the quality of the soil.

Article 3 of the proposed directive provides that in the development of sectoral policies likely to exacerbate or reduce soil degradation processes, Member States shall identify, describe and assess the impacts of such policies on these processes, in particular in the areas of regional and urban spatial planning, transport, energy, agriculture, rural development, forestry, raw material extraction, trade and industry, product policy, tourism, climate change, environment, nature and landscape. Thus, under this proposal Member States would have to identify, describe and assess the impacts of sewage sludge spreading in agricultural fields on the exacerbation or reduction of soil degradation.

[5] http://ec.europa.eu/environment/soil/pdf/com_2006_0232_en.pdf

- **Proposal for a Directive on the promotion of renewable energy sources.[6]**

Biogas can be produced from sewage sludge treatment, via a process called anaerobic digestion. Article 2 of the proposed directive on the promotion of renewable energy considers that sewage treatment plant gas is energy from renewable energy sources.

The proposed directive sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. Overall, in 2020 there shall be at least a 20% share of energy from renewable sources in the Community's gross final energy consumption. Such targets are likely to create incentives for the use of renewable energy sources of biogas from sewage sludge. An increase in the production of biogas from sewage sludge is expected to contribute to a reduction in greenhouses gas emissions.

3.2 Member State legislation and policy

The development of guidelines, codes of practice and statutory controls has been an ongoing process at national level since the 1986 Directive was implemented. In some Member States (i.e. Sweden and UK), voluntary agreements set more stringent requirements than those in the Directive or in national regulations. Other initiatives have been the development of quality assurance systems, such as in Germany and Sweden. (This section also provides some information from non-EU Members, notably Switzerland and the US.)

A comprehensive review of national regulatory frameworks has been carried out for the European Commission by Sede and Andersen (2002). This study reported that most EU15 had adopted more stringent limits and management practices than were originally specified by the Directive, either through binding rules or via codes or practice and other voluntary agreements (Sede and Andersen, 2002).

For example, the standards for PTEs adopted in different countries vary considerably (Tables 5 and 6). In addition, standards for compounds not included in the Directive (i.e. pathogens and organics) have been set by some national regulations (Tables 7 and 8).

For the limit values of contaminants in soil-treated sludge (Table 5), most national requirements are similar to the ones specified in the Directive, apart from Denmark, Finland and the Netherlands which have more stringent limits. Some Member States (Spain, Portugal and the UK) have defined limit values for different categories of soil pH, while the regulations set by Latvia and Poland and the new proposed standards in Germany have defined different categories of soil based on their granulometry (Table 5). In addition, several Member States (Finland, France, Hungary, Luxembourg, Netherlands, Sweden, Belgium (Flanders) and three Lander in Austria) have introduce limitations in terms of maximum annual load of heavy metals on a ten year basis.

A comparison of heavy metal concentrations in sewage sludge (Table 6) between Member States shows that most Member States have more stringent limits than the ones in the Directive.

Agricultural application has been effectively prevented in some countries due to prohibitively stringent national limit values for heavy metals (e.g. the Netherlands, Belgium (Flemish region)). Concerns about the potential consequences for human health and the environment of potentially toxic substances and harmful microorganisms in sludge have even led to the banning of the use of sludge in agriculture in some countries, including Switzerland, despite the recognition that there is no conclusive scientific evidence that the practice is harmful. (FOEN, 2003).

[6] European Parliament legislative resolution of 17 December 2008 on the proposal for a directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (COM(2008)0019 – C6-0046/2008 – 2008/0016(COD))

Table 5 Maximum permissible concentrations of potentially toxic elements in sludge-treated soils (mg kg^{-1} dry soil) in EC Member States and US, (SEDE and Andersen, 2002)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	1-3	100-150(4)	50-140	1-1.5	30-75	50-300	150-300
Austria							
Lower Austria	1.5/1h)	100	60	1	50	100	200
Upper Austria	1	100	100	1	60	100	300/150(9)
Burgenland	2	100	100	1.5	60	100	300
Vorarlberg	2	100	100	1	60	100	300
Steiermark	2	100	100	1	60	100	300
Carinthia							
if 5<pH<5.5	0.5	50	40	0.2	30	50	100
if 5.5<pH<6.5	1	75	50	0.5	50	70	150
if pH>6.5	1.5	100	100	1	70	100	200
Belgium, Flanders	0.9	46	49	1.3	18	56	170
Belgium, Walloon	2	100	50	1	50	100	200
Bulgaria							
pH=6-7.4	2	200	100	1	60	80	250
pH>7.4	3	200	140	1	75	100	300
Cyprus	1-3	100-150	50-140	1-1.5	30-75	50-300	150-300
Denmark	0.5	30	40	0.5	15	40	100
Finland	0.5	200	100	0.2	60	60	150
France	2	150	100	1	50	100	300
Germany (6)	1.5	100	60	1	50	100	200
Germany (7)							
Clay	1.5	100	60	1	70	100	200
Loam/silt	1	60	40	0.5	50	70	150
Sand	0.4	30	20	0.1	15	40	60
Greece	3	-	140	1.5	75	300	300
Ireland	1	-	50	1	30	50	150
Italy	1.5	-	100	1	75	100	300
Luxembourg	1-3	100-200	50-140	1-1.5	30-75	50-300	150-300
Estonia (10)	3	100	50	1.5	50	100	300
Hungary	1	75/1 (8)	75	0.5	40	100	200
Latvia	0.5-0.9	40-90	15-70	0.1-0.5	15-70	20-40	50-100
Lithuania	1.5	80	80	1	60	80	260
Malta							
pH 5<6	0.5	30	20	0.1	15	70	60
pH 6-7	1	60	50	0.5	50	70	150
pH >7	1.5	100	100	1	70	100	200
Netherland	0.8	10	36	0.3	30	35	140
Portugal							
Soil ph<5.5	1	50	50	1	30	50	150
5.5<soil<7	3	200	100	1.5	75	300	300
Soil ph>7	4	300	200	2	110	450	450
Poland							
Light soil	1	50	25	0.8	20	40	80
Medium soil	2	75	50	1.2	35	60	120
Heavy soil	3	100	75	1.5	50	80	180
Romania	3	100	100	1	50	50	300
Slovakia	1	60	50	0.5	50	70	150
Slovenia	1	100	60	0.8	50	85	200
Spain							
Soil ph<7	1	100	50	1	30	50	150
Soil ph>7	3	150	210	1.5	112	300	450
Sweden	0.4	60	40	0.3	30	40	100
UK(1)	3	400 (5)	135	1	75	300 (3)	20
USA (2)	20	1450	775	9	230	190	1500

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

Other elements only restricted in some countries or regions:

	Arsenic	Molybdenum	Cobalt
Steiermark		10	50
Belgium (Flanders)	22		
Hungary	15	7	30

Table 6 Maximum level of heavy metals (mg per kg of dry substance) in sewage sludge used for agricultural purposes. (SEDE and Andersen, 2002, Alabaster and LeBlanc, 2008)

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Directive 86/278/EEC	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Austria							
Lower Austria	2	50	300	2	25	100	1500
Upper Austria	10	500	500	10	100	400	2000
Burgenland	10	500	500	10	100	500	2000
Voralberg	4	300	500	4	100	150	1800
Steiermark	10	500	500	10	100	500	2000
Carinthia	2.5	100	300	2.5	80	150	1800
Belgium (Flanders)	6	250	375	5	100	300	900
Belgium (Walloon)	10	500	600	10	100	500	2000
Bulgaria	30	500	1600	16	350	800	3000
Cyprus	20-40	-	1000-1750	16-25	300-400	750-1200	2500-4000
Czech republic	5	200	500	4	100	200	2500
Denmark	0.8	100	1000	0.8	30	120	4000
Estonia	15	1200	800	16	400	900	2900
Finland	3	300	600	2	100	150	1500
France	20	1000	1000	10	200	800	3000
Germany (1)	10	900	800	8	200	900	2500
Germany (2)	2	80	(600)	1.4	60	100	(1500)
Greece	20-40	500	1000-1750	16-25	300-400	750-1200	2500-4000
Hungary	10	1000/1(3)	1000	10	200	750	2500
Ireland	20		1000	16	300	750	2500
Italy	20		1000	10	300	750	2500
Latvia	20	2000	1000	16	300	750	2500
Lithuania	-	-	-	-	-	-	-
Luxembourg	20-40	1000-1750	1000-1750	16-25	300-400	750-1200	2500-4000
Malta	5	800	800	5	200	500	2000
Netherlands	1.25	75	75	0.75	30	100	300
Poland	10	500	800	5	100	500	2500
Portugal	20	1000	1000	16	300	750	2500
Romania	10	500	500	5	100	300	2000
Slovakia	10	1000	1000	10	300	750	2500
Slovenia	0.5	40	30	0.2	30	40	100
Spain	20	1000	1000	16	300	750	2500
Spain	40	1750	1750	25	400	1200	4000
Sweden	2	100	600	2.5	50	100	800
United Kingdom	PTE regulated through limits in soil						

(1) Regulatory limits as presented in the German 1992 Sewage Sludge Ordinance (BMU, 2002)
(2) Proposed new limits (BMU, 2007)
(3) Chromium VI

Other elements only restricted in some countries or regions:

	Arsenic	Molybdenum	Cobalt
Lower Austria			10
Steiermark	20	20	100
Belgium (Flanders)	150		
Denmark	25		
Netherlands	15		
Czech republic	30		
Hungary	75	20	50
Slovakia	20		

For organic contaminants (OCs), there is no consistent approach in setting limit values in sludge between different countries (Table 8) (Smith 2008). Some countries, such as the UK, US and Canada, have argued that there is no technical justification for setting limits on OCs in sludge, on the basis that research has shown that the concentrations present are not hazardous to soil quality, human health or the environment (US Environmental Protection Agency, 1992b,c; WEAO, 2001; Blackmore et al., 2006). However, other countries have established limits for different groups of OCs. For example, in Germany, limits are set for the persistent compounds, AOX (total adsorbable organo-halogen), PCBs (polychlorinated biphenyls) and PCDD/Fs (polychlorinated dibenzodioxins and Polychlorinated dibenzofurans), but not PAHs (polycyclic aromatic hydrocarbons). However, Germany's proposed revised regulation (BMU, 2007) includes a limit for one PAH, benzo(a)pyrene, and France regulates PAHs and PCBs, but not PCDD/Fs. Denmark, on the other hand, has established controls for \ bulk volume chemicals including DEHP (Bis(2-ethylhexyl)phthalate), LAS (Linear Alkylbenzene Sulfonate) and NP/NPE (Nonylphenol/Nonylphenol ethoxylate).

Table 7 Standards for maximum concentrations of pathogens in sewage sludge (Sede and Andersen, 2002; Alabaster and LeBlanc, 2008)

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

a) applies to advanced treated sludge only
b) tbc – need to be checked

Table 8 Standards for maximum concentrations of organic contaminants in sewage sludge (mg kg-1 DS except PCDD/F: ng TEQ kg-1 DS) (CEC 1986, EC, 2000 and 2003; SEDE and Andersen, 2002; Alabaster and LeBlanc, 2008; and Smith, 2008;)

	Absorbable organic halides (AOX)	Bis(2-ethylhexyl) phthalate (DEHP)	Linear Alkylbenzene Sulfonate (LAS)	Nonylphenol/ Nonylphenol ethoxylate (NP/NPE)	Polycyclic aromatic hydrocarbon (PAH)	Polychlorinated biphenyls (PCB)	Dioxins/Furans (PCDD/F)	others
Directive 86/278/EEC	-	-	-	-	-	-	-	
EC (2000)a)	500	100	2600	50	6b	0.8c	100	
EC (2003)a)			5000	450	6b	0.8c	100	
Austria								
Lower Austria	500	-	-	-	-	0.2 d)	100	
Upper Austria	500					0.2 d)	100	
Vorarlberg	-					0.2 d)	100	
Carinthia	500				6	1	50	
Denmark (2002)		50	1300	10	3b			
France					Fluoranthene: 4 Benzo(b)fluoranthene: 2.5 Benzo(a)pyrene: 1.5	0.8c)		
Germany (BMU 2002)	500					0.2 e)	100	
Germany (BMU 2007) f)	400				Benzo(a)pyrene: 1	0.1 e)	30	MBT+OBT:0.6 Tonalid: 15 Glalaxolide:10
Sweden	-	-	-	50	3b)	0.4c)	-	
Czech Republic	500					0.6		

a proposed but withdrawn
b sum of 9 congeners: acenapthene, fluorene, phenanthrene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1,2,3-c,d)pyrene
c sum of 7 congeners: PCB 28, 52, 101, 118, 138, 153, 180
d sum of 6 congeners:PCB28,52,101,138,153,180
e Per congener
f Proposed new limits in Germany (BMU 2007)

The remainder of this section reviews the rules and requirements in selected Member States.

In **Sweden** the Swedish Environmental Protection Agency (Naturvårdsverket) (SEPA) by mandate from the Government has implemented the Directive through the *Regulation regarding protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture* (Kungörelse SNFS (1994:2) med föreskrifter om skydd för miljön, särskilt marken, när avloppsslam används i jordbruket). The Regulation is more stringent than the Directive in that it bans the usage of sewage sludge on pastureland and it regulates the necessary analyses for toxins in soil and sludge. Besides the Regulation, Sweden has adopted legislation on several other aspects of sewage sludge such as maximum permissible concentrations of potentially toxic elements in sewage sludge for commercial use, management of fertilizers (including sludge) in agriculture, requirements and permissions for sewage water treatment plants, deposit of sludge etc. In 1994, SEPA, the Federation of Swedish Farmers (LRF) and the Swedish Water and Waste Water Association (VAV) signed a voluntary agreement regarding quality assurance. This has primarily led to additional requirements for organics and the creation of a consultative group. In Sweden a quality assurance system (ReVAQ) has been designed in concert by the concerned parties, water companies, farmers, nature conservation and the food industry. These stakeholders studied the risks and then agreed the standards that they would endorse for using treated sludge on land. Aspects of the DIN ISO certification are included in the system. A pilot implementation has been successful and the next phase is to develop it as a national scheme. Two main drivers have been the need to heighten acceptance of and trust in the use of sludge in agriculture and to aid the achieving of national environmental targets (EWA 2008).

In the **UK**, a voluntary code was agreed in 2001 between the UK Water Industry and British Retail Consortium, known as the Safe Sludge Matrix (ADAS, 2001), that requires more rigorous control over sludge treatment, pathogen removal and use on land than was previously required by the guidelines in the *Code of Practice for Agricultural Use of Sewage Sludge* and the Statutory Instrument (DoE, 1989; UK SI, 1989) implementing the Directive. Importantly, the Matrix also introduced a two tier system of treatment for sludge with regard to the extent of pathogen removal, and strict land use controls that were analogous to the US EPA's Class A and B pathogen reduction requirements in the Part 503 Standards for the Use or Disposal of Sewage Sludge for agricultural use of sludge (US EPA, 1993).

In **France**, agricultural use of sludge is regulated by the Decree No. 1133 of December 8, 1997 and by the Enforcement Order dated January 8, 1998. This recent legislation was implemented in the broader context of the 1992 Water Act, the 1975 and 1992 Waste Acts and the Health Code. In particular, the 1992 Waste Act restricts the landfilling of sewage sludge from 2002 onwards: from this date, landfilling is limited to waste that cannot be recovered at reasonable cost (defined as "ultimate waste").

France's 97/1133 Decree establishes that before any spreading of sludge on land, a preliminary study must be carried out by the sludge producer identifying the sludge treatment and quality as well as the soil quality. In addition, a land spreading forecast must be established each year, specifying the quantities of sludge to be spread on land, the scheduling of each spreading operation as well as the parcels which will receive sludge. A report on the sludge spread on land and on the resulting impacts on soil qualities must be prepared at the end of the year (defined as the end of the "agricultural campaign"). Both the land spreading forecast and annual report must be transmitted to the local authorities by the sludge producer.

The spreading on land of more than 800 tonnes of sludge (DM) per year is subject to authorisation. For industrial sludge a preliminary study is required for such a permit and must include an evaluation of health risks. The French association of land spreading operators have developed a methodology to evaluate health risks of spreading operations (SYPREA 2007). Since March 2004 there are standards of quality regarding composted sludge approved by national authorities. The compost which reaches this quality standard is being considered as a product. Moreover a quality assurance scheme regarding the beneficial reuse of sludge in agriculture has been set out by the SYPREA. Thirty-seven criteria, which are controlled every year by an independent body, guarantee the respect of the best practices of sludge land spreading.

The French legislation on the spreading of sewage sludge is globally more stringent than Directive 86/278/CEE. For example, it provides that minimal distances should be respected between housings, river banks, bathing places, water wells, shellfish zones and the place where sewage sludge is spread. Furthermore, unlike Directive 86/278/CEE, the French legislation bans the spreading of sewage sludge when the soil is covered by snow or frost or during periods of strong rainfall, and it bans application on slopes.

In **Germany** the application of sewage sludge on land is regulated by the *Sewage Sludge regulation of 15 April 1992 (Klärschlammverordnung, AbfKlärV, last amended 20.10.2006) (BMU, 1992)*. This 1992 regulation strengthened an earlier (1982) version, introducing more stringent limit values for heavy metals. The use of untreated sludge is generally forbidden, as is the use of sludge on horticultural, grassland, forestry land, on land in protected areas, on land in water protection areas, and on river banks. Field vegetables may not be grown on land if sludge has been applied that year or the year before. If crops are used as fodder, sludge can only be applied before seeding and has to be incorporated into the soil. Although there are a number of restrictions governing the spreading of sewage sludge in agriculture, there are still concerns in some parts of Germany that the law governing this outlet is not strict enough.

In 2007, a draft for a new ordinance for sewage sludge (BMU, 2007) was issued by the Ministry of Environment (BMU), following an expert seminar held in December 2006 at the BMU in Bonn (www.bmu.de/abfallwirtschaft/fb/klaerschlamm). Delegates from some Federal States wanted to ban the agricultural use of sewage sludge, mainly because of concerns over the accumulation of organic contaminants in the soil (e.g. Baden-Württemberg (Kaimer (2006)), but recognised that this would not be possible under existing EU and German national legislation. Although the Federal Ministry for the Environment (BMU) as well as most Länder do not support a total ban of the use of sludge on land, some of the Länder think that the currently discussed revision of the German sewage sludge regulation does not go far enough and a total ban should be made possible. In June 2008 the Bavarian Minister for the Environment requested an EU wide ban of the use of sewage sludge on land or a provision in the directive for Member States to allow a ban. Bavaria has already reduced the amount of sludge used from 55% in 1997 to 20% in 2008. The Land wants to further reduce this amount by building several incineration plants at waste water treatment plants. Baden –Württemberg also has proposed an end to the use of sludge on agricultural land and has already initiated a “de facto” ban by restricting certain agricultural subsidies to farmers that do not use sewage sludge on their fields.

The main issues of the 2007 draft revision are a significant reduction of existing limit values for heavy metals and new limit values for organic substances (lower limits for dioxins/dibenzofurans, and some PCB congeners, and the introduction of a limit for benzo(a)pyrene). It was envisaged that the process of adopting the revised ordinance would be initiated in autumn 2008.

In the **Netherlands,** Directive 86/278 has been transposed into national legislation mainly through the “Decree on the quality and use of other organic fertilisers” (Besluit kwaliteit en gebruik overige organische meststoffen), abbreviated as “Boom” (BOOM 1991) The decree entered into force on the 1st of January 1993 – after the Commission concluded on the failure of a timely transposition of the directive in 1990. In 1998, the original decree was replaced by a new “Decree on the quality and use of other organic fertilisers” (BOOM 1998).
In sum, the provisions of Chapter II of the Decree concern the quality of organic fertilizers other than of animal origin such as compost, mud and other sediments, compost, etc. Article 8 includes measures for analysing and certifying these substances. The producers of the fertilizing substances are obliged to keep a register in which the information specified in Article 9 is inserted. Chapter III establishes rules with respect to the use of the fertilizing substances concerned. The use of fertilizing substances other than those which are in conformity with requirements laid down in the attachments is prohibited by Article 12. Articles 28 – 36 contain rules respecting the distribution on the land of fertilizing substances concerned. The 1998 Boom Decree sets more stringent limit values for heavy metals in sludge and in soil than the Directive. This has essentially ended the spreading of sewage sludge on agricultural land in the Netherlands. In principle, the use of sewage sludge is not allowed on land that is not used for agricultural purposes (Article 14 of the Decree). The requirements of quality are based on the Fertilisers Law (Meststoffenwet, 1986), whereas the norms of use are based in the Law on soil protection of the (Wet bodembescherming, 1986 and amendments). The 1998 Decree has been amended in 1996, 2001 and 2005 (amending the Decree use of Fertilizers of Animal Origin 1998, the Decree Quality and Use of Remaining Organic Fertilising Substances, and the Decree Discharge Open Cultivation and Livestock Breeding). Strengthening of norms regarding the use of nitrogen in the Netherlands is mainly based on laws transposing both the Nitrates and Water Framework Directive.

4 Economics of Sludge Treatment and Disposal

Agriculture application, incineration or landfilling are the main routes for sludge management across Europe. The amount of sludge that is incinerated significantly increases when agricultural recycling is discouraged or banned. Increasingly, the landfill option is becoming restricted to the disposal of ash from the incineration of sludge. Minor routes include land reclamation and incorporation, usually of ash, into building materials. The incorporation of whole sludge into bricks has also been tried. These minor routes will not be considered further at this point.

Of the developing processes, pyrolysis is probably the most significant. This can be viewed as an alternative to incineration and may prove to be of lower cost. The solid char that is produced may, however, not prove that easy to dispose of. Sometimes the char is incinerated which would appear to remove much of the advantage claimed for pyrolysis. Pyrolysis will not be considered further in this section but new technology options will be considered in the next stage of reporting (Task 3). Dried sludge can be used as a fuel in e.g. power stations. This could be viewed as incineration in stages, though in this case the ultimate disposal route may not be to landfill. In the UK, power stations are not allowed to burn waste material without meeting the stricter flue gas requirements applicable to waste incinerators, which makes this option unattractive to the electricity generators. No costs are given for this route.

Any disposal option/route requires the sludge to be treated in a range of unit processes which contribute to the overall cost. These include:

- Mechanical thickening and dewatering with the aid of polyelectrolytes for sludge conditioning.
- Anaerobic digestion.
- Drying.
- Lime treatment.
- Heating for pasteurisation.
- Incineration.
- Composting.
- Landfilling. Also land reclamation.
- Use in agriculture. A variant is silviculture where sludge is used in a fast rotation coppice.
- Transport.
- Storage.
- Many sludge treatment processes require odour control plant.

As well as the capital costs, there are operating costs which include:

- Labour.
- Energy. Drying in particular is a major user of energy and composting is a moderate user. Anaerobic digestion produces methane which is usually used in combined heat and power engines to produce a significant surplus of electricity, which can be sold. Incineration also generates electricity but less than used within the process.
- Transport fuel.
- Chemicals such as polyelectrolyte and lime. Lime is used for lime treatment and also to treat incinerator flue gas.
- When a sludge product is used in agriculture, the farmer requires less chemical fertiliser. This is a monetary benefit, whether it accrues to the farmer as is usually the case or to the operator responsible for the sludge.

- Even when the use of chemical nitrogen and phosphorus is reduced according to the levels of available nitrogen and phosphorus in sludge, crop yields can be higher. This could be due to a portion of the N or P in the sludge classed as unavailable, actually having some availability, or to other nutrients in the sludge or to the organic matter acting as a beneficial soil conditioner. The extra crop yield can be given a value.
- Instrumentation and analysis associated with regulatory requirements.
- Landfill tax and landfill gate fees.

A costing exercise for the European Commission was reported in ‘Disposal and recycling routes for sewage sludge’ (Sede and Andersen, 2002). Where costs have been obtained by WRc, these have been in broad agreement.

These costs are shown in Figure 1, in 2002 Euros.

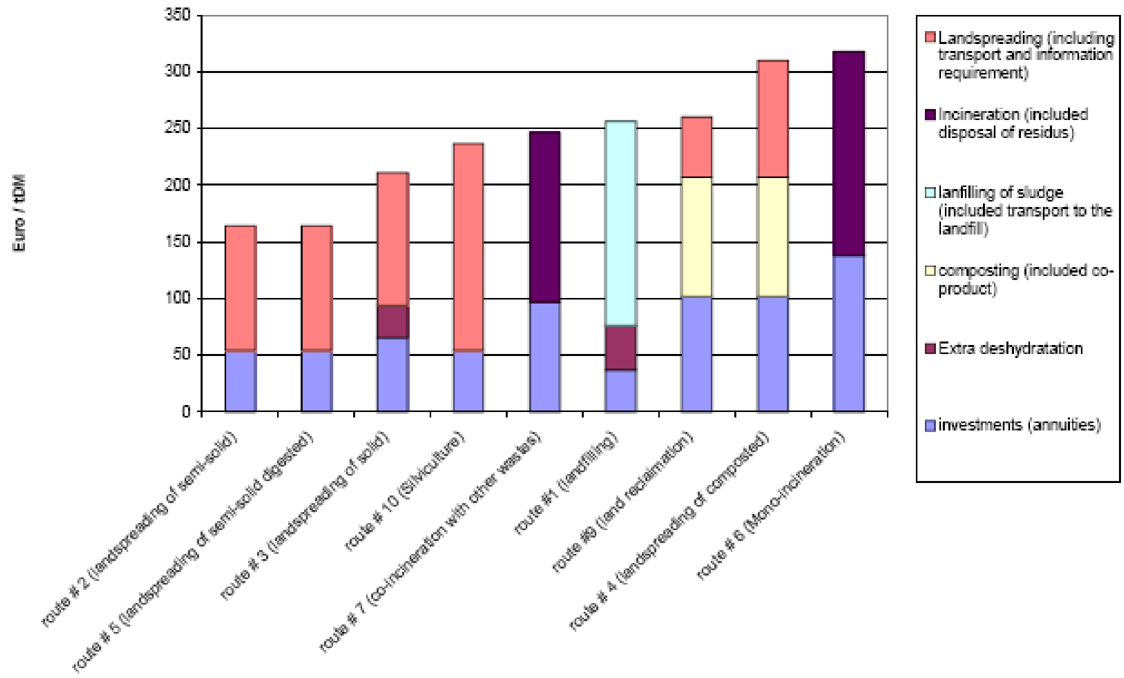

Figure 1 Average internal costs of sludge disposal and recycling in Europe (Euro/ tonne dry matter)

(From SEDE AND ARTHUR ANDERSEN (2002) *Disposal and Recycling Routes for Sewage Sludge*, European Commission, DG Environment – B2, 2002. Available at: http://ec.europa.eu/environment/waste/sludge/sludge_disposal.htm)

The costs in Figure 1 include operating costs and annualised investment costs for capital items. Two of the most commonly employed options are Route #3, the use of sludge cake, usually digested, in agriculture at €210/t DM, and Route #6, incineration in a dedicated incinerator at €320/t DM. Routes that were not costed included lime treatment and any that involved drying. The use of limed raw sludge cake in agriculture in the UK, is cheaper than the use of digested sludge cake (Route #3). Drying is very energy intensive and any route that involves drying would be at least as expensive as dedicated incineration. Despite its expense, drying is used quite frequently since it offers great flexibility to the operator in terms of storage and final destination.

Costs for routes based on use in agriculture assumed that extended storage periods of up to 9 months were required. If these were not required, costs would reduce by €50/t DM. This matches very well with the situation in the UK, where with 3 months storage, the costs for using digested sludge cake in agriculture are around 50% those of dedicated incineration. If additional storage is required this is assumed to be carried out by the farmer at the field-side at no extra cost.

Incinerators require extensive maintenance. If full throughput is required at all times, extra standby capacity is required, increasing costs by 50%.

The costs in Figure 1 include any benefits from energy recovery but not the value of displaced chemical fertiliser, which was costed separately. The value of displaced chemical fertiliser plus additional crop yield for a range of sludge products is shown in Figure 2.

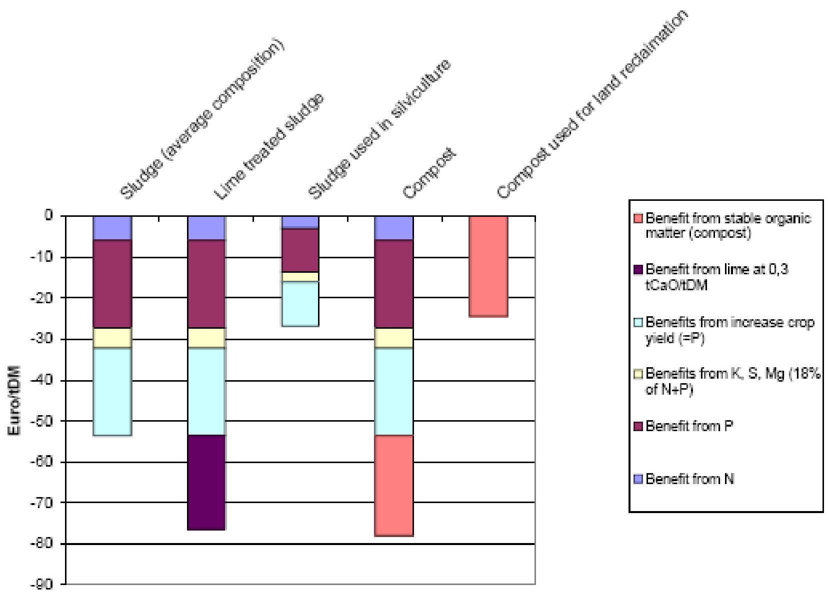

Figure 2 Internal benefits of sludge recycled to land (€/tDM)
(From SEDE AND ARTHUR ANDERSEN (2002) *Disposal and Recycling Routes for Sewage Sludge*, European Commission, DG Environment – B2, 2002. Available at: http://ec.europa.eu/environment/waste/sludge/sludge_disposal.htm)

When comparing routes, the appropriate benefits from Figure 2 should be added to the costs in Figure 1. As an example, to the cost of €210/t DM for the use of sludge cake in agriculture, Route #3, should be added €-53/t DM for the benefit of reduced fertiliser requirement and increased crop yield resulting in just under €160/t DM, which could reduce further given the low storage assumption. This is very much less than the €320/t DM for dedicated incineration.

In the Sede and Andersen (2002) study a range of external impacts was quantified. Some of the impacts from airborne pollutants are quantified in monetary terms but this goes beyond the scope of this section.

Current estimates are that 45% of the EU15 total of 9 million tDM of sewage sludge are used in agriculture (CEC 2006b, Alabaster and LeBlanc, 2008). If this route was lost, to be replaced by incineration, the cost would be of the order of €650 million per year. Andersen suggested a policy of pollution prevention, needed to maintain the agricultural route in the light of the draft revisions to the regulations regarding the use of sewage sludge in agriculture, would cost a similar amount.

5 Agricultural Value of Sewage Sludge

Application of sewage sludge to land recycles nitrogen (N), phosphorus (P), other macronutrients (such as calcium, potassium and sulphur), micronutrients (such as copper and zinc) and organic matter and so confers very positive agricultural benefits. Sewage sludge has also been used successfully in land reclamation, on forest land and in other land applications.

The focus of investigations into the agricultural value of sewage sludge has been on the availability to crops of the N and P it contains and the soil conditioning capability of its organic matter content. The availability factor is the key to determining the fertiliser replacement value of sludge and thereby quantifying its agricultural benefit to farmers.

The availability of sludge N to crops is broadly in the range 15-85% compared with the availability of N in inorganic fertiliser. The availability of N in sludge is largely determined by the treatment process given to the sludge before application to the land. Selection of sludge treatment process is concerned principally with factors such as stabilisation, sanitisation and volume control but it is also important, if the sludge is for agricultural use, to have a sludge product which farmers will want to apply to their land. In general terms the N in anaerobically digested, dewatered sludge cake (20-30% dry solids content) will be at the low end of the scale (15-20% available) whilst liquid digested sludge (3-8% dry solids content), which contains readily plant-available ammonia, will be at the high end of the scale (up to 85% available). Dewatered sludge cake has logistical advantages over liquid sludge and is the sludge product most widely used in agriculture. Sludge cake has the positive attribute that much of its N content is combined with organic matter and will be slowly released to the growing crop roots in the soil as the organic matter decays. Also, the dry solids: N content of sludge cake is comparatively high so an application of sludge cake will add more organic matter to the land before the N limit is reached.

P availability is less influenced by sludge treatment process is likely to be about 50% available in most sludge products. In the case of advanced-treated thermally dried sludge products nutrient availability may be influenced by the physical properties of the dried material. Hard dry sludge pellets of 90%+ dry solids content will break down only gradually in the soil causing very slow release of nutrients.

Thus the agricultural benefit of sludge products has been defined as effectively as is possible for an organic material and many farmers use sludge products, recognising their value and economic benefit. Sludge may be supplied free to the farmer or there may be a charge for a service which would include derivation of rate of application (usually based on the N requirement of the crop and often in the range 5-10 tonne dry solids of sludge per hectare), supply and incorporation of sludge and follow-up monitoring. Demand for sewage sludge in agriculture and for other land uses would undoubtedly be enhanced if it was clearly recognised as a product not a waste, and was accepted as being suitable for use in organic farming and other organic growing practices.

The limiting factor determining the rate of application of sewage sludge to the land is usually the maximum permissible addition of total N which for most purposes is 250 kg N/ha per year as set out in the Nitrates Directive 91/676/EEC. This figure will be reduced in Nitrate Vulnerable Zones to 175 kg N/ha per year. In some circumstances it may be permissible to apply 500 kg N/ha every 2 years if the N availability of the material is low as could be the case for dewatered sludge cake and sludge compost. This would be good for soil conditioning purposes as such an application would supply a beneficial quantity of organic matter to the land. In particular, effective land reclamation operations often require heavy applications of organic matter and nutrients to resuscitate impoverished substrates.

Rate of application of sludge may also be limited or not permissible where the P index of the soil is comparatively high (3-4+) and the P restriction may extend as the requirements of the Water Framework Directive are implemented. Sewage sludge is a P-rich fertiliser product in terms of its P/N content in relation to the P/N requirements of crops. Thus an application of sludge to the land to meet the N requirement of the crop will exceed its requirement for P. Any move to change the permissible rate of application of sludge to land away from the N factor to a baseline determined by the crop requirement for P would have serious implications for the operational viability of the agricultural outlet for sludge because the rate of application would be significantly reduced. Smith (2008) in his review noted that P concentrations in sludge are increasing with the expansion of P removal during waste water treatment and so careful management of nutrient inputs to soil in sludge is necessary to avoid excessive P application. Smith (2008) considered that more information was required on the long-term fate and release of P in sludge-treated agricultural soil in order to assess the agronomic benefit of P and the efficiency of P utilisation by crops. This information is needed as a basis for controlling P accumulation in soil and for minimising risk to the water environment.

Directive 86/278/EEC states that, 'Whereas sludge can have valuable agronomic properties and it is therefore justified to encourage its application in agriculture provided it is used correctly; whereas the use of sewage sludge must not impair the quality of the soil and of agricultural products'. The Directive states also in Article 8 that, 'the sludge shall be used in such a way that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired'. These broad requirements remain sound at the present time and most Member States have available more detailed guidance on how to utilise effectively the nutrient and organic matter content of sludge in agriculture, based on information obtained from field trials carried out on local farms. In view of this, it would seem to be unnecessary to alter 86/278/EEC as regards sludge utilisation and nutrient management with the proviso that a watching brief is kept on P and more information is obtained about the accumulation and fate of P in sludge-treated soils.

6 Contaminants and Pathogens

6.1 Potentially Toxic Elements

The potentially toxic elements (PTEs) include heavy metals and other inorganic elements which may be found in sewage sludge. When sludge is applied to the land the PTEs will tend to accumulate in the cultivated layer of topsoil and following repeated applications of sludge the PTEs could theoretically accumulate to toxic concentrations which might adversely affect for example crop growth and quality, soil fertility and the food chain. Directive 86/278/EEC sets limits for cadmium, copper, nickel, lead, zinc and mercury. Chromium was on the list but was not given a limit. Some Member States have set limits for more PTEs e.g. in the UK there are additional guideline limits for arsenic, fluoride, molybdenum and selenium (see section 3). The way in which Directive 86/278/EEC sets the PTE limits is flexible because they are given as permissible ranges in both soil and sludge and implementation. The Directive states: 'Whereas, moreover, it is necessary to prevent these limit values from being exceeded as a result of the use of sludge; whereas, to this end, it is necessary to limit the amount of heavy metals added to cultivated soil either by setting maximum quantities for the amounts of sludge used per annum and ensuring that the limit values for the concentration of heavy metals in the sludge used are not exceeded or by seeking to ensure that limit values for the quantities of heavy metals that can be added to the soil on the basis of a 10-year average are not exceeded'.

New developments on PTEs in sludge recycled to land include the effect of Zn on soil microorganisms and soil fertility, and the impact of Cd in soil on Cd concentrations in certain foods. Effects of PTEs on soil microorganisms and soil fertility have been the subject of detailed field investigations in the UK (DEFRA 2002, DEFRA 2007). Definitive effects requiring changes to the soil metal limits have yet to be identified but the findings confirm that the precautionary change for Zn from 300 mg/kg to 200 mg/kg for soils of pH value 5.5 – 7.0 was appropriate.

Commission Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs set limits for Cd in foodstuffs 'as low as reasonably achievable' following the precautionary principle. The limits are close to background levels which occur naturally in foodstuffs from uncontaminated sources. The levels for Cd in cereal grains and offal may not be compatible with the existing soil limit of 3 mg Cd/kg where sludge is recycled to land. This needs further evaluation – however, concentrations of Cd (and indeed of other PTEs) in sludge have declined substantially over the years due to tighter controls on discharges from industrial premises and reduction in the use of PTEs in industry. In practice, it is unlikely that applications of sludge to the land, at rates determined as they are by N content, would increase the concentration of Cd in the soil to the extent that the limits for Cd in grain or offal would be exceeded.

A recent risk assessment of sludge in soil conducted by INERIS for EFAR considered the presence of the metals, cadmium, chromium III, copper, mercury, nickel, lead and zinc (together with the organic compounds, mentioned in drafts related to revision of the Sludge Directive in 2003) (EFAR, 2008). They evaluated the potential hazard of each substance to derive a toxicological reference value (TRF), which they compared with an exposure value to give a hazard quotient (Exposure ÷ TRF), a value over 1 being considered concern for human health. The exposure value considered consumers, neighbours and farmers as receptors, and ingestion via soil, water, animals, vegetables and fish for a 70 year lifespan. The results confirmed that the major exposure pathway is the ingestion of plants and animals. The major substances were the heavy metals, zinc, lead, cadmium, copper and nickel. The study concluded that the contribution of sludge spreading to land to the global risk is low compared to the ingestion of food produced on non-spread lands. Nevertheless, the report suggested a reduction in the permissible Pb concentration in sludge for recycling from a maximum of 750 mg/kg ds (in 86/278/EEC) to 500 mg/kg. This would achieve an acceptable level of risk with 70 years of exposure based on very conservative assumptions.

Smith (2008) points out that there remains further scope to reduce the concentrations of problematic contaminants, and PTEs in particular, in sludge. He suggests that this should continue to be a priority and pursued proactively by environmental regulators and the water industry as improving the chemical quality of sludge as far as practicable is central to ensuring the long-term sustainability of recycling sewage sludge in agriculture.

Monitoring and research needs to continue to assess the significance of new developments (including PTEs of new interest e.g. tungsten) as they arise.

6.2 Organic Contaminants

The presence of organic contaminants (OCs) in sludge has been considered to a much greater extent in recent years; the European Commission and JRC has launched their own review in 2001 (EC 2001). The list of potential contaminants that have been detected in sludge is now extensive and includes: products of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dioxins), solvents (e.g. chlorinated paraffins), flame retardants (e.g. polybrominated diphenyl ethers), plasticisers (e.g. phthalates), agricultural chemicals (e.g. pesticides), detergent residues (e.g. linear alkyl sulphonates, nonylphenol ethoxylates), pharmaceuticals and personal care products (e.g. antibiotics, endogenous and synthetic hormones, triclosan) (Smith, 2008).

Some countries such as UK, USA and Canada have not set any limit on OCs in sludge suggesting that research indicates that concentrations present are not hazardous to human health, the environment or soil quality. However, other countries have set limits for some OC groups. For example, Germany has set limits for PCBs and dioxins but not PAHs while France has limits for PAHs and PCBs but not dioxins. Denmark has set limits for a range of OCs including linear alkyl sulphonates, nonylphenol and nonylphenol ethoxylates and the phthalate, di(ethylhexyl)phthalate (DEHP). Therefore, agreement on which OCs should be regulated in sludge could prove to be a major point of discussion when the Sludge Directive is considered for revision.

A considerable amount of information is known on the fate and behaviour of these substances to enable assessment of their potential effects on human health. Ingestion of crop plants and grazing livestock that have taken up OCs from sludge is a potential exposure route for humans. OCs have a number of physicochemical properties which may affect their behaviour in sludge and potential uptake into plants and animals. OCs include volatile compounds which are rapidly lost to the atmosphere from sludge and sludge-treated soil; compounds with little persistence which are mineralised by microorganisms; and persistent compounds which are strongly absorbed to sludge and the soil organic matrix. Compounds with some water solubility have a greater potential for plant uptake but are also more susceptible to rapid degradation or lost through volatilisation or leaching. For example, nonylphenol and nonylphenol ethoxylates have the potential for uptake by crops but are rapidly degraded in soil (half-life of 20-60 days for nonylphenol). The principal concern for livestock grazing on sludge-treated pasture is the potential accumulation of lipophilic OCs in meat fat and milk. Of the main OCs, only the chlorinated hydrocarbons meet this criterion. The review of Smith (2008) suggests that the potential impact of OCs on grazing animals, in terms of subtle physiological responses is very difficult to measure in practice.

The polymer, polyacrylamide, is used extensively as a polyelectrolyte to aid mechanical dewatering of sludge and may constitute up to 1% of the dry sludge. Small amounts of the unchanged monomeric, acrylamide, may be present with the polymer and this has the potential to form *N*-nitrosodimethylamine. While the polymer is inert, both acrylamide and *N*-nitrosodimethylamine are under assessment as potential carcinogens (both classified as 2A, probable human carcinogens, by the International Agency for Research on Cancer (IARC)). However, rapid degradation in soil and absence of plant uptake and accumulation suggests no transmission to the human foodchain via sludge.

Pharmaceuticals and personal care products have been increasingly detected in waste water. However, although less is known about their behaviour in the environment, it is envisaged that their fate and behaviour will depend on their physicochemical properties as for other OCs described above. There are particular concerns about the presence of antibiotics and the antimicrobial agent, triclosan and their potential indirect effects on human health through effects and resistance in the microbial environment. The present of antibiotic populations of bacteria in soil has been linked to the use of antibiotic in livestock. Although the concentrations of pharmaceuticals in waste water appear to be low, as more knowledge is gained on their presence in sludge, further assessment of their potential effects on human health may need to be made.

There is also concern over the presence of endocrine disrupting chemicals including natural and synthetic hormones and the much less potent industrial agents such as phthalates and their presence in sludge. Endogenous and synthetic oestrogenic compounds do partition to particulates and may be associated with sludge but there is only limited information at present on levels and biodegradation. It appears likely that oestrogenic substances excreted from farm livestock waste will constitute a greater load to the soil than sludge.

Another emerging group of potential contaminants about which nothing is known at present in terms of fate and behaviour in waste water processes are nanoparticles. These are being increasingly used in a range of technologies from personal care products to industrial processes. As more is known about their fate in the environment, assessment will have to be made on their potential presence in sludge spread to land.

There have been a number of risk assessments conducted on the presence of OCs in sludge (reviewed by Smith, 2008). These have concluded that exposure to OCs from the agricultural use of sludge is no greater than background levels. A recent risk assessment of sludge in soil conducted by INERIS(EFAR, 2008) considered the presence of the PTE together with the OCs mentioned in drafts related to revision of the Sludge Directive in 2003, PAHs (with benzo[a]pyrene considered separately), dioxins, PCBs, nonylphenols and nonylphenol ethoxylates and linear alkyl sulphonates, together with DEHP. They evaluated the potential hazard of each substance to derive a toxicological reference value (TRF), which they compared with an exposure value to give a hazard quotient (Exposure ÷ TRF), a value over 1 being considered concern for human health. The exposure value considered consumers, neighbours and farmers as receptors, and ingestion via soil, water, animals, vegetables and fish for a 70 year lifespan. The results confirmed that the major exposure pathway is the ingestion of plants and animals and that heavy metals were the major substances, with PAHs and PCBs being the only major OCs. The study concluded that the contribution of sludge spreading to land to the global risk is low compared to the ingestion of food produced on non-spread lands. OCs such as linear alkyl sulphonates, DEHP and nonylphenols did not contribute significantly to global risk.

Another consideration when assessing the need for OCs to be considered for regulation in any revision of the Sludge Directive is that many of the potential contaminants are already being controlled under other legislation and so the potential levels in sludge are already decreasing. For example, nonylphenols, DEHP, polybrominated diphenyl ethers and other flame retardants, some pesticides and some chlorinated solvents are on the Priority Hazardous Substances or other pollutants lists for the Water Framework Directive. So it appears likely that the majority of the known pollutants will be increasingly controlled at source.

In summary, the reviews of the research on OCs in sludge conducted so far have concluded that they are unlikely to have an adverse effect on human health and will be increasingly controlled by regulation. However, contaminants such as DEHP and chlorinated paraffins, found in sludge at higher levels will need to be further assessed. Further vigilance is also required on emerging contaminants such as pharmaceuticals, where the potential fate and behaviour in waste water, sludge and soil is unclear at present.

6.3 Pathogens, Treatment of Sludge and Land Uses Practices

6.3.1 Current situation

Sludges produced from the treatment of waste water contain a broad range of pathogenic organisms, including viruses, bacteria, parasitic protozoa and helminths. Human, animal and plant populations are exposed to the risk of contact with pathogens in sewage effluents and sewage sludge in the following main ways:

- discharge of sewage into watercourses and bathing waters;
- recycling of sludge onto agricultural land, or renovated land.

Of these only discharge of sewage into bathing waters is subject to specific microbial controls at European level, under the Directive on Bathing Waters (2006/7/EC), whose requirements were developed following extensive human exposure trials.

The risk of pathogen transmission from sewage sludge into human, animal or plant receptors continues to be a major concern to the public, which has been reflected in individual country regulations and codes of practice, and in the significant reduction or complete elimination of agricultural use of sewage sludge in some countries in the EU.

Implementation of the requirements of Directive 86/278/EEC provides effective barriers to the transmission of disease. These have been implemented in different ways in different countries. Although the Directive provided no specification of microbial quality or guidance on appropriate treatment methods the only clear evidence for transfer of disease from sewage sludge has been in a few instances where its requirements have not been properly implemented or where operators may have been using unhygienic practices.

This has not allayed public concerns over the potential for disease transfer. In some countries, for example the UK, regulatory requirements stemming from the Directive, with guidance provided on the types of processes that have been regarded as providing appropriate levels of treatment have been supplemented by "voluntary" agreements that enhance sewage sludge quality requirements. Hence the "Safe Sludge Matrix" in the UK was devised after extensive study of the evidence for pathogen decay in treatment and recycling processes.

The Safe Sludge Matrix provides descriptions of two levels of treatment to achieve specified numbers of *E.coli* and *Salmonella* spp in sludge. The enhanced treated sludge quality standard is only achieved as a result of a degree of treatment that achieves at least some additional pasteurisation, usually involving a thermophilic stage, and potentially also multistage treatment that reduces the likelihood of significant amounts of sludge failing to be retained for a minimum period in the process.

By instituting this and also developing a control and monitoring philosophy for sludge treatment processes that identify critical points in a process stream and ensuring that these are measured and have to meet previously agreed criteria in order for sludge to be regarded as treated or enhanced treated sludge, there appears to be improved acceptance that sludge may be beneficially used on agricultural land without unacceptable hazards to public health.

6.3.2 Pathogen exposure and consequences

Direct exposure is considered an occupational health risk to those producing and applying sludge to land. Epidemiological evidence indicates risks of illness are low from this route when sludge has been treated. There have been some examples of illness resulting from poor hygienic practice (e.g. failure to wash hands, lack of protective equipment).
Various studies have assessed the health risk of workers and other populations in the vicinity of sludge operations as a result of aerosol dispersion of pathogens and residues in the sludge. Some findings (for example Tanner et al, 2008) have suggested that there may be a significantly increased risk of illness in close proximity to loading operations from field site storage of treated sludge to the spreader trucks. Other findings on the health effects on populations residing nearby have not shown any unequivocal evidence for increased risks. These studies are difficult to carry out and many of them suffer from low population numbers and lack of equivalent non-exposed populations, as well as difficulties in assessing measurable illness. It is possible that a combination of endotoxins and pathogens may enhance infectivity.

Various indirect transmission routes exist. The most obvious are sludge applied to land and subsequent use of the land for food production, either for crops or animal husbandry. These routes have been widely studied (Carrington et al, 1998) with attempts to carry out risk assessments using assumptions about ingestion and infection rates. There have been no clearly identified public infections resulting from agricultural use of sewage sludge when it has been used in accordance with the provisions in the Directive, including local additional controls. Gale *et al.* (2003) applied Quantitative Microbial Risk Assessment (QMRA) to assess human exposure to a range of pathogens from sludge applied to land subsequently used to cultivate a range of agricultural crops. Generally, the risks were found to be low although a number of uncertainties were recognised, particularly regarding the lack of reliable data on the long term decay characteristics of pathogens in the environment.

Run-off from land on which sludge has been used is another possible route, with discharges into recreational water, or sources of water used for producing drinking water or longer term contamination of groundwater. This also ties into requirements under the Water Framework Directive. Some workers have reported that faecal indicators and viruses can be detected at a considerable distance in groundwater from possible sources of contamination.

The risk of presence of animal pathogens in sewage sludge cannot be excluded where waste from abattoirs or other animal processing may enter sewer system. Bacteria and parasites may infect humans and animals. Viruses tend to be host specific although there have been recent concerns over zoonotic transmission of certain viruses. Helminths have well defined life-cycles and host specificities but animal to animal transmission may occur where the land is used for grazing.

Plant pathogens may also be present, derived for example, from vegetable washings. Most washing is probably now carried out immediately post harvest, and is likely to be in the vicinity of the producer, so that there may now be a reduced likelihood of transmission of significant levels of pathogens into uninfected areas. Increased use of food waste disposal into sewers may be an additional route for introduction of plant pathogens into sewage and sludge.

6.3.3 Pathogen risk minimisation

The Directive 86/278/EEC includes:

- A requirement for treatment of sludge to reduce its health hazards before using it in agriculture
- A permit, on certain conditions, to use untreated sludge, without risk to human or animal health, if it is injected or worked into the soil;
- Restrictions on applications to sensitive crops and on use of the soil for periods after application.

These conditions provide barriers to the transmission of risks of infection.

In the UK extensive studies (CEC, 1992) on use of sewage sludge on agricultural land were carried out that led to guidance documents and codes of practice to control use and operations, prior to the implementation of the 1986 directive. Risks of animal, plant and human infections were recognised, although there was a lack of clear evidence that for recorded outbreaks of salmonellosis in animals sewage sludge was the route of infection, as most routes for infection were within existing agricultural activities. Other animal infections were also more closely related to agricultural activities than to the water industry.

The EU COST 68 working group studies (CEC, 1992) found some limited evidence for viral hepatitis due to use on vegetables, run-off from fields with incorrect application, and direct contamination of operators using very poor personal hygiene. The 1986 restrictions on planting, grazing and cropping, in conjunction with local additional controls have been considered appropriate to allow time for sufficient viral inactivation.

Time is not necessarily a secure barrier, as some parasites are capable of surviving non-thermophilic sludge treatments and persist in the environment for long periods of time. These include *Cryptosporidium*, and *Ascaris* spp.

Many plant pathogens could be present in sewage sludge. In the UK, before 1989, studies (Carrington et al, 1998) identified the potato cyst nematode as a significant sludge related hazard which resulted in a specific ban on sludge use on land to be used for seed potato growth in the UK Code of Practice. Some other plant diseases may also be transferred into sewage sludge but have not been considered to have sufficient risk to justify exceptional treatment or recycling restrictions.

The Sewage Sludge Directive provides no examples of appropriate treatment processes, but defines treated sludge as sludge that has undergone *"biological, chemical or heat treatment, long-term storage or any other appropriate process so as significantly to reduce its fermentability and the health hazards resulting from its use"*.

The appropriateness of sludge treatments for individual applications is derogated to individual countries to regulate, with an exemption to report on the treatments required for treatment works of less than 5000 population equivalent.

The use of untreated sewage sludge is only permitted in the directive under specific conditions of requiring injection or working into the soil and under regulation by each country (Art.6).

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

Variants of treatment methods that include thermal stages and multiple barriers to inhibit short-circuiting enable greatly improved reliability and confidence in the expected pathogen content of treated sludge. HACCP is also now used in the UK to manage treatment processes in conjunction with the Safe Sludge Matrix to provide assurance that processes are well managed.

There are areas of uncertainty in pathogen inactivation in treatment processes. For example, inactivation mechanisms in the widely used anaerobic digestion process are poorly understood, with potential for improvements; measurements of *E.coli* after dewatering processes sometimes show unexpected increases in concentration; and thermal inactivation may be linked to development of viable but non-culturable vegetative cells, also leading to difficulty in assessing the true pathogen quality of a treated sludge.

6.3.4 Pathogens of greatest risk

The occurrence of human pathogens is of most concern and has been the subject of a considerable amount of research to assess the health risks associated with the land applications of sludge. Largely, the organisms responsible are those pathogens that infect through the faecal-oral route, although respiratory and blood borne organisms may occur although prevalence generally low.

The nature and extent of human pathogens present largely depends on prevailing levels of infection in the community where the waste water is derived and the treatment used to produce the Sludge. Demographic variation of illness across the EU will influence the pathogen composition in waste water and may place a greater burden on the treatment barriers.

Potential issues include:

- new and emerging organisms, including antibiotic resistance,
- impact of climate change.

There are no widely accepted new risk pathogens in sewage sludge, although from time to time there are new public concerns about individual human pathogens. Since the work carried out for the 1986 Directive there have been developments in understanding quantitative microbial risk assessments and new assessments have been carried out for some pathogens including new variant CJD and *E. coli* O157;H7, in response to particular topical concerns.

6.3.5 Areas of uncertainty

- Since the 1986 directive some animal health issues have been recognised to be due to a range of pathogens potentially present in sludge – rotaviruses, cryptosporidium, and various bacteria;

- Full review of wide range of pathogens was not included during development of the studies associated with the 1986 directive, and whilst information was developed for the UK implementation of the safe sludge matrix this may need to be validated for other EU states;
- Sludge treatment is a crucial barrier to prevent disease transmission and requires better regulation and improved monitoring. The current indicators of process performance, *E. coli* and *Salmonella*, are vegetative bacteria and are not sufficiently robust to act as surrogates for the fate and behaviour of all pathogens of concern. Other organisms have been considered (e.g. enterococci and spore forming bacteria). However, consideration should be given to process verification by monitoring time and temperature requirements and relegate indicator and pathogen monitoring to process validation. This approach fits very much alongside the strategy being adopted in the forthcoming revision to the Drinking Water Directive and the adoption of Water Safety Plans. On this basis, a number of specific issues should be considered, such as;

- Should all EU be regulated in the same way, with the same sludge qualities required;
- What are suitable indicator organisms – see bathing waters enquiries – *E.coli* has been considered to be a good indicator as it is usually present at high concentrations, has similar sensitivities to treatments as a range of pathogens, and inexpensive measurement methods are well established. *Salmonella* is also used in the UK to monitor enhanced treatments. Faecal streptococci, used for bathing water standards, and Clostridia, as an indicator for spore forming pathogens have both been considered as additional or alternative indicators.
- Alternatively, should treatment processes be defined on the basis of process performance and validation;
- Should the impact of regrowth / reinfection potential be taken into account – pseudo stabilised versus stabilised sludges (CEN standard) on process verification if the existing indicator organisms continued to be used ;
- Should all sludges be fully safe for all handling at all stages subsequent to leaving a treatment works, without requiring any knowledge and training of operators or applying a degree of training to reduce occupational exposure ;
- Is the importance of the agricultural outlet sufficiently great for all sludge to be treated to the extent that there is no significant risk of further fermentation and odour generation;
- Are there newly understood exposure pathways; the improved knowledge of quantitative microbial risk assessment methods may be beneficial in improved assessments of a wider range of pathogens than so far carried out.
- Sustainability – long term decay of pathogens; build up of pathogen pool? Has land with long term sludge application greater background of wide range of pathogens
- Aerosol measurements – some have been carried out to assess the extent of distribution of indicator organisms in air during sludge recycling, and have so far indicated that risks of transmission through this route are relatively low, but the extent of the studies has been limited. These studies are difficult to carry out and need to be co-ordinated with other epidemiological studies.
- How will changing compositions of sewage sludge affect pathogen content; for example, co-treatment of food wastes, and other biodegradable materials either as a result of deliberate diversion from less beneficial routes, including household diversion to drains and sewers of materials hitherto treated as domestic solid wastes.

7 Water and Air Pollution

The preamble to Directive 86/278/EEC states that: 'Whereas sludge should be used under conditions which ensure that the soil and surface and ground water are protected, in accordance with Directives 75/440/EEC (OJ No L194,25.7.1975, p.26) and 80/68/EEC (OJ No L 20, 26.1.1980, p.43)'. One of the rules in Article 8 of 86/278/EEC which shall be observed when using sludge states: 'The sludge shall be used in such a way that account is taken of the nutrient needs of the plants and that the quality of the soil and of the surface and ground water is not impaired'. If the sludge is applied to meet, as far as possible, the plant nutrient requirements of the crop then the potential for leaching or runoff of excess nutrients will be reduced. In short, the control of water pollution where sludge is recycled to land is managed by adjusting the rate of application to be compatible with crop requirements for nutrients and applying land use practices which restrict or prohibit sludge application where there is a high risk of water pollution.

The principles for water pollution control set out in Directive 86/278/EEC remain sound but a revision could take account of updates in water pollution control legislation and guidelines for land use practices where sludge is used on the land. Domestic guidelines in some Member States already work to these updates which include the Nitrates Directive 91/676/ EEC and The Water Framework Directive 2000/60/EC.

In order to provide a perspective on the potential for water pollution control from landspreading of sewage sludge it can be estimated that in the EU, sludge contributes <5% annually of the total amount of organic manure recycled to land (most of which is of farm animal origin) and is applied to <5% of the available agricultural land bank. Sludge represents a minor input of nutrients to the land compared with farm animal manure and inorganic fertilisers.

The Nitrates Directive 91/676/EEC was designed to protect waters against pollution caused by nitrates from agriculture. It aims to reduce the level of nitrate losses in the catchments of polluted waters, and to prevent further new pollution. The Directive requires Member States to designate areas at risk from nitrate pollution as Nitrate Vulnerable Zones (NVZs) and to establish mandatory "action programme" measures within them. The Action Programmes control both the timing and rate of applications of both inorganic (chemical) nitrogen fertilisers and organic manures (including sewage sludge). For organic manures, farm-based limits of 250 kg N/ha on grassland and 170 kg N/ha on arable land will apply to the overall area of the farm within the NVZ. A field-based limit of 250 kg N/ha will apply to dressings of organic manure to individual fields. Sludge is applied to land in accordance with 91/676/EEC, usually at a rate supplying 250 kg N/ha. In addition, farmers are required to maintain adequate records of their cropping and stocking, together with details, in the form of fertiliser and manure plans, of all applications of in organic nitrogen and organic manures.

The Water Framework Directive 2000/60/EC was designed to provide an integrated approach to managing water bodies in the EU by considering in an holistic manner all the environmental drivers and pressures within river basins. The WFD legislation supersedes and updates existing legislation, and although this will not include the sludge Directive 86/278/EEC, it will potentially have an impact on the application of sludge to land. Nitrogen and phosphorus are under scrutiny because of their potentially significant impact on surface waters in causing eutrophication. The need to reduce diffuse N and P from agricultural routes may result in further limitations being placed on N and P inputs to soils, this will affect landspreading of all fertilising materials. The WFD may result in higher concentrations of P in sludge as concentrations of P in final effluent from waste water treatment works are further restricted (see Section 4 on Agricultural Value of Sewage Sludge).

Apart from nutrients, sewage sludge is organic manure with a significant chemical oxygen demand (COD) and which contains enteric microorganisms which further demonstrate the need to manage sludge recycling operations so that runoff into surface water in particular is avoided. This requires attention to farm and fieldside storage, imposition of buffer zones adjacent to banksides and water sources, and taking account of topography, application rates and prevailing soil and weather conditions. Operational guidance on landspreading of sewage sludge is included in the domestic guidelines for sludge recycling in some Member States and in more general guidance on good agricultural practice.

While the emphasis of control on water pollution where sludge is used on land lies with management of N and P, PTEs, organic micropollutants and pathogens have also been investigated in this context especially as regards leaching into groundwater. A watching brief needs to be kept on leaching of persistent organic micropollutants from sludge-treated soil.

Odour is usually the issue immediately noticed by the general population during distribution of sludge onto agricultural land (see Stakeholder Interests, section 9). Odour is also a very important factor at sewage treatment works and increasingly works have to meet control requirements, including covers on tanks and limiting the storage of raw and treated sludges at the works and appropriate emission controls and treatment processes. Very many chemicals are present in odour plumes, including ammonia, hydrogen sulphide and mercaptans.

8 Greenhouse Gas Emissions and Carbon Footprint

Responsible operators will generally wish to report their emissions of greenhouse gases. This will often include a list of their on-site emissions and certain off-site emissions for which they are particularly responsible such as those associated with the use of electricity and, in the case of sludge, emissions associated with its use in agriculture. Carbon footprints are more likely to be used to assist in the selection of sludge treatment processes or routes. A carbon footprint is based on a life-cycle analysis and draws a wider envelope around a process, such that in addition to the emissions above it will also include emissions embodied in materials of construction and consumables such as chemicals, emissions associated with transport and perhaps a wider range of off-site emissions.

The major greenhouse gases associated with sludge processing and disposal or re-use are carbon dioxide, CO_2, methane, CH_4 and nitrous oxide, N_2O. Sludge solids contain from 30-40% carbon, most of which is converted to carbon dioxide during treatment and disposal or use. This carbon dioxide is considered to be ‘short cycle’. It is returning CO_2 to the atmosphere that was withdrawn by plants in the recent past. This CO_2 does not contribute to global warming. The Intergovernmental Panel on Climate Change, IPCC, does not require countries to report such short cycle CO_2 and it is not considered further in this section. There are still considerable emissions of fossil fuel derived or ‘long cycle’ CO_2 associated with energy use, transport and embodied in materials of construction and consumables and which does contribute to global warming. Emissions of CH_4, while technically containing short-cycle carbon, are considered to be as a result of the anthropogenic conversion of CO_2 to CH_4. Since the latter has a much greater global warming potential this should be reported or included in any assessment of carbon footprint.

CO_2 emissions are associated with:

- The use of energy. Most countries will have produced country specific emissions factors for major sources of energy such as electricity and natural gas. The former, in particular will be based on the particular mix of electricity generation installed in a country.
- Transport. IPCC publish default CO2 emission factors for transport based on vehicle type and miles travelled or on quantities of fuel used.

- CO_2 emissions are associated with materials of construction and consumables used. These embodied emissions include that associated with the energy consumed during manufacture, particular process emissions such as the CO_2 produced during the manufacture of cement and the carbon contained within materials such as plastics. Embodied emission factors are obtainable from databases associated with LCA software.

When a process generates useful net energy, this is seen as displacing the requirement for fossil fuel and the CO_2 associated with the generated energy is considered to be a negative emission. The largest generation of electricity is associated with the use of biogas from the anaerobic digestion of sludge in combined heat and power plant, CHP. Significant amounts of energy are generated in steam turbines on sludge incinerators. Frequently, the electricity generated is less than that consumed by the incineration process. The incineration of a well dewatered raw sludge is most likely to lead to a small surplus of energy for export but less than from the digestion of the equivalent amount of sludge. The incineration of dried sludge may produce much larger amounts of electricity but this would be balanced by the energy requirements for drying.

When a product is beneficially used, such as sludge in agriculture, the CO_2 embodied in displaced chemical fertiliser is considered to be a negative emission. If the carbon in sludge was prevented from being converted to CO_2 over a sufficiently long time, this would be considered to be sequestration, and could be ascribed a negative emission. IPCC allows the estimation of sequestration of carbon in soil due to change of use, but not due to the addition of manure or sludge. Some researchers consider that a portion of the carbon in sludge used in agriculture will be sequestered in the soil but it is not believed that any national inventories of greenhouse gas emissions consider sequestered carbon from sludge used in agriculture.

Significant amounts of methane are generated during the processing, storage and disposal or use of sewage sludge. On-site emissions in the UK have been estimated, as shown in Table 9.

Table 9 Methane losses associated with anaerobic digestion and application of cake to land

Source	**Loss as % of total gas produced**	**Loss (kg CH_4/tonne DS)**	**Loss as % of total gas produced**	**Loss (kg CH_4/tonne DS)**
	Existing plant with secondary digestion		New plant with buffer storage	
Losses via annular space of floating roof digesters	2.5%	3.3	0.0%	0.0
Venting due to ignition failure and downtime at flare stacks	0.21%	0.29	0.21%	0.29
Incomplete combustion	1%	1.45	1.0%	1.45
Fugitive emissions	3.8%	5.1	1.0%	1.3
Secondary digestion/buffer storage	5.9%	8	1.5%	2.0
Total	13.4%	18.1	3.7%	5.1

The first two columns are considered applicable to typical existing plant and form the basis for the UK to report emissions of methane from sludge treatment. The second two columns are applicable to new plant which are all of fixed roof type, will have a lower level of fugitive emissions and where 14-day secondary digestion is replaced by a much shorter period of storage prior to dewatering. There are no further emissions of methane if the digested sludge is incinerated and considerable further emissions if the sludge is sent to landfill, a disposal route which has almost ceased in the UK. When sludge is used in agriculture there are further emissions from the emissions of storage of solid cake, which might be from within a sewage treatment works or from field-side storage. Further methane emissions are associated with the spreading of sludge cake on land, which, however, are minimal in a cool climate such as the UK. IPCC Good Practice Guidelines contains emission factors for the storage and spreading of sludge.

When sewage sludge is used in agriculture, there are associated emissions of nitrous oxide as nitrogen mineralises and oxidises. These can be broken down into direct emissions from the soil following application of sludge, and indirect emissions. The indirect emissions come from both nitrogen other than N_2O which is volatilised (mostly ammonia) and which later deposits back onto the land leading to further N_2O emissions and from ammonia in leachate which ends up in rivers where it stimulates further N_2O emissions. The direct emissions of N_2O from the use of sewage sludge in agriculture are equal to 0.01 times the nitrogen content in the sludge.

When sludge is used in agriculture it will replace the use of chemical fertiliser. The nitrous oxide emissions associated with that fertiliser are considered to be a negative emission. If all of the nitrogen in the sludge were available to plants the N_2O emissions from the soil after application would be balanced by the reduced N_2O emissions from the chemical fertiliser. In fact as little as 20% of the nitrogen in digested sludge cake is considered to be readily available to plants so the emissions of N_2O from its spreading are greater than the reduction in N_2O from the displaced fertiliser.

There are also significant emissions of N_2O resulting from the incineration of sewage sludge.

Table 10 compares the estimated greenhouse gas emissions from a UK study between incineration (TD-thermal destruction) and the use of digested sludge cake (MAD-mesophilic anaerobic digestion) in agriculture. The greatest single emission comes from methane lost during anaerobic digestion. As a result the total emissions from the agricultural route appear greater than from incineration. If, however, the reduced methane emissions appropriate to modern digestion plant without secondary digestion had been used, the methane losses from the process would fall by over 300 kg CO_2eq/tonne raw DS, reducing emissions to around zero, significantly better than from incineration.

Table 10 A comparison of greenhouse gas emissions between incineration of raw sludge and the use of digested sludge cake in agriculture

Treatment / Disposal Option	**Contributions from different operational sources (all expressed as kgCO_2eq/tRawDS)**							
	Natural gas usage	**Electrical energy**	**Consumables**	**Transport**	**CH_4 from process & agriculture**	**N_2O from process & agriculture**	**Fertiliser displacement**	**Total**
1. TD of raw sludge	0	-156	84	1	0	308	0	236
2. MAD and recycle dewatered digested sludge cake to AL	0	-267	106	11	465	101	-137	279

9 Stakeholder Interests and Public Perception

The principal stakeholders in the sewage sludge recycling to land operation are:

- **Sludge producers**. Recycling of sewage sludge to land is the main outlet for sludge in the EU where suitable land is accessible. The recycling to land option is therefore central to the sludge management strategy of most sludge producers. However, there are differences between Member States in the extent of use of the outlet. For instance, the Netherlands does not recycle sludge to land. The reasons for these differences are discussed in the next phase of reporting on this project.
- **Farmers**. Sludge has proven agricultural value and is usually a cost-effective alternative to other fertilisers so there is a steady demand from farmers in most Member States to recycle sludge on their land.
- **Farmers' advisors**. Advisors are generally supportive of sludge recycling so long as they are reassured that the operation is efficient and properly regulated and does not affect the acceptability of farm products to customers.
- **Landowners**. There may be some concerns about long-term effects of contaminants in sludge on soil fertility where repeated applications of sludge to the land have been made.
- **Regulators**. Sludge recycling to land is established as the BPEO for sludge management and Regulators are generally supportive of sludge recycling provided that operations are carried out in accordance with the appropriate rules and guidelines.
- **Farmers' customers, food processors and retailers**. There should be no problem here so long as regulations and guidelines for sludge recycling have been followed on the farm and the recycling operation is seen to be entirely 'safe'. A problem can arise if the processor/retailer perceives that the acceptance of products may be jeopardised if customers are aware that they have been grown on land treated with sewage sludge.
- **The public**. Studies have shown that the public are generally supportive of sludge recycling when the process of sewage treatment has been explained to them and the options for sludge disposal described (Davis, 2006). However, public nuisance factors (lorries, odour) are of key importance and must be controlled and preferably avoided if the confidence of the public in sludge recycling is to be retained. There is definite public sensitivity to odour nuisance from sewage treatment works and from sludge recycling operations in the field. Every effort must be made to avoid odour nuisance and the negative public response which can escalate to threaten the recycling outlet at least on a local basis.
- **Special interest groups**. In the UK, the pressure group 'Surfers Against Sewage' has carried out a survey of public attitudes to sewage sludge disposal in south West England (Davis, 2004). The report concluded that the 'best' routes for sewage sludge disposal in south west England were spreading on agricultural land for food or non-food crops. Or should either of these two routes become unusable, pyrolysis and gasification was viewed as the main viable large-scale option for sludge disposal in the area. During focus group sessions, when attendees listened to a 25-minute presentation and had the chance to ask questions about sludge disposal, most people agreed that sludge disposal to land was the best option, with 98% of those surveyed happy for sludge to be disposed of in this way and to eat crops grown on sludge-fertilised soil.
- **The media**. Waste water treatment and safe disposal of sludge are central to the protection of public health and should thereby have a very positive public image. However, because of their faecal association sewage treatment and sewage sludge disposal are prone to a negative and sometimes sensational press response often triggered by odour nuisance.

10 Future Trends

Large increases in quantities of sludge produced have taken place since 1995 (30% overall between 1995 and 2005) in the EU15 members, as a result of the UWWTD. The increase was not the same proportion in all countries. Although , much of the development required under the UWWTD has now taken place in the existing 15 Member States, the new 12 Member States, and some of the EU-15 members, have still a long way to go before complying with the UWWT Directive and thus it is likely that a similar rate of increase will continue.

Based on an annual average sludge production rate and population prediction, future sludge quantities produced in the EU-27 can be estimated. In the EU-15, in countries with a high connection rate to sewerage and high level of treatment complying with the UWWT Directive, sludge production rates are about 25 kg per person and per year.

Overall it is predicted that 50 % of sludge is likely to be recycled to land (Alabaster and Leblanc 2008). The situation in the existing 15 member States should not change dramatically over the next 5 years. There are some indications in the new Member States which have no previous experience in this sludge management route, that agriculture recycling may become a more significant outlet in the future.

The concentrations of metals in sewage sludge in Western Europe have significantly been reduced since mid 80's as a combination between increased management of industrial effluents and a reduction of heavy industrial production. The extent of further reductions is unclear, although the range of loadings may be significantly different between different parts of the EU (including new Member states).

Changes in composition as a result of increasingly rigorous nutrient removal requirements may become more significant. This is most likely to increase phosphorus concentration. This may be linked to changes in metal concentration if P-removal is carried out using metal salts (aluminium or iron).

Recovery of energy from biodegradable materials is encouraged by the EU energy policy, in particular to increase the use of biofuels. There is potential to increase sludge production if non-sewage biodegradable materials become incorporated into the sludge treatment route. In contradiction to this, treatment processes are increasing their capability to convert organic solids to transferable fuels with less residual solids. The balance between increase and decrease of mass of residual solids from sewage sludge treatment is therefore unclear.

It is likely that processes that provide enhanced pathogen removal will become more widely used, as they also commonly produce a sludge that is less fermentable and so less odorous and will attract less public concern or criticism. Processes that can reliably and cost-effectively demonstrate substantially reduced pathogen concentrations are likely to be more widely used.

There is a continual desire to reduce sludge volumes during treatment and intensify process operations.

Co-treatment of sewage sludge with a variety of other imported organic materials, particularly with reference to digestion processes, is currently not generally carried out, for reasons that include regulatory constraints. There are potential advantages of co-treatment in terms of asset utilisation (access to energy conversion systems, utilisation of existing infrastructure).

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants. It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertiliser. A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology.

Pyrolysis is still not an established process for sewage, but would offer increased energy recovery with a reduced cost and environmental impact compared to incineration.

Other sources of sludge, food waste, organic fractions of municipal waste, might compete for available land.

Though the carbon in sewage sludge is short cycle, the prevention of its release as CO_2 would be considered ‘sequestration’ (see Section 10). If a reliable route to sequestration could be developed, this might be more valuable than use in agriculture.

The subject of future trends will be considered further in the next stage of reporting for this project (.

11 Monitoring, record keeping and reporting

Information on sludge operations is primarily collated by the sludge producer; however, there may be several sources of the pertinent information:

- The occupier of the land receiving the sludge
- The person that applied the sludge to the land
- The sludge producer which supplied the sludge

The collated results required to be made available to a governing body would ideally relate to:

1. The location of the land receiving sludge
2. Sludge treatment, quantity and quality
3. Soil quality

The frequency of monitoring sludge **quantity** depends on the amounts applied to land units (each location), totalled over each year followed for example by the EPA (Alabaster and LeBlanc, 2008). Thus ideally, records need to be kept of sludge quantity per land unit and per unit time and this is specified in Directive 86/278/EEC. Amounts of sludge need to be recorded in metres cubed per year (total and amount to agriculture) and if possible metres cubed per land unit.

Table 11 Operational sludge data

Record	**Total produced**	**Quantity to agriculture**	**Quantity to land unit**
Units	m^3 per year	m^3 per year	m^3 per land unit per year

Data quality will depend on following standard procedures of measurement, sampling and analysis, and once more, observing the correct frequency of the analyses to be carried out.

11.1 Sludge analysis

Sludge quality will reflect original inputs to sewers and so variability can be assessed taking into account this background. Also subsequent quality will affect efficient treatment process operation. Knowledge of inputs of synthetic organic compounds and other undesirable contaminants can signal seeking specialist advice before use in agriculture (CoGAP, 2009).

Table 12 Sludge quality parameters

Parameter	**Dry matter (DM)**	**Organic matter**	**pH**	**Nitrogen and Phosphorus**	**Heavy Metals (6+)**
Units	% (w/w)	% of DM	'Units'	mg kg^{-1} DM	mg kg^{-1} DM

Parameters currently covered by directive 86/278/EEC are as above, where the heavy metals are; Cd, Cu, Hg, Ni, Pb and Zn. In the UK, further detail on crop nutrient analyses is advisory, for example total nitrogen and total phosphorus and, ammoniacal nitrogen (CoGAP, 2009). Also additional metals are currently included in UK guidelines; Cr, Mo, Se and As, and fluoride. All these additional parameters would be expressed as concentration in the sludge dry matter (mg kg^{-1} DM).

Limit values for the amounts of heavy metals (seven, as above) which may be added annually to agricultural land, based on a 10-year average (kg ha^{-1} yr^{-1}) are given in directive 86/278/EEC in annex 1C. These additions of metal have to be estimated from the sludge quantities and sludge metal analyses.

The frequency of analysis of the parameters in Table 12 above is recommended every six months for the provisions of the directive 86/278/EEC, but more frequently if sludge is found to be particularly variable and, only annually if it is thought consistent over a full year. However, consideration of the size of the waste water treatment plant is also made when deciding on frequency of analysis (CEC, 2006). Because it has been shown that sludge quality varies widely even on a daily basis, it is imperative that the adopted sampling procedure be validated by experimentation and that the sample error be established (Beckett, 1980).

11.2 Soil analysis

For sludge recycled to agricultural land from small sewage treatment plants (< 300 kg BOD/day, equivalent to 5000 population) designed primarily for the treatment of domestic waste water, soil analysis is **not** required according to Directive 86/278/EEC. When sludge is from plants larger than this soil should be analysed prior to the use of sludge and, at a suitable frequency thereafter to prevent soil metal concentrations from being exceeded. Currently only soil metals and pH are included as limit values in soil receiving sludge in the Directive 86/278/EEC. Heavy metals included are; Cd, Cu, Hg, Ni, Pb and Zn, as for sludge analysis. Soil pH is also recorded as this is related to the limit values for concentrations of heavy metal in soil.

Table 13 Soil Quality parameters

Parameter	**pH**	**Cd**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**
Units	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM	mg kg^{-1} DM

11.3 Sampling and analysis methods

In the UK both sampling and analytical methods are specifically listed from those by the Standing Committee of Analysts: Methods for the Examination of Waters and Associated Materials, in the code of good agricultural practice (CoGAP 2009). In Directive 86/278/EEC, only brief details of soil and sludge sampling are given, and it is recommended simply that strong acid digestion followed by atomic absorption spectrometry are used for analysis of heavy metals in sludge and soil. Since then the Comité Européen de Normalisation (CEN) have published national standards for sludge characterisation through their technical committee; TC 308 and these would be best to follow for sludges. Relevant examples of the CEN published methods for sludges are given in Table 14 below.

Table 14 CEN/TC 308 - Sludge analyses selected published standards

Standard reference	Title	Citation in OJ	Directive
CR 13097:2001	Characterization of sludges - Good practice for utilisation in agriculture	No	-
EN 12176:1998	Characterization of sludge - Determination of pH-value	No	-
EN 12879:2000	Characterization of sludges - Determination of the loss on ignition of dry mass	No	-
EN 12880:2000	Characterization of sludges - Determination of dry residue and water content	No	-
EN 13342:2000	Characterization of sludges - Determination of Kjeldahl nitrogen	No	-
EN 13346:2000	Characterization of sludges - Determination of trace elements and phosphorus - Aqua regia extraction methods	No	-
EN 14671:2006	Characterization of sludges - Pre-treatment for the determination of extractable ammonia using 2 mol/l potassium chloride	No	-
EN 14672:2005	Characterization of sludges - Determination of total phosphorus	No	86/278/EEC
EN ISO 5667-13:1997	Water quality - Sampling - Part 13: Guidance on sampling of sludges from sewage and water treatment works (ISO 5667-13:1997)	No	

Note: selected from list published on CEN website:
http://www.cen.eu/cenorm/sectors/sectors/environment/tcs/index.asp

In the full list of published standards for sludge characterisation on the CEN website, standards for microbial analyses are also included. Also included in Table 13 is a standard on sampling of sludges from sewage and water treatment works.

Soil analyses methods are under development by CEN but none are yet published covering the relevant parameters. Methods for the standard six heavy metals in soil (total by aqua-regia strong acid) are in practice broadly the same as those for sludges.

Representative soil samples are described in Directive 86/278/EEC as samples made up by mixing together 25 core samples taken over an area not exceeding 5 hectares which is farmed for the same purpose. In UK methods it is also recommended that the 25 samples are taken in a 'W' pattern over the field (Standing Committee of Analysts, 1986).

The directive designates soil samples are to be taken to a depth of 25 cm, (or less when the surface soil is below this but not less than 10 cm). In the UK, however, a plough depth of 20 cm is typical for arable land, hence soil sampling to 15 cm is recommended, to avoid edge effects (UN 2008 pp344) and, if land is under permanent or semi-permanent grass soils are sampled to 7.5 cm.

Detailed quality assurance procedures on reporting are now being followed by many of the UK water companies in line with those recommended by Water UK (Water UK, 2004).

12 Summary of areas of uncertainty and knowledge gaps

12.1 Sludge production and management and quality in the EU

Although it is expected that sludge production in the EU27 will continue to increase as population grow and the new Member States continue to implement the UWWT Directive towards 2010, there is no guarantee that all countries will be fully complying by that time. There is also a noticeable trend in some Member States which have high level of connection and treatment of sludge quantities decreasing. The reasons for this will need to be further investigated as this could add uncertainties to our future sludge estimates.

Although overall it is predicted that 50 % of sludge is likely to be recycled to land, there are uncertainties about the future sustainability of this outlet due to public opinion and the competition for land with other organic wastes. The main alternative to landspreading is likely to continue to be incineration with energy recovery for sludge produced at sites where land suitable for recycling is unavailable. Sludge management may continue to vary widely between Member States according to their particular circumstances. A number of other important factors which could influence sludge management in the future need to be evaluated.

Developments in sludge treatment will continue and there may be move towards enhanced treatment for sludge going to land so that the product to be recycled is effectively odour and pathogen free. The subject of future trends will be considered further in the next stage of reporting for this project (Section 3).

The concentrations of metals in sewage sludge in Western Europe have significantly been reduced since mid 80's as a combination between increased management of industrial effluents and a reduction of heavy industrial production. The extent of further reductions is unclear, although the range of loadings may be significantly different between different parts of the EU (including new Member states).

12.2 EU legislation, other EU acquis and Member State controls on the use of sludge on land

Directive 86/278/EEC could be said to have stood the test of time in that sludge recycling has expanded without environmental problems arising since it was adopted. However, several Member States have adopted stricter requirements since. Moreover, EC legislation has evolved in many related fields, such as chemicals regulation. Any revision should aim to retain the flexibility of the original Directive which has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the EU.

12.3 Economics of sludge treatment and disposal.

The baseline and future analysis of sludge management must take account of costs, and information in Section 3 provides the basis to do this.

12.4 Agricultural value of sewage sludge.

Application of sewage sludge to land provides positive agricultural benefit. Demand for sewage sludge in agriculture and for other land uses would undoubtedly be enhanced if it was clearly recognised as a product instead of a waste, and if it were accepted as being suitable for use in organic farming and other organic growing practices. However, a watching brief needs to be kept on P in soils receiving sludge and more information obtained about the accumulation and fate of P in soils.

12.5 Potentially toxic elements

Consideration needs to be given to adjusting the maximum permissible soil metal limits in Directive 86/278/EEC for cadmium and zinc in soil and for lead in sludge.

12.6 Organic contaminants (OCs)

Directive 86/278/EEC does not include specific limits for organic contaminants. Some Member States have set limits for OC groups, while others have not. In summary, the reviews of the research on OCs in sludge conducted so far have concluded that they are unlikely to have an adverse effect on human health and will be increasingly controlled by regulation. However, contaminants such as DEHP and chlorinated paraffins, found in sludge at higher levels will need to be further assessed. Further vigilance is also required on contaminants such as pharmaceuticals, where the potential fate and behaviour in waste water, sludge and soil is unclear at present.

12.7 Pathogens, treatment of sludge and land use practices

There is scope to update the controls set out in 86/278/EEC as regards the use of untreated sludge on the land, through the introduction of microbiological standards related to degree of sludge treatment. Such an update should take into account new developments in quality control of sludge treatment processes (such as HACCP) and in the safe management of sludge on the land.

Alist of 13 areas of uncertainty about pathogens is identified in paragraph 6.3.5

12.8 Water and air pollution

The principles for water pollution control set out in Directive 86/278/EEC remain sound; nonetheless, a revision could take account of the development in EC water pollution control legislation (notably the Nitrates Directive 91/676/ EEC and Water Framework Directive 2000/60/EC). A revision of the Directive might also call for guidelines for land use practices where sludge is used on the land. In both cases, one area for emphasis should be the controls of nitrogen and phosphorus. Apart from nutrients, sewage sludge is an organic manure with a significant chemical oxygen demand (COD) and which contains enteric microorganisms – this further underlines the need to manage sludge recycling operations so that runoff into surface water in particular is avoided. A revision of the Directive could draw on the operational guidance on landspreading of sewage sludge prepared in some Member States as well as more general national guidance on good agricultural practice.

While the emphasis of control on water pollution where sludge is used on land lies with management of N and P, PTEs, organic micropollutants and pathogens have also been investigated in this context especially as regards leaching into groundwater. A watching brief needs to be kept on leaching of persistent organic micropollutants from sludge-treated soil.

Odours – see stakeholder interests below

12.9 Greenhouse_gas emissions and carbon footprint

The information presented in this report provides the basis for quantifying these factors for different sludge treatment and disposal options as part of their overall environmental assessment.

12.10 Stakeholder_interests and public perception

Ten principal stakeholder groups have been identified and their interests listed.

For the general public, there is a strong sensitivity to odour nuisance from sewage treatment works and from sludge recycling operations in the field. Every effort must be made to avoid odour nuisance and the negative public response which can escalate to threaten the recycling outlet at least on a local basis.

Farmers' customers, food processors and retailers may also be affected by a perception that the use of sewage sludge could lead to environmental and health concerns. There should be no problem here so long as regulations and guidelines for sludge recycling have been followed on the farm and the recycling operation is seen to be entirely 'safe'. A problem can arise if the processor/retailer perceives that the acceptance of products may be jeopardised if customers are aware that they have been grown on land treated with sewage sludge.

12.11 Monitoring, record keeping and reporting

The requirements in this area included in Directive 86/278/EEC need to be updated with particular reference to the Standards prepared by CENT C/308.

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