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

Draft Summary Report 2
Baseline Scenario, Analysis of Risk and Opportunities

This report has been prepared by Milieu Ltd, WRc, and RPA for the European Commission, DG Environment under Study Contract DG ENV.G.4/ETU/2008/0076r. The primary author was Bob David. Additional expertise was provided by Anne Gendebien, Rod Palfrey and Judith Middleton

The views expressed herein are those of the consultants alone and do not necessarily represent the official views of the European Commission.

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Executive Summary

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

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

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

This is the second deliverable of the study: the first was a review of literature on the topic, *Assessment of existing knowledge*. The aim of this second report is to develop a baseline scenario to 2020 concerning the spreading of sewage sludge on land and to analyse the relevant risks and opportunities. This report provides information to establish a baseline scenario under which Directive 86/278/EEC remains in place and is not revised.

This study has used existing sources of data as well as forecasts. On this basis, it can be broadly estimated that as compliance with the UWWT Directive is achieved, total sludge generation in the EU15 may increase from 2005 to 2020 by about 20% to 10.4 Mt DS; and for the EU12, by approximately 100% to 2.5 Mt DS. Thus, the total for EU sludge generation in 2020 will be approximately 12.9 Mt DS per annum, compared with 10 Mt DS in 2005, an overall increase of 2.9 Mt DS per annum or about 30%.

From the data on sludge disposal and recycling in the Member States, the proportion of sludge recycled to agriculture has not altered significantly since 1995, remaining at around 40 – 50%. The situation in some Member States has changed; the Netherlands, for example, no longer recycles sludge to land, while the UK and some other Member States have increased the amount of sludge to land. It seems reasonably likely that by 2020 the overall recycling figure for the EU15 will remain at around 40 - 50% and that the EU12 – where overall sludge recycling to land is currently lower – will move towards this value as the UWWT Directive is implemented and the disposal to landfills is phased out. The main alternative to recycling to land will be thermal treatment.

The report considers the expected impacts of current EU legislation, such as the Nitrates Directive, the Water Framework Directive, as well as that of the new renewable energy goals.

The report assesses future trends and future risks and opportunities which are relevant to revision of Directive 86/278/EEC. The areas considered are: sludge production, sludge quality (agricultural value; potentially toxic elements; organic contaminants; pathogenic micro-organisms); sludge treatment, land restrictions; other routes and other factors which have an impact on the outlet such as greenhouse gas emissions and carbon footprint; stakeholder interests and public perception.

This report is presented as a draft for comments on the part of Member States, stakeholders and researchers as part of the first consultation for the study. For this reason, a total of 28 questions are interspersed through the main sections of the report. These request further data as well as opinions and suggestions for individual topic areas.

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List of abbreviations

BOD, BOD5	Biochemical Oxygen Demand; a measure of the nutrient load in a sample of sewage; commonly taken as 60g/pe/d
DM	Dry matter, or dry solids, or total solids
DS	Dry solids, dry matter, total solids
HACCP	Hazard Analysis and Critical Control Point
IPPC	Integrated Pollution Prevention and Control
MS	Member State of the European Union
MSW	Municipal solid waste
OC	Organic contaminant
PAH	Polycyclic aromatic hydrocarbons
pe	population equivalent; often taken as equal to a BOD load of 60g/pe/d, or for sewage sludge dry solids, 55g – 70g / pe / day.
PTEs	Potentially Toxic Elements; refers to heavy metals
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
TS	Total Solids, dry matter, dry solids; mass of material remaining after drying for 14 hours at 105°C
UWWTD	Urban Wastewater Treatment Directive
WFD	Water Framework Directive
WWTP	Wastewater treatment plant

1 Introduction

Although it could be said that the Sludge Directive 86/278/EEC has permitted sludge recycling to operate effectively across the wide range of agricultural and other environmental conditions found within the expanded EU, since its adoption, the situation in the EU has since changed substantially and all these changes must be considered.

Several Member States have adopted stricter requirements than the 86/278 Directive, new research findings in the field have been published, 12 new Member States with specific sludge management practices have joined the EU, technological progress has been made and new EC regulatory orientations (e.g. in wastewater, waste, soil, emission controls and energy policy, etc.) which have various impacts on sludge production and management, have been or are being implemented. Moreover, several Community legislative requests have been made to the Commission to revise this Directive; the Thematic Soil Strategy and the waste prevention and recycling Strategy.

This is the second deliverable of the study on “Environmental, economic and social impacts of the use of sewage sludge on land” for the European Commission (DG Environment). This assessment will build on the existing studies and knowledge (see report 1) and fill any identified knowledge and data gaps in order to provide a full picture of the current situation and the future needs.

The aim of the report is to develop the baseline scenario and the analysis of future risks and opportunities. It aims to prepare a debate on the possible need for future policy action, seeking views on how to improve sludge land recycling management in line with the waste hierarchy, possible economic, social and environmental gains, as well as the most efficient policy instruments to reach this objective.

From the baseline scenario, an assessment will be undertaken of the likely benefits and costs of additional or changed policy measures on the recycling of sewage sludge to agriculture in the EU when compared to the existing and planned policies. The assessment will find if the current policy measures are sufficient to address the issue of proper sewage sludge recycling to agricultural land and whether additional measures on sludge management would deliver significant improvements. The final set of options to be assessed will be based on the results of the baseline scenario and analysis of risks and opportunities as well as those from the consultation.

It is clear that there are data gaps and uncertainties with regards to sewage sludge recycling options, highlighted throughout the report. The Commission would therefore like to invite all Stakeholders to provide any data available to facilitate the subsequent Impact Assessment of different revision options. We have also included directed questions in sections throughout this document. We will invite stakeholders to contribute their knowledge and views on this assessment via a web consultation.

2 Baseline scenario

If no changes are implemented to the current Sewage Sludge Directive, the foreseen changes over the next 10 years due to other Community legislation and policies mentioned below will possibly affect the sewage sludge recycling route in terms of:

- Quantity and quality of sludge generated.
- Sludge treatment requirements.
- Restrictions for application of sewage sludge on soil and
- Monitoring and control requirements.

The baseline or "business as usual" scenario acts as the reference against which the other scenarios are compared. It is therefore the scenario that would emerge if the Directive 86/278/EEC was not revised and was still in force during the considered period of time. Hence, the necessity of considering a baseline scenario that accurately reflects current trends in technical progress, public behaviour, and regulatory policies.

The general objective of the baseline scenario is to provide an appropriate assessment of policies and practices across the EU over the next 10 years (2010 and 2020) and their possible implications on the production and treatment of sewage sludge and recycling to land for each Member State and at EU27 level.

2.1 Sludge quantities

The sludge quantities produced are directly linked to the volume and characteristics of wastewater treated which is dependant on the rate of wastewater collection, type of treatment, size of population connected and type of industries connected.

Sludge production is mainly linked to the following factors:

- size of the population,
- rate of population connected to public sewer system;
- level of wastewater treatment (no treatment, primary, secondary or tertiary treatment),
- type of sludge treatments applied; and
- size and number of industries connected to sewerage system.

2.1.1 Regulatory framework

The 91/271 UWWT Directive has had and will have a direct impact on sludge production in the EU in the next 15 years as it continues to drive the investment in wastewater collection and treatment capacities in the EU. In the EU15, the time schedules for achieving the environmental objectives of the UWWT Directive were phased (1998 – 2000 –2005), depending on the characteristics of the affected waters and the size of the wastewater pollution load ('agglomeration'). As for the new Member States in Central and Eastern Europe and the Mediterranean, interim targets and staged transition periods were allowed which should not be later than 2015 (2019 for Romania) (Table 1).

Table 1 Transitional periods for the implementation of UWWT Directive in EU 12

Member State	Final deadline
Bulgaria	31 Dec 2014
Cyprus	31 Dec 2012
Czech republic	31 Dec 2010
Estonia	31 Dec 2010
Hungary	31 Dec 2015
Latvia	31 Dec 2015
Lithuania	31 Dec 2009
Malta	31 Dec 2006
Poland	31 Dec 2015
Romania	31 Dec 2018
Slovakia	31 Dec 2015
Slovenia	31 Dec 2015

The latest available information (for 2003) on the implementation of the Urban Waste Water Treatment (UWWT) Directive can be found on http://ec.europa.eu/environment/water/water-framework/implrep2007/index_en.htm (CEC, 2008). Preliminary reports on the latest figures (end of 2005) have recently been made available. Unfortunately there is not a comprehensive picture of the implementation as only 18 Member States have provided information in time (10 out of the EU15 and 8 out of the EU12).

By 1 January 2003, overall, 81.4% of total reported load (470 million pe) for EU15 was treated to the required level of treatment as defined by the UWWT Directive. At the end of 2005, development of collecting systems had made good progress but there were still differences between Member States regarding compliance with secondary treatment. Most of the 18 Member States have reported a rate of collecting systems above 95% of total load. Overall, the pollution load for these 18 Member States amounted to 313 million pe from 13,734 agglomerations above 2000 pe. Collection systems were in place for 93% of the total load. Secondary treatment was in place for 87% of the load. More stringent treatment is used for 72% of the load.

For the previous reporting period, Denmark, Germany and Austria had recorded high levels of compliance of close to 100%, closely followed by the Netherlands (90%) with an only slightly less ambitious record, while the implementation across the other Member States is less successful and still represents a major challenge (Figure 1). In Denmark, Germany, and Sweden the majority of the population is connected to wastewater treatment works with tertiary treatment (EEA 2005).

For the new Member States, the investment programme is on-going and is not expected to be completed before 2015 (2019 for Romania). According to EEA reports (EEA 2005, EEA 2009), in Malta, almost 90% of population has no treatment of their wastewater. More than 65% of the population in the Czech Republic, Estonia, Latvia and Lithuania are connected to wastewater treatment, and roughly half of the wastewater treated undergoes tertiary treatment. For Poland and Hungary around 60% of the population are connected to wastewater treatment systems. In Poland about half of the connected wastewater is given tertiary treatment, whereas in Hungary only 10% gets tertiary treatment. The lowest connection rate is found in Slovenia, where almost 70% of the population are not connected to wastewater treatment systems. For Slovakia there is no detailed information on treatment type available. In Bulgaria and Romania, only around 40% of the population are connected to wastewater treatment, with most of the connected wastewater receiving primary or secondary treatment but with no tertiary treatment.

Although all EU15 countries should have been complying with all the requirements of the Directive by the end of 2005, this was not the case. Although there are uncertainties regarding the delay and level of compliance achieved for the 27 EU Member States over the next 15 years, for the baseline scenario, we have assumed that, by 2020, all Member States of the EU27 should have completed their obligations under the UWWT Directive. We have assumed that by 2010, the EU15 would have achieved full compliance as well as Czech Republic, Estonia, Lithuania and Malta. For the other EU12, the level of compliance would not have changed from 2006.

Table 2 below shows the number of agglomerations in the EU27 and the generated load discharge (CEC 2006). Figure 1 shows the percentage conformity for the EU15 states. Based on our assumptions regarding compliance with the UWWT in the different Member States, by 2020, a total of 671 million pe for EU27 will be discharged and treated in wastewater treatment plants.

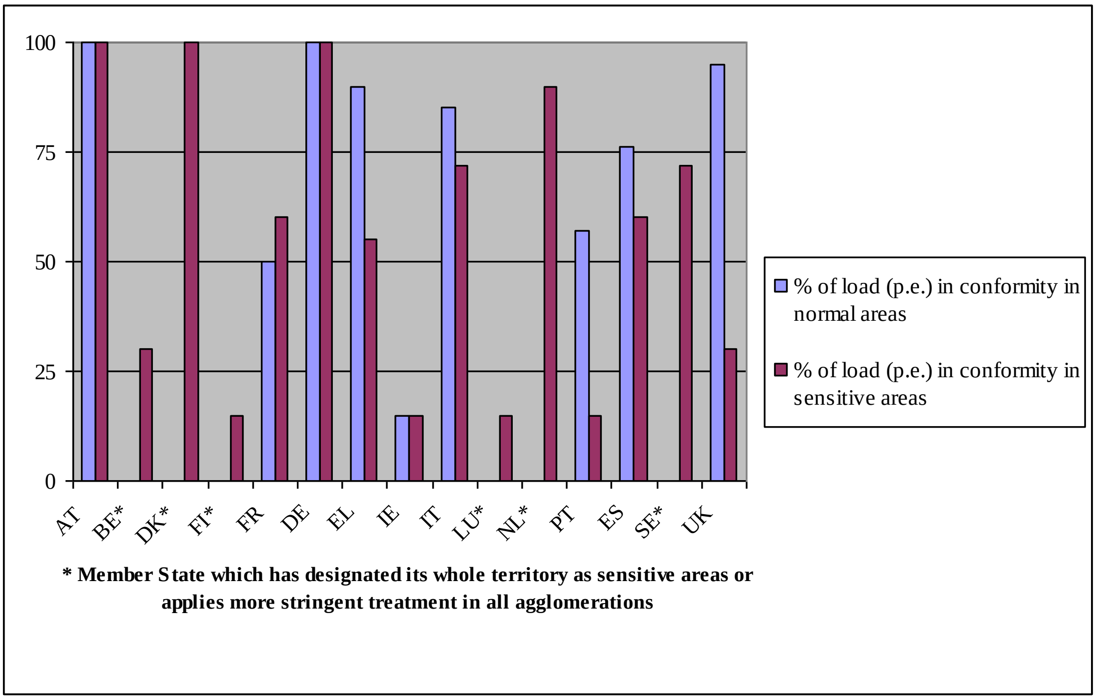

Figure 1 **Compliance with treatment level by EU15 Member States (as reported by 1/01/2003) (CEC 2007)**

	Agglomerations (having the load of more than 2,000pe) to which the Directive applies		Agglomerations >10000 pe discharging to sensitive areas and >15000 pe discharging to normal areas		Agglomerations 2000-10,000 and number of agglomerations >10,000 pe discharging to normal areas		Big cities / big dischargers (having generated pollution load of more than 150,000 pe)	
	Number	**Load (million pe)**	**Number**	**Load (million pe)**	**Number**	**Load (million pe)**	**Number**	**Load (million pe)**
EU15	31374	550	8500	476	22874	74	556	252
EU10	3348	85	1103	73	2254	12	98	39
EU2	2903	36	367	22	2536	14	0	0
Total EU27	**37625**	**671**	**9970**	**571**	**27664**	**100**	**654**	**291**

Table 2 **Total number of agglomerations in EU27 and total generated organic pollution load discharged (CEC 2006).**

2.1.2 Size of population

A factor to take into account for estimating future sludge quantities is the population growth. The EU population growth is currently 0.4% per year (CEC 2008). For the baseline scenario, we have assumed that there would be no new accession between 2010 and 2020.

The current population growth is positive in some of the old EU15 Member States (Ireland close to 3%, Spain, Cyprus, Luxembourg, over 1%), while in Germany there has been a recent slight decline in population, a pattern that is reported to be common for most of the new Member States like Bulgaria, the Baltic States, Romania, Hungary, Poland and Croatia.

Figures from CEC (2008) show that from around 2010 onwards, the population is expected to decline for the European Union as a whole and that by the year 2050 the population of the European Union is expected to have declined from its current 493 million inhabitants (2007) to 472 millions. The Eurostat projections (Table 3), on the other hand show future population for the EU27 increasing to about 500 millions by 2010 and to 514 millions by 2020.

Table 3 Population projection for 2010 and 2020 (Eurostat 2009)

Member State	**2010**	**2020**
Austria	8,404,899	8,723,363
Belgium	10,783,738	11,321,733
Denmark	5,512,296	5,661,099
Finland	5,337,461	5,500,929
France	62,582,650	65,606,558
Germany	82,144,902	81,471,598
Greece	11,306,765	11,555,829
Ireland	4,614,218	5,404,231
Italy	60,017,346	61,420,962
Luxembourg	494,153	551,045
Netherlands	16,503,473	16,895,747
Portugal	10,723,195	11,108,159
Spain	46,673,372	51,108,563
Sweden	9,305,631	9,852,965
United Kingdom	61,983,950	65,683,056
EU15	***396,388,049***	***411,867,857***
Bulgaria	7,564,300	7,187,743
Cyprus	820,709	954,522
Czech Republic	10,394,112	10,543,351
Estonia	1,333,210	1,310,993
Hungary	10,023,453	9,892,967
Latvia	2,247,275	2,151,445
Lithuania	3,337,008	3,219,837
Malta	413,542	427,045
Poland	38,092,173	37,959,838
Romania	21,333,838	20,833,786
Slovakia	5,407,491	5,432,265
Slovenia	2,034,220	2,058,003
EU12	***103,001,331***	***101,971,795***
EU27	**499,389,380**	**513,837,632**

2.1.3 Domestic connection rate

Wastewater pollution load and thus sludge production is directly linked to the proportion of inhabitants connected to wastewater treatment plants. Following the implementation of the UWWT Directive which requires the collection of wastewater from all agglomerations above 2000 pe, the current rate of connection is steadily increasing across the EU.

From the latest available information, at the end of 2005, developments of collecting systems have made good progress but there are still differences between Member States regarding compliance with secondary treatment. Most of the 18 Member States have reported a rate of collecting systems above 95% of total load apart from, in decreasing order: Lithuania (93%), Estonia (89%), Hungary (80%), Slovakia (76%), Slovenia (73%), Cyprus (49%), and Romania (47%). No information was submitted by Bulgaria, Czech Republic, Greece, Ireland, Italy, Latvia, Malta, Poland, Spain, and the UK.

Although some Member States will not reach 100% coverage, for our baseline scenario we have considered that by 2010, EU15 will be fully connected to sewage collection systems and that by 2020, the whole of the EU27 will have achieved full coverage.

2.1.4 Industrial connection rate and level of pre-treatment

Industrial and trade effluents discharging to municipal sewer systems also contribute to pollution load and sludge production at municipal wastewater treatment plants (see below). The ratio between the total pollution load in influent of a treatment plant expressed in population equivalent (pe) and the number of inhabitants ranges from 1 (small communities without industry) to more than 2 (larger cities).

Industries connected to municipal sewers contribute to sewage sludge production in the following ways:

- Untreated industrial effluent permitted under a trade effluent licence;
- Treated effluent which may not be treated to sufficient standard for discharge to a surface water and still contain degradable material or separable suspended solids;
- Treated effluent with waste sludge from the treatment process combined together in a discharge to sewer;
- Combination of liquids and solids transported separately but to be treated as part of the municipal sewage treatment processes.

In Austria (Alabaster and LeBlanc, 2008) the actual BOD5 load to all Austrian treatment plants is, on average, ~2 pe/capita. Figures from other Member States have not been thoroughly investigated and this could be clarified during the consultation period.

We have considered that the contribution of industries to sludge solids production will not change from 2005 till 2020, as a result of opposing effects that include the following factors:.

- Industrial production is expected to grow due to economic growth which will increase liquid and solid effluents.
- Quantities discharged by industry will decrease due to process improvement and pollution prevention;
- The rate of industries with strong wastewaters connected to the sewer may decrease, due to increasing industrial onsite wastewater treatments. Sludge produced from some of these processes may be managed as a separate material.

2.1.5 Level of treatment

The type of wastewater treatment influences sludge production. However it is difficult to predict such changes at Member State level as these will be highly dependant on local situations at each plant. Works that are required to achieve reduced effluent phosphorus concentrations, for example, may see an increase or a decrease in amount of sludge production. Biological P removal may result in slightly lower rates of sludge production rate due to biomass recycle and longer retention times while chemical P removal may result in up to 65% more secondary sludge produced. For N removal, there is a likely reduction in sludge production due to the installation of long sludge age systems, or no change, unless separate denitrification processes are required driven by addition of other chemicals.

Sludge stabilisation processes also have an impact on the ultimate sludge quantities to be disposed of. The most recently constructed sludge treatment processes that involve anaerobic digestion have been designed to achieve increased conversion of volatile solids to biogas. The increase from 45% volatile solids destruction to 55% volatile solids destruction could lead to a reduction in sludge production by 10% to 15% at a single works, or if all works in the country were modified or replaced to achieve the same extent of conversion.

No attempt has been made at this time to closely model the forms of sludge treatment used in each country as the combinations of sewage and sludge treatment processes lead to a very wide variety of possible scenarios.

2.1.6 Sludge production trends

Sludge production rate per capita is considered to be a good indicator for future sludge estimates at Member State level. However, current sludge production per capita shown in Table 4 varies greatly across countries. Countries that have the most comprehensive infrastructure and treatment technologies (e.g. secondary and tertiary treatments) produce the largest mass of sewage sludge per person. Countries which have less developed wastewater treatment infrastructure and collect and treat wastewater from lower percentages of their populations produce less sewage sludge per person on a national level. The proportion of industrial discharges to municipal sewer influence the sludge production rate by increasing the relative sludge production per capita.

For our baseline scenario, we have considered that sludge production will increase and be stabilised once the UWWT Directive is fully implemented. We have considered that full implementation of UWWT across all of the 27 Member States will be achieved by 2020.

The sludge production per capita in the complying countries (i.e. Austria, Denmark and Germany) should be a good indicator of the maximum sludge quantities that can be expected when a Member State will be in compliance with the UWWT Directive. Per capita, sludge production in these countries ranges from 23 to 29 kg/person per year. Thus an average 25 kg per capita per year is a good estimate for maximum sludge production rate.

Thus for our baseline scenario we have considered that, by 2020, sludge production per capita across the 27 EU Member States will reach at least 25 kg per capita per year. This value has been used for estimating future sludge production in Member States which currently have lower sludge production rates. For countries with higher rates, future sludge production rates have been estimated using these higher values.

Table 4 Current annual sludge production (period 2004-2006) and production rate per capita in the EU27

Member State	Year data recorded	Sludge production (t DS / year)	Population [a] ($x10^6$)	Sludge production (kg DS /capita)
Austria	2005	238,100/ 420,000 [b]	8.3	29/ 50 [b]
Belgium				
• Wallonia	2003	23,520	3.4	7
• Flemish	2005	76,254	6.1	13
Denmark	2002	140,021	5.5	25
Finland	2005	147,000	5.2	28
France	2002	910,255	64.4	14
Germany	2006	2,059,351	82.2	25
Greece	2006	125,977	11.1	11
Ireland	2003	42,147	4.5	9
Italy	2006	1,070,080	59.6	18
Luxembourg	2003	7,750	0.48	16
Netherlands	2003	550,000	16.5	33
Portugal	2002	408,710	10.6	38
Spain	2006	1,064,972	46	23
Sweden	2006	210,000	9.2	23
United Kingdom	2006	1,544,919	61	25
Sub-total EU15		***8,786,569***	***394***	***22***
Bulgaria	2006	29,987	7.6	4
Cyprus	2006	7,586	0.77	10
Czech republic	2006	220,700	10.3	21
Estonia	2006	nd	1.3	?
Hungary	2006	128,380	10	13
Latvia	2006	23,942	2.3	10
Lithuania	2006	71,252	3.4	21
Malta		nd	0.4	
Poland	2006	523,674	38.1	14
Romania	2006	137,145	21.5	6
Slovakia	2006	54,780	5.4	10
Slovenia	2006	19,434	2	10
Sub-total for EU12		***1,216,880***	***103***	***12***
Total		**10,003,449**	**497**	**20**

Notes:

a) Based on data from national Statistical offices. Depending on Member States, reference year is mainly 2007 or 2008 with a few figures for 2006

b) without/with industrial discharges especially from cellulose and paper industry

Questions for the consultation

If you disagree with our assumptions on per capita sludge production rate for your country please provide corrections and if possible explain the reasons using the following supporting questions.

Q1 – What are the special reasons in your country that result in a reported sludge production rate of less than 23kg/pe/year or greater than 28 kg/pe/year?

Q2 - What change in the rate of sludge production do you expect will take place up to 2020?

Q3 - Why would any change in the reported rates of sludge production per person take place?

Q4 – What proportion of total sewage sludge reported here is due to industrial sources in your country? Is this expected to change, and to what proportion?

Although, it may not be the case, for our baseline scenario, by 2010, we have considered that compliance with the UWWT Directive should have been achieved in all EU15 and in 4 of the EU12, i.e. Czech Republic, Estonia, Lithuania and Malta. For the remaining EU12, sludge production in the baseline year of 2010 will remain the same as reported for 2006 and that by 2020, full compliance with the UWWT Directive will be achieved across the EU27. Unless recent figures (calculated after 2005) on future sludge production have been found in the literature, future sludge production quantities have been calculated using the 25 kg/capita per year figure or greater if reported in Table 4 and population projection in Table 3.

Table 5 Future forecasted (2010 and 2020) sludge quantities arisings in the EU27

Member State	**2010 (x10^3 tds pa)**	**2020 (x10^3tds pa)**
Austria	270	280
Belgium	170	170
Denmark	140	140
Finland	155	155
France	1,600	1,600
Germany	2,000	2,000
Greece	260	260
Ireland	135	135
Italy	1,500	1,500
Luxembourg	10	10
Netherlands	560	560
Portugal	420	420
Spain	1,280	1,280
Sweden	250	250
United Kingdom	1640	1,640
EU15	***10,393***	***10,400***
Bulgaria	47	180
Cyprus	8	16
Czech Republic	264	264
Estonia	33	33
Hungary	175	200
Latvia	25	50
Lithuania	80	80
Malta	10	10
Poland	520	950
Romania	165	520
Slovakia	55	135
Slovenia	40	50
EU12	***1,418***	***2,484***
EU27	**11,811**	**12,884**
Note: As working estimates 2010 production rates have been taken to be the same as 2020 production for states expected to be in full compliance in 2010. For non-compliant states a rounded 2006 production rates have been used – see text in Annex 2 for detail		

Future sludge production has been estimated to increase by approximately:

- For the EU15 - 20% to 10.4 Mt DS by 2020, and
- For the EU12 - 100% to 2.5 Mt DS by 2020.

This gives a grand total for EU27 sludge production by 2020 of approximately 13 Mt DS per annum, compared with 12.0 Mt DS in 2010, an overall increase of about 30% compared with 2006 (Table 5 above). Figure 2 (below) presents the past and future trends for sludge production in the EU15 and EU12.

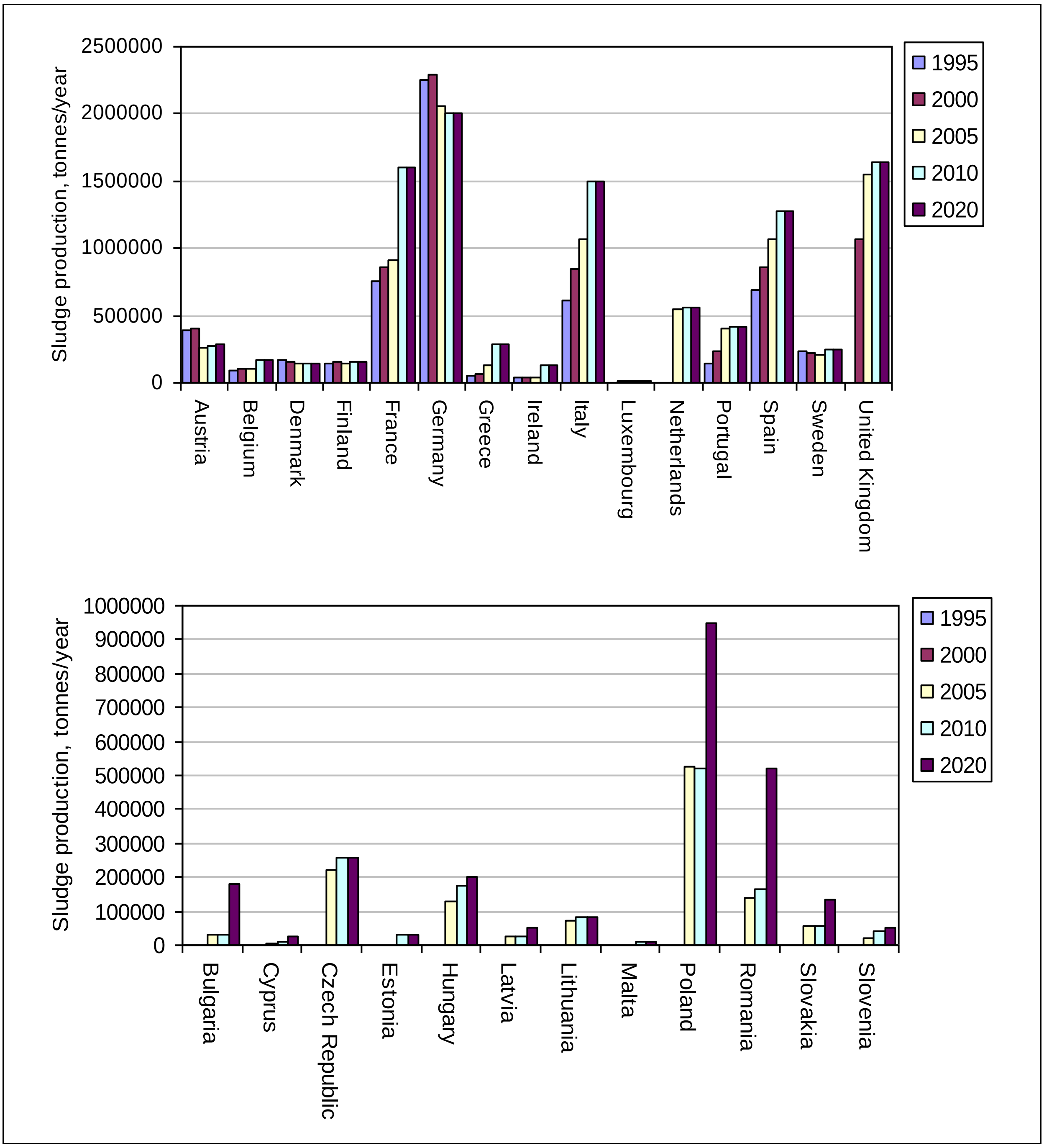

Figure 2 Past and future trends in sludge production in the EU15 and EU12 sludge production case studies

Sludge estimates in Austria and Slovenia

Austria (Doujak, 2007) is already in line with the UWWT Directive requirements with about 1,500 municipal sewage treatment plants collecting wastewater from about 90% of a population of 8.2 million for a territory of 84,000 km^2. Municipal sludge production amounts to 266,000 tds pa; 47% are thermally treated; 18% recycled to agriculture; 1% sent to landfill and 34% to other outlets including composting (77%), landscaping (12%) and unknown (data for 2005). The connection rate to sewer and treatment plant is forecast to be 92% of population by 2010 and sludge production to amount to 273,000 t DM and to stabilise to a maximum of 94% by 2015/2020 with a total municipal sludge production of 280,000 tds – 100% coverage is not foreseen. In 2015/2020, the outlets for municipal sewage sludge are forecast to be: 5% going to agriculture, 10% to be treated by bio-mechanical treatment and 85% to be treated thermally.

Slovenia is reported to struggle to implement EU environmental legislation on wastewater treatment (Slokar, 2006). Slovenia's two million people live in 6,000 settlements, scattered over 20,000 km^2. About 53% of population is connected to about 200 municipal WWTPs while 42% of the population rely on septic tanks. Nevertheless, it is reported that when work on wastewater treatment plants for the country's three largest cities are completed, 60% of the nation's settlements will be compliant with the UWWTD. Sludge production amounts to 30,000 tds (2005 data). Although sludge was recycled in the past in agriculture; after 2002, the quantities decreased down to 1% due to the quality of the sludge and most sludge is landfilled. By 2010, with the construction of 50 new WWTPs, sludge production is forecast to amount to 40,000 tds. Thermal treatment will be the preferred option.

The values in Table 5 forecast that each country will produce sludge at a rate at least equal to 25 kg/pe/year even if not currently doing so as treatment works develop to meet current frequently applied requirements. These include a small proportion of works with sewage effluent quality requirements that include restrictions on phosphorus and nitrogen concentrations. No adjustment has been made to these data to apply more detailed analysis of the likely increase in works that are required to achieve reduced effluent phosphorus concentrations and do so by using chemical treatments. These works would significantly increase the amount of sludge production from the combination of the chemical treatment and the associated requirement for low effluent suspended solids concentrations.

The sludge production values are the reported values of treated sludge, but before any conversion to ash through incineration or sludge powered generators. No attempt has been made at this time to closely model the forms of sludge treatment used in each country as the combinations of sewage and sludge treatment processes lead to a very wide variety of possible scenarios.

Two case studies from Austria and from Slovenia illustrate the disparity in meeting the EC requirements and thus the uncertainties in future forecasted sludge production (see box above).

Questions for the consultation

In assessing the likely amount of sludge production in 2020 the effect of the WFD and the UWWTD must be considered with respect to nutrient removal processes used in sewage treatment. Biological nutrient removal (N and P) which can meet requirements for total N<10mg/l and P < 2mg/l may have little impact on sludge production dependant on requirements for imported additional substrates, but use of chemical P removal to enable reliable enhanced P removal may increase whole works sludge production by 30% or more. This assumes current common technologies, and does not take into account any future off-line sludge processing to extract nutrients.

Q5 – What proportion of your country is likely to have sewage effluent consents for:

- Total Nitrogen
- Phosphorus.

Q6 – What are the likely consent values?

- Total Nitrogen < 15mg/l – for what population
- Total N < 10 mg/l, P < 2mg/l – for what population
- Total N < 10mg/l, P < 1mg/l – for what population
- Total N < 10 mg/l, P < 0.2mg/l – for what population

Q7 – What other combinations of consents may have significant impact on treatment processes?

Q8 – How will these consents be achieved?

- Biological nitrogen removal
- Tertiary nitrogen removal using chemical addition (methanol)
- Biological nitrogen and phosphorus removal
- Chemical phosphorus removal
- Combination of chemical and biological removal
- Other likely common process combination

2.2 Sludge disposal routes

The main factors in decision-making for selecting a disposal route for sewage sludge are transportation cost, PTEs concentration in sludge, and landfill capacity. Furthermore, the efficiency and cost of dewatering and drying are important for each disposal option. In addition to the factors mentioned above, EU and national regulation is an important factor as it can impose stricter limits values precluding its use in agriculture. Another important factor is public confidence.

Other factors which can also affect the decision in this field are concerns about global warming and the focus on energy efficiency and sustainability at wastewater treatment and wastewater sludge management facilities driven by energy prices.

Which approach prevails in any given region seems to be best predicted by the following factors:

1. population density;
2. availability of agricultural land; and
3. local social, political – and thus regulatory requirements.

2.2.1 Regulatory framework

Although, the Sludge Directive only concerns sewage sludge used in agriculture, this cannot be looked at in isolation of the other routes. For example, existing legal requirements on landfilling, thermal treatment as well as alternative energy production, by restricting or encouraging one outlet can have an indirect impact on sewage sludge recycled to land. In addition, other sources of sludge, food waste, organic fractions of municipal waste, might compete for available land and thus restrict the amount of sewage sludge which is recycled to land in the future.

If the Directive 86/278/EEC is not revised, some Member States may change their national legislation in the future – several have indicated that they would like to do so and some have already published draft proposals (for example, Germany) and/or introduced their own national voluntary guidelines to supplement the Directive (for example, The UK Sludge Safe Matrix).

It seems unlikely that if sewage sludge use is banned already, and consequently alternate routes have been found, that there would be a reversal unless sludge could be beneficially mixed with other organic wastes (to improve for example the conditioning properties) and processed using a high quality treatment (negligible pathogens, no smell) then the zero use could be reversed to a limited extent.

We have considered the baseline scenario as the current regulatory situation in each Member State regarding sludge recycled to agriculture/land. No other safe prediction can be made regarding possible developments of national legislation in the coming years.

The Community regulatory framework on waste management and energy is impacting on sludge management. Community waste policy applies a five-step waste management hierarchy as a priority order. The highest priority is given to waste prevention, followed by preparation for reuse, recycling, other recovery and disposal. Recycling to land of sewage sludge fits within the highest priority and is thus supported by the EC waste regulatory framework.

EC controls on landfills are reducing and restricting the proportion biodegradable waste (including sewage sludge) disposed into landfills. This potentially creates a desire to recycle more sludge to land and/or to improve or change treatment of sludge. Treatment and disposal methods that stabilise and reduce solids mass and volume will be encouraged, especially with energy recovery; these include thermal decomposition processes.

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

Facilities in which biological treatment takes place will have to comply with higher standards through the upcoming review of the IPPC Directive.

The Thematic Strategy on Soil addresses the wider subject of carbon depletion in soil and how to avoid and remedy it. This will take into account the potential of using compost as a means to increase the carbon content of soil.

A summary of drivers that may affect the disposal of sludge is shown below with a judgement of the importance of each driver in either promoting use or restricting the use of sewage sludge on land.

Technical issues will continue to require research, and best management practices for sludge management will continue to evolve. For example, the potential for excessive phosphorus to be applied to soils through sludge and animal manures may require application of developing technologies for removal of phosphorus. Likewise, current issues about trace chemical contaminants in sludge used on soils will continue to require support for research and analysis of risks.

Driver	Expected consequences	Potential influence on use of sludge on land	Overall Importance
EC Landfill Directive	• Reduction of biodegradable fraction in landfill • Increased treatment of sludge (i.e. composting) • Increase diversion of sludge to land • Increased diversion of sludge to incineration	Uncertain (Both positive and negative)	High
Incineration Directive	• Regulates emission limit values for selected potential contaminants (e.g. NOx, SOx, HCl, particulates, heavy metals and dioxins), • indirect improvement of sludge quality	Positive	Low
IPPC Directive	• Permits for biological treatment of organic waste (if pre-treatment before disposal) (i.e. composting capacity and of anaerobic digestion)	Negative	Medium
Renewable energy Directive	• By 2020, 20% share of energy from renewable sources • Incentives for the use of renewable energy sources such as biogas from sewage sludge.	Positive	Medium
Waste Directive	• Recycling has priority over energy • End of waste status for compost	Positive	Medium
Decision 2006/799/EC – eco-label requirements for soil improvers – sewage sludge not eligible	• Increased competition with alternate improvers that meet eco-label criteria • Sludge users not currently demanding additional quality standard • Reduces prospect of promoting sewage sludge as a beneficial product	Negative	Low – no significant demand for eco-label sludge
Decision 2007/64/EC – revised eco-label requirements for growing media – sewage sludge not eligible	• Sewage sludge not used currently to any significant extent as a growing media • Eliminates opportunity of promoting co-digested or co-composted materials	Negative	Low
Environmental Liability Directive 2004/35/EC	• In countries that adopt a strict liability regime for the use of sewage sludge on land, this might a) somewhat encourage the use of sewage sludge; and b) where used, encourage a preference for sludge treated to higher standards.	Negative	Low

Questions for the consultation

If you disagree with our judgements on regulatory influences on agricultural recycling please provide us with corrections and if possible explain the reasons using the following questions.

Q9 – In your country, what are the special conditions that encourage or discourage the amount of agricultural recycling?

Q10 – What change do you expect to take place in the rate of agricultural recycling by 2020?

Q11 – How will the existing regulations noted above affect your recycling and other disposal routes?

Q12 – Will the Nitrate Directive and the WFD have a significant effect on restricting or reducing the availability of land for agricultural recycling of sewage sludge? How much of an effect?

2.2.2 Population density and land availability

Population density and the availability of agricultural lands for sludge recycling to land will continue to be an important factor influencing policy decisions on sludge management. Indeed, these factors interact with social and political factors.

Even though most Member States hypothetically would only need to utilize less than 5% of their agricultural area to apply all of sludge produced, there still needs to be a relatively high level of acceptance by farmers and public for this outlet to be sustainable.

A simple view of the opportunity for using agricultural land for recycling sewage sludge is shown in Figure 3. The amounts of sludge produced and the amounts that are recycled to agriculture have been normalised to the total ‘utilisable’ agricultural land. This shows distinct differences between Member States, with the Netherlands having the smallest ‘utilisable’ area compared to the amount of sludge production. In general the EU12 have greater opportunities for recycling to agriculture.

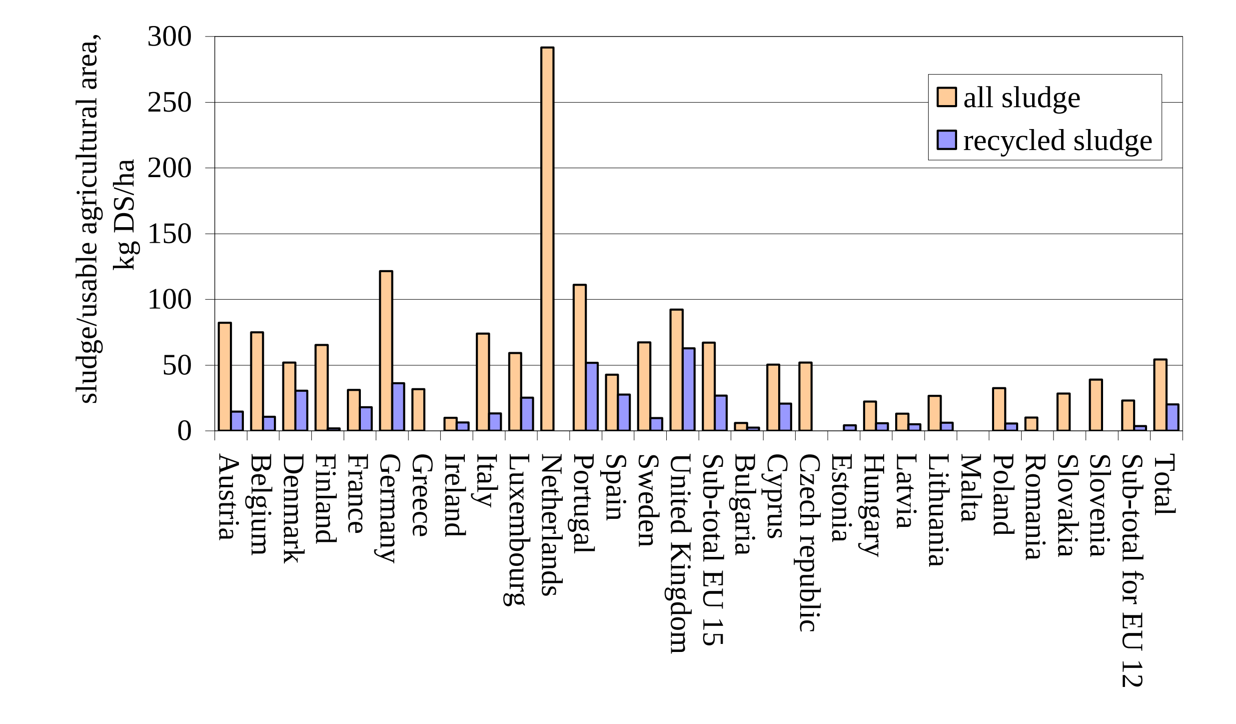

Figure 3 Comparing sludge arisings and extent of agricultural land: Total arisings and sewage sludge recycling to land per hectare of available agricultural land[1]

This approach does not take account of other recycling that may be taking place, such as the use of animal manure, which represents an alternative to sewage sludge and reduces the amount of available land for the latter. Nor does it take account of the different nature of farming across different countries: sewage sludge may be less suitable for some uses than for others.

In northern Europe, some of the most densely populated countries as well as regions (notably Netherlands; as well as Vienna and many cities in Germany) rely almost entirely on incineration as they have limited available agricultural land for the spreading of sludge.

2.2.3 Incineration as an alternative

Concerns have also been expressed about contaminants in sludge applied to soils. While scientific studies have not indicated major concerns, the future development of public opinion in this area is uncertain. These issues are addressed further in section 2.7.

A further influence will be the potential attraction of incineration of sewage sludge as an alternative, in particular as a potential source of renewable energy.

It can be noted that in general sewage sludge incineration occurs in large cities, but large cities do not always rely on incineration and some prefer recycling to land. However, as technology advances and population densities increase, a country may move toward more incineration for sludge management. This shift is advancing more quickly now, because of the higher costs of fossil fuel energy as well as European policy goals calling for the increased use of renewable energy.

Whether this trend toward incineration will continue is uncertain. Some studies have found incineration of sewage sludge to be much more costly in terms of total life cycle analysis,

[1] Data for utilisable agricultural land from: www.ec.europa.eu/agriculture/agrista/2008/table_en/2012.pdf

economically and environmentally – including impacts on greenhouse gas emissions. In contrast, the most sustainable option has been assessed to be treatment by anaerobic digestion followed by some form of use on soils that offsets fertilizer use, such as composting. It is very important that these decisions take full account at each individual location of all factors including land availability, transport requirements, energy recovery and greenhouse gas emissions.

Some policy makers consider incineration to be a second choice to the recycling of sludge to land. However, negative public perceptions of sludge use on land may direct the political decision in favour of incineration.

2.2.4 Past, current and future trends in sludge treatment and disposal options

In 2008, sludge recycling to agriculture appears to be the dominant management option across the EU27 and is growing in the some of the new Member States (for example, Bulgaria). Many are developing sludge recycling programmes, and this option is expected to substantially replace landfill in the coming years. Figure 4 presents overall trends in management routes for the EU15, EU12 and overall EU members. Figure 5 presents past and future trends in terms of member country sludge recycling to agriculture in the EU15 and EU12.

The two most common treatments prior to sludge applications to agriculture seem to be anaerobic digestion and lime stabilization. In some of the old Member States (EU15), land application of raw and/or limited treated sludge is diminishing and composting and other treated products are increasingly used. There is also an increase of advanced treated sludge to be used in non-agricultural applications.

In many countries, corn is the crop most likely to receive sludge, but vineyards, orchards, grains, and other crops are also fertilized with sludge. Most countries discourage or prohibit the use of sludge on food crops destined for direct human consumption, and, if allowed, there are prescribed waiting periods between applications of sludge and harvesting of crops.

Most of the sludge used in domestic, horticultural, and green space (landscaping, parks, sports fields) is composted; some is heat-dried (for example, heat-dried pellet fertilizer).

Sludge is also used as a soil improver on degraded soils at mine sites, construction sites, and other disturbed areas such as in Portugal (Duarte) where sludge has been used for stabilising soils after forest fires. However, use of sludge in forests is relatively uncommon or even prohibited in some Member States.

Most Member States are, in general, moving away from landfilling to recycling sludge to land and/or – to a lesser extent – incineration with some recovery of energy.

Some (for example, Germany) have diversified outlets, with growing reliance on incineration with energy recovery (sludge powered generators) while some countries are committed to single options (for example, Netherlands relies almost entirely on incineration or Romania on landfilling). Norway implements the Sewage Sludge Directive as an EEA country, and it has followed a path that combines extensive use of sewage sludge on land, high environmental standards and public acceptance (see box)

Sewage sludge recycling in Norway

Norway recycles the majority of sludge to land. The reasons for successfully achieving this high level of recycling with public acceptance are many but include:

- stringent standards for the content of heavy metals (stricter than the EU standards) and pathogens, and
- high priority given to control of the odour nuisance.

This requires sanitation systems that keep significant levels of toxic elements (heavy metals) and chemicals (POPs, PPCPs, etc.) out of wastewater and thus sludge. It requires industrial and commercial pre-treatment programmes, stringent regulatory controls that encourage the recycling to soils of high-quality sludge and other organic residuals in integrated, nutrient management systems.

The level of public understanding and support is a major determinant in whether or not a country recycles significant portions of its wastewater sludge to soils. Therefore, public consultations, local demonstration projects, with the involvement of diverse stakeholders, to show the benefits of sludge recycling to land, and information to political leaders, regulators, and the public are important.

Finally, the development of products (other than soil amendments) from sewage sludge continues to be explored. Incinerator ash and melted slag are being used more in construction materials (mostly cement) and there are some examples of extracting phosphorus (P) from wastewater sludge and distributing it as fertilizer. But the complex technologies and operational costs required to extract or produce products from sewage sludge continue to be less cost efficient in comparison to the traditional, proven options such as recycling to land, incineration, and landfilling.

In comparison, there are relatively few EU15 countries – notably Austria, the Flemish region of Belgium and Germany – that are currently moving away from sludge recycling to land. Together with the Netherlands, they are moving toward more incineration with a focus on energy recovery. On the other hand, some cities are focusing on increasing methane gas production from anaerobic digestion, because of the energy benefits and climate change focus.

Although the proportion of sludge recycled to agriculture has not altered overall since 1995, at around 40 – 50%, the situation in some Member States has dramatically changed. Thus the overall recycling average of 40% of sewage sludge obscures substantial differences between Member States (see Annex 2). These trends have been used to predict future trends in sludge recycling to land in the different Member States. Table 6 summarises past trends regarding sludge recycled to land in the EU based on figures reported to the Commission between 1995-2006. Some of the main changes include:

- In Italy, in the mid 1990's, experts were predicting that incineration was going to increase; this did not happen and today, composting is on the increase.
- In the Netherlands, in 1996, 11% of wastewater sludge was recycled in agriculture and 82% was disposed in landfills while currently, most of the sewage sludge is sent to incinerators inside the country or in Germany, some of it after composting or heat drying.
- In Bulgaria, in 1996, all the sewage sludge was sent to landfill. New national regulations should lead to a high level of land application and a reduction in landfilling.

Table 6 Past trends (1995-2006) in sludge recycling to agriculture and current (2006) level of recycling in the EU27

Increasing (current %)	Status quo [1)] (current %)	Diminishing[2)] (current %)	Already very little use[3)]
United Kingdom (70%)	Sweden (10%)	Italy (18%)	Netherlands
Spain (65%)	France (60%)	Finland (3%)	Flemish Region [4)] (Belgium) (3%)
Ireland (63%)	Norway (~95%)	Austria (10%)	
Latvia (37%)	Denmark (50%)	Germany (30%)	Greece
Portugal (46%)	Walloon Region (50%)	Czech Republic (12%)	Slovenia
Bulgaria (40%)	Lithuania (25%)	Slovakia (0% but 61 % being composted)	Romania
Estonia	Poland (17%)	Cyprus (40%)	Malta
	Luxembourg	Hungary (26%)	

Note:
1) Although the quantities recycled to land have decreased over the years, the level seems to have stabilised in the last 3 years.
2) Although quantities recycled to agriculture are reported to have decreased over the years, for some of these Member States this masks the fact that sludge is still used on land but there has been a shift towards composting followed by recycling to agriculture and/or to other land uses
3) Although for some of these Member States (i.e. Netherlands and Flemish Region) recycling to land is definitely no longer an option while for some it may well become a sustainable outlet (i.e. Romania).
4) Although for the latest reported year (2006) 3% was still recycled to land, there was indication that no more sludge would be recycled to land in the following years.

The future trends in sludge management for most of the Member States are detailed in Annex 2, together with Table 8 and Table 9 that summarise sludge management routes for each country and the EU15, EU12 and EU27 groups. The trends for the EU15, EU12 and EU27 groups for the agriculture, incineration (or thermal treatments), landfill, and other routes (including land recovery, compost production) are shown in Figure 4 with additional details for the agricultural route for individual countries shown in Figure 5.

The overall trends for the EU27 are summarised below:

- Continued increased level of sewer connection and wastewater treatment across the EU27 which means more sewage sludge being produced which will need proper management.
- Increased treatment of sludge before recycling to land through anaerobic digestion and other biological treatments, like composting. The use of raw sludge will no longer be acceptable.
- Potential increased restrictions on types of crops being allowed to receive treated sludge.
- Enhanced production and utilisation of biogas. For example, trials with anaerobic co-digestion of wastewater sludge and MSW have proved to produce increased volumes of methane and to improve the quality of the wastewater sludge in Italy, Norway and Slovenia. Another technique is lysis and thermophilic anaerobic digestion as tested in the Czech Republic.
- Production of alcohols and other fuels directly from sewage sludge using pyrolysis and gasification.
- Similar proportion of treated sludge recycled to agriculture at around 40-50% by 2020. The situation in the existing 15 Member States should not change dramatically over the next 5 years. There are some indications in the new Member States which have no previous experience in this sludge management route that agriculture recycling may become a more significant outlet in the future.
- Phasing out sludge being sent to landfill due to EC restrictions on organic waste going to landfill and increased dislike by the public of use of landfill disposal. The most likely change will be for Member States which currently rely heavily on landfill as sludge disposal options –

these quantities will be diminishing over the next 15 years. By 2010, in these Member States, the proportion of sludge going to landfill will be lower than currently reported, and we have assumed that by 2020 there will be no significant amounts of sludge regularly going to landfill in the EU27.

- The main alternative to landspreading is likely to continue to be incineration with energy recovery for sludge produced at sites where land suitable for recycling is unavailable.
- Co-treatment of sewage sludge with a variety of other imported organic materials, particularly with reference to digestion processes, is currently not generally carried out, for reasons that include regulatory constraints. There are potential advantages of co-treatment in terms of asset utilisation (access to energy conversion systems, utilisation of existing infrastructure).
- Where population densities make it more difficult to recycle to land and/or where animal manures are over-abundant, increased treatment of sludge with energy recovery through anaerobic digestion, incineration or other thermal treatment, with recycling of the ash.
- Increased application of sludge to fuel crops such as miscanthus, hybrid poplars and other non-food energy crops.
- Increased industrial water pre-treatment and pollution prevention, reducing or eliminating discharge of toxic substances (heavy metals, chemicals) and improving sludge quality.
- Introduction of semi-voluntary and voluntary quality management programs such as the ones in place in England and Sweden to increase the safety of sludge use on food chain crops.
- Increased attention to climate change and mitigation of greenhouse gas emissions and thus recognised additional benefits of sludge applications to soils.
- Increased attention to recovery of organic nutrients, including those in sludge.

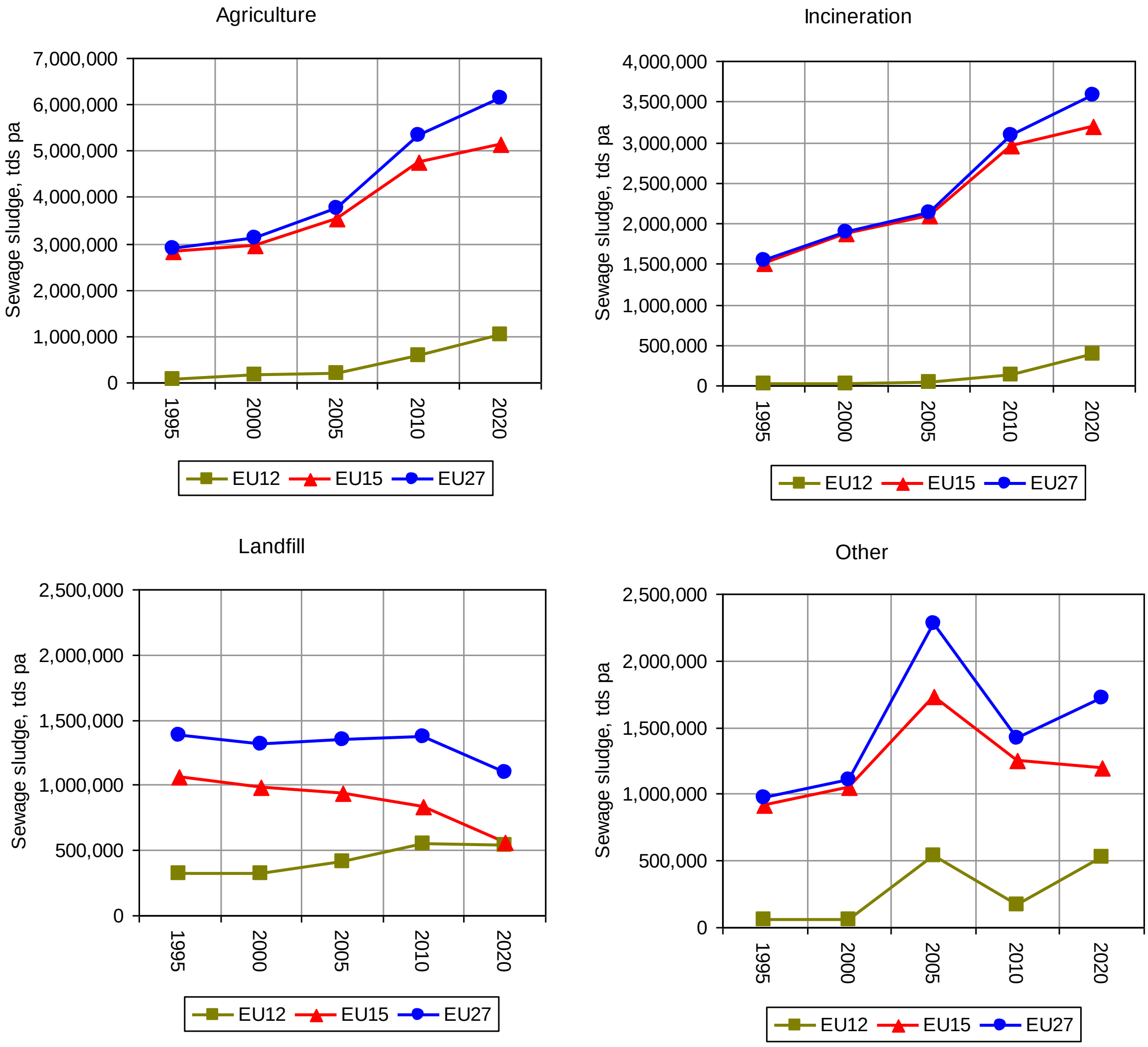

Figure 4 Main routes for sewage sludge recycling and disposal in the EU

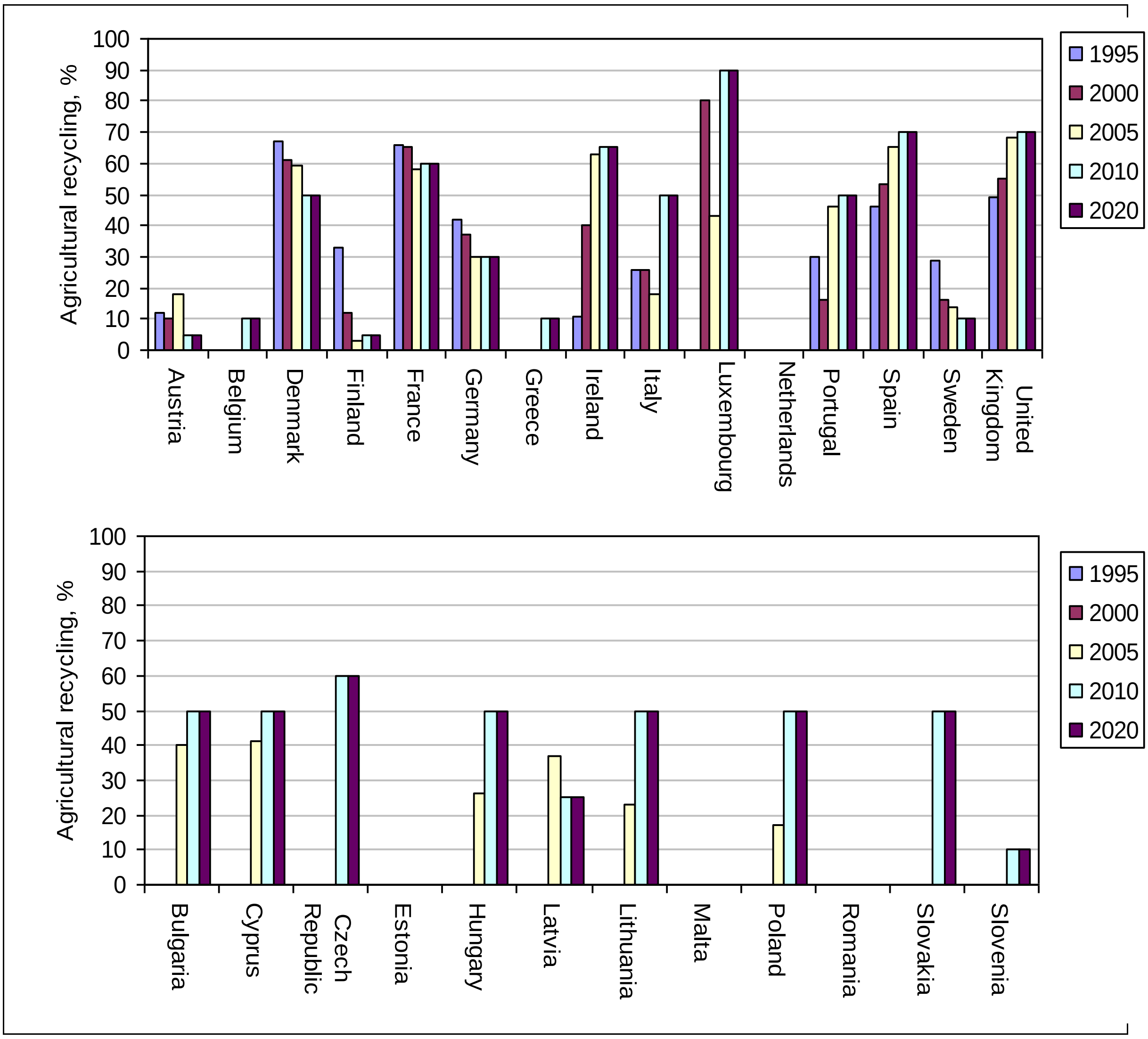

Figure 5 **Past and Future trends for sludge recycling to agriculture in the EU15 and EU12**

2.3 Sludge quality

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

As new and existing environmental legislation at Community level is implemented (for example, REACH), it should also have a positive impact on the quality of sludge as better understanding and reduced use of hazardous substances is encouraged and better controls on environmental emissions are implemented.

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants.

It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertilizer. A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology. This has however not been covered in detail country by country but will be further researched during the consultation. It can be noted that in general sewage sludge incineration occurs in large cities, but large cities do not always rely on incineration and some prefer recycling to land. However, as technology advances and population densities increase, a country may move toward more incineration for sludge management. This shift is advancing more quickly now, because of the current increases in costs of fossil fuel energy.

2.3.1 Regulatory framework

A summary of drivers that may affect the quality of sewage sludge is shown below with a judgement of the importance of each driver.

Driver	Consequence	Potential influence on use of sludge on land	Importance
EC Regulation 1907/2006 – REACH regulations	• Reduction in poorly degradable chemicals in sludge • Increased confidence in sludge composition; improved acceptability	Positive	Medium
EC Regulation 466/2001 – foodstuff contaminants limits, including cadmium to be as low as reasonably achievable	• Sludges that contain measurable trace metals may be increasingly difficult to use on agricultural land • Increased landbank required to manage metal rich sludges • Diversion of metal rich sludges to thermal processes or investment in metal removal processes	Negative – EU15 mostly low Cadmium contents; some high contents in individual EU12 countries	Low
Decision 2006/799/EC – eco-label requirements for soil improvers – sewage sludge not eligible	• Increased competition with alternate improvers that meet eco-label criteria • Sludge users not currently demanding additional quality standard • Reduces prospect of promoting sewage sludge as a beneficial product	Negative	Low – no significant demand for eco-label sludge
Decision 2007/64/EC – revised eco-label requirements for growing media – sewage sludge not eligible	• Sewage sludge not used currently to any significant extent as a growing media • Eliminates opportunity of promoting co-digested or co-composted materials	Negative	Low
Monitoring of organic contaminants in sewage and sewage sludges	• Public perception that sludges may contain substances with adverse effects on health drives unacceptability of agricultural use	Negative	Medium
Water Framework Directive 2000/60/EC – enhanced nutrient removal requirements	• Increased phosphorus concentrations, may be linked to increased metals • Increased production	Negative	Low

Local controls on pathogen content	• Improved public acceptability defends and increases available landbank • Enhanced treatment reduces nuisance and so defends available landbank • Enhanced treatment can improve energy efficiency • Operating costs to customers increase	Positive – apart from operating cost negative	High
Compost standards – PAS 100	• Need to improve definition and quality standards of sewage sludges to compete with alternate materials	Negative	Low

2.3.2 Potentially toxic elements, PTEs

It has been confirmed by several studies (Sede and Andersen 2002, Smith 2008) that since the mid 1980's concentrations of heavy metals in sewage sludge have steadily declined in the EU15 (illustrated by figures for France, Austria, Germany and the UK) due to regulatory controls on the use and discharge of dangerous substances, voluntary agreements and improved industrial practices; all measures that lead to the cessation or phasing out of discharges, emissions and losses of these PTEs into wastewater and the wider environment.

The extent of further reductions is unclear. There is probably a minimum for PTE concentrations in sludge determined by diffuse inputs of PTEs to the sewer, which are less easily controlled. The range of loadings may be significantly different between different areas of the EU (including the new Member States). Indeed, Smith (2008) has pointed out that there remains further scope to reduce the concentrations of problematic contaminants, and PTEs in particular, in sludge. He suggests that this should continue to be a priority and pursued proactively by environmental regulators and the water industry as improving the chemical quality of sludge as far as practicable is central to ensuring the long-term sustainability of recycling sewage sludge in agriculture.

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

2.3.3 Organic contaminants

The presence of organic contaminants (OCs) in sludge has been increasingly considered and the list of potential contaminants that have been detected in sludge is now extensive and includes: products of incomplete combustion (polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and dioxins), solvents (e.g. chlorinated paraffins), flame retardants (e.g. polybrominated diphenyl ethers), plasticisers (e.g. phthalates), agricultural chemicals (e.g. pesticides), detergent residues (e.g. linear alkyl sulphonates, nonylphenol ethoxylates), pharmaceuticals and personal care products (e.g. antibiotics, endogenous and synthetic hormones, triclosan).

However, at present, only a few countries, such as France, Germany and Denmark, have set limits for some individual OCs in sludge, while others, such as UK, USA and Canada have not, citing that research suggests that concentration present in sludge are not hazardous to human health, the environment or soil quality. Agreement on which, if any, OCs should be regulated in Europe could be important when the Sludge Directive is considered for revision.

OCs are being increasingly monitored in both sewage treatment waters and sludge and environmental waters. Improving analytical methods mean that OCs can be detected at very low concentrations. This fact and new toxicological information on effects at low levels and possible synergistic effects of mixtures mean that the presence of OCs in sludge will be increasingly under scrutiny, although present research does not indicate a concern for human health.

Pharmaceuticals are one group of OCs being extensively monitored in the sewage treatment process. While they are normally present at extremely low levels, it is possible that rapidly increasing use of a drug in, for example, a pandemic flu epidemic, may lead to a high concentration at the sewage treatment works and its potential presence in sludge. This potential problem will need to be considered, preferably in advance of the problem occurring.

Other OCs which are continuing to cause concern as they are detected in environmental waters are endocrine disrupting chemicals, including natural and synthetic oestrogenic hormones, such as 17β-oestradiol and ethinyl oestradiol and much less potent industrial chemicals such as nonyl and octyl phenols and their ethoxylates, and phthalates. Oestrogenic substances do partition to particulates and may be associated with sludge. Better known OCs such as PAHS, dioxins, flame retardants and perfluorinated compounds (and their new alternatives as they are phased out) will continue to be studied while novel technology may lead to the emergence of new OCs or substances such as nanoparticles, which will require new methodology for the detection of their potential presence in sludge and assessment of their risk to human health, the environment and soil quality.

While concern over OCs in sludge will continue and probably increase as our ability to detect low levels and their effect also increases, it should be remembered that many potential contaminants are already controlled by legislation, such as the Water Framework Directive. Therefore, levels in sludge of these chemicals should already be decreasing. The new REACH regulations although not specifically concerning waste, will add to our knowledge of toxicity, use, exposure and disposal of a wide range of chemicals which can be of use in predicting potential presence in sludge. As this knowledge increases, emerging hazardous pollutants will also be controlled where necessary, although persistence in the environment may mean that it takes some time before concentrations in the environment are undetectable.

2.3.4 Nutrient value

The concentrations of nitrogen (N) and phosphorus (P) are the factors which determine the rate of application of sludge to the soil in most landspreading operations. This results from the need to comply with the Nitrates and Water Framework Directives (91/676/EEC and 2000/60/EC respectively). Changes in the N and P composition of sludge as a result of increasingly rigorous nutrient removal requirements from wastewater may become more significant. They are most likely to increase the P concentration of sludge. This may be linked to changes in the metal concentration of sludge if P-removal is carried out using metal salts (aluminium or iron).

2.3.5 Pathogens

The Sludge Directive provides no specific controls on pathogen content apart from the general requirement for treatment before use in agriculture. It permits implementation of local rules or codes of practice suitable for local conditions and circumstances. Treatment under the sludge directive requires biological, chemical or heat-treatment, long term storage and any other appropriate process to reduce fermentability and health hazards associated with its use.

Local controls which specify indicator pathogen limits in the sludge have been implemented in several of the EU15 countries. These have been driven by stakeholder demands (farmers, food retailers, public requirements). Associated with these developments have been demands to reduce nuisance, in particular, odour, and perceptions that aerosols may contain pathogens. To meet these requirements sludge producers have been installing new treatment processes that achieve more reliable and greater levels of pathogen destruction during treatment.

The installation of processes that recover greater fractions of the energy present in the sewage sludge is also a factor in the greater reduction of pathogens initially present in the sewage sludge.

There are no widely accepted newly present pathogens in sewage sludges. However, concerns are frequently raised regarding one or more pathogens that may be normally present, or present as a result of unusual levels of population infections.

It is likely that a combination of:

- Replacement and new sludge treatment equipment;
- Economic and environmental drivers that enhance energy recovery and efficient treatment;
- Public and agricultural products users pressure on producers;

will combine to continue to enhance the microbial quality of treated sludges, both in countries in which there are existing pathogen content controls and extend these to countries that have hitherto not had specific additional pathogen content controls.

Other materials are in competition with sewage sludge as beneficial fertilizers for agricultural use, including a variety of composted organic wastes. Increasingly these are also being made to standards, such as the UK PAS100 standard, that includes specifications for pathogens content in the compost.

Questions for consultation

If you disagree with our estimations and assumptions concerning your country please provide us with corrections and if possible explain the reasons, using the following supporting questions if they are applicable.

Q13 – In your country what are the most significant local restrictions on sewage sludge quality that affect the availability of land for sewage sludge recycling?

Q14 – What changes to local statutory or practice requirements do you expect up to 2020 (in terms of limits on quality, etc.)?

Q15 – To what extent do the current requirements in the EU sludge directive affect the availability of land for sludge recycling? To what extent are the requirements believed to be unsuited to current farming and public needs?

Q16 – In your country what changes to the concentrations of metals in sludges do you expect up to 2020?

Q17 – What changes to concentrations of the nutrients nitrogen and phosphorus do you expect up to 2020? Will changes to sewage effluent phosphorus concentration requirements affect the balance of nutrients in sewage sludge?

2.4 Sludge treatment requirements

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

2.4.1 Regulatory framework

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

These overall requirements have been interpreted and implemented within individual Member States differently, in part based on specific local conditions and circumstances. In general, untreated sludge is no longer applied and where it is to be used on land, it is usually stabilised by mesophilic anaerobic digestion, or aerobic digestion and then treated with polymers and mechanically dewatered using filter presses, vacuum filters or centrifuges. Other treatment processes for sludge going to land include long-term storage, conditioning with lime, thermal drying and composting.

A number of Member States have introduced stricter controls on sludge recycling to land than those required by Directive 86/278/EEC and this trend is likely to continue, in parallel with developments in sludge treatment process technology. For example, The Safe Sludge Matrix, agreed between the British Retail Consortium and the UK Water Companies, requires either conventionally treated or enhanced (or 'advanced') treated sludge be used on agricultural land. Conventional treatment requires that at least 99% of pathogens have been destroyed and enhanced treated sludge requires that it is free from *Salmonella* spp. and that there has been a 99.9999% reduction in *E.coli* as a surrogate for a range of other pathogens. Enhanced treatment processes produce residual sludges for recycling to land which are low in odour and sanitised. These advanced treatment sludges have the advantages that they cause much less odour nuisance during landspreading, and do introduce fewer pathogens into the agricultural environment – so public perception and acceptability problems are likely to be avoided.

A summary of drivers that may affect the quality of sewage sludge is shown below with a judgement of the importance of each driver.

Driver	**Consequence**	**Potential influence on use of sludge on land**	**Importance**
Directive 86/278/EEC – Sludge use on agriculture – requires treatment	• Sludge treatment methods must be installed and used	Positive; most sludge is already treated in most countries	Low
Proposed directive on promotion of renewable energy sources	• Would promote use of more efficient and complete energy recovery biogas production processes • May promote other sludge powered generation systems (thermal processes) •	Positive – treats sludge as a resource with value	Medium
Directive 2000/76/EC on incineration of waste	• Allows use of thermal processes when appropriate to meet publicly acceptable standards so maintaining range of treatment options	Positive	Low
Local use of HACCP procedures	• Enables claims of treatment quality standards to be defended • Identifies treatment critical points for efficient monitoring	Positive	Medium
Local rules on renewable energy obligations and uses	• Promotes treatment efficiency	Positive	Medium

2.4.2 Future treatment of sludge

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

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

A considerable amount of work is underway at research level, and with some individual treatment works on recovery of nutrients from sewage sludge. These are particularly linked to phosphorus, as complexes such as struvite, or in purified forms, but there are also methods to separate metals, such as iron from chemical P removal sludges, and to produce organic acids by fermentation to supplement biological nutrient removal plants. It is likely that sludges will increasingly be required to meet more rigorous compositional standards to justify their use as fertilizer.

When updating plants operators have the following factors foremost:

- Reducing sludge solids quantity;
- Increasing energy recovery;
- Meeting current standards (current regulation AND any additional code of practices);
- Minimising operating costs;
- Capital cost minimisation is required by operators or financial regulators.

Treatment processes are listed below and described in more detailed in Annex 1.

Current	**Proven new processes or variants being used to replace or supplement existing processes**	**Novel**
MAD – Mesophilic anaerobic digestion TD – Thermal destruction (normally now with energy recovery) Lime addition for stabilisation or pasteurisation Compost Aerobic or Thermophilic aerobic digestion Landfill Drying	THP – Thermal Hydrolysis Process APD – Acid phase digestion processes Co-digestion or co-composting with non-sludge organic materials Wet oxidation (after digestion)	Pyrolysis Gasification (Both of the above already exist but few installations)

Questions for consultation

We have made estimations of current and future sludge management routes in individual countries, shown in Table 8 and Table 9 in Annex 2. If you disagree with our estimates, or our judgment of influences of treatment and management processes in your country, please correct them, and if possible explain the reasons, using the following supporting questions.

Q18 – What are the proportions of your sludges that are treated with the following main processes:

- Anaerobic digestion
- Advanced anaerobic digestion
- Drying
- Lime treatment

Q19 – What are the proportions of sludge converted or disposed of using:

- Incineration
- Landfill
- Other thermal processes (gasification, pyrolysis, wet oxidation)

2.5 Restrictions for application of sewage sludge on soil

2.5.1 Regulatory framework

A summary of drivers that may affect the use of sludge for agricultural and soil improvement purposes is shown below with a judgement of the importance of each driver in either promoting use or restricting use of sewage sludge.

The Nitrates Directive could be a significant restricting factor locally for the application of sewage sludge to land in regions where nitrates vulnerable zones have been identified and intensive animal production zones. The rules for organic farming could also have a negative impact on the proportion of sludge recycled to land as in most Member States – organic farming labels implicitly or specifically mean that no sewage sludge is allowed to be recycled to land.

The other drivers may have an impact but it has been estimated that it would be low negative.

We have, however, not carried out a detailed analysis of the effect of this impact at this stage. This aspect will need to be discussed during the consultation period.

According to the latest implementation report (CEC 2007), during the period 2000-2003, progress has been made in nitrate vulnerable zone designation. Seven out of fifteen Member States took the option in the Nitrates Directive not to identify specific nitrate vulnerable zones, but to establish and apply an action programme through the whole territory. In addition to Austria, Denmark, Finland, Germany, Luxemburg and the Netherlands, Ireland established a whole territory approach in March 2003. Other Member States increased, in several cases substantially, the nitrate vulnerable zones since 1999: United Kingdom (from 2,4% to 32,8% of the territory), Spain (from 5% to 11%), Italy (from 2% to 6%), Sweden (from 9% to 15%), Belgium (from 5,8% to 24%). Motivation for increased designation was not always provided.

Overall, in EU15, designation of nitrate vulnerable zones increased from 35.5% of the territory at the end of 1999 to 44% at the end of 2003. From 2003 onwards further designations were made, in Italy, Spain, Portugal and United Kingdom, Northern Ireland. Belgium has established the procedure to increase its designation to include 42% of Wallonia territory and all Flanders

Driver	**Consequence**	**Potential influence on use of sludge on land**	**Importance**
Directive 91/676/EEC – Nitrates Directive	• Nitrate vulnerable zones limiting fertilizer application • Good agricultural practice required with particular care in the zones • Sludge cake may be more beneficial as nitrogen in slow release form	Negative	Medium
Council Regulation (EC) No 834/2007 on organic production and labelling of organic products	• No clear ban on organic labelling of sewage sludge • Member state practices generally do not accept sewage sludge as organic	Negative	Medium
EC Decisions 2006/799 and 2007/64 on criteria for the award of a Community eco-label to growing media	• Growing media containing sludge shall not be awarded an eco-label	Negative	Low
Soil protection – proposal for amending Directive 2004/35/EC	• Impacts of sludge recycling to land to be evaluated	Negative	Low
Directive 2003/87/EC on greenhouse gas emissions	• Impact on ammonia production	Positive	Low
The effort sharing Decision	• Recovery of biogas from sludge treatment	Positive	Low
Directive 2006/118/EC – groundwater protection against pollution and groundwater quality standards	• Spreading of sludge requires local rules • In some areas may require change in farming or forestry practice	Negative	Low
Directive 2008/105/EC – EQS for pollutants to achieve good surface water quality	• Local rules may be required either to control pollutants in the sludge or to control sludge distribution and incorporation in soil • Undefined sludge composition in competition with defined inorganic fertilizers	Negative	Low

2.5.2 Future land use restrictions

As Member States increase their designation of vulnerable zones, land application of sewage sludge will be more restricted in terms of loading rate and land available for application.

Questions for consultation

If you disagree with our judgements on the effects of regulatory requirements on sewage sludge agricultural recycling in your country please correct them, and provide explanations using the following questions if they are applicable.

Q20 – What are the likely impacts of the Nitrates Directives on the current sludge recycling proportion in your country? By how much?

Q 21 – What local codes of practice or other restrictions related to land use have the greatest impact on sludge recycling to agricultural land in your country?

Q22 – What changes in land use are likely to affect sewage sludge recycling?

Q23 – Will the lack of eco-label qualities (including organic farming) affect the use of sewage sludge in your country? By how much? Would other standards improve desirability?

2.6 Monitoring and control requirements

2.6.1 Regulatory framework

The existing Directive imposes periods of prohibition between sludge spreading and grazing or harvesting. These vary according to the Member State (EC 2006). In Ireland, Spain, Luxembourg, the Netherlands, Portugal and the United Kingdom, the provisions of the Directive apply: that is, sludge must be spread at least three weeks before grazing or harvesting and on soil in which fruit and vegetable crops are growing, or at least ten months for soils where fruit and vegetable crops that are eaten raw are cultivated in direct contact with soil. In the other Member States the rules are generally stricter than those provided for by the Directive. Some Member States ban the application of sludge on forestry or land recreation areas.

Some Member States have published specific Code of Good Agricultural practices for land application of sludge and have also introduced quality assurance systems (for example, HACCP, Hazard Analysis and Critical Control Point management). HACCP applies risk management and control procedures to manage and reduce potential risks to human health and the environment from agricultural application of sludge. It is designed to provide assurance that specified microbiological requirements are met and that risk management and reduction combined with appropriate quality assurance procedures are in place, thus preventing the use on farmland of sludge that does not comply with the microbiological standards.

2.6.2 Future monitoring and controls

Although there is no regulatory requirements, the use of quality assurance systems will be generalised on a voluntary basis mainly though the pressure from the food industry.

Questions for consultation

Q24 – Are further restrictions needed on types of crops and or specific land areas (i.e. forest) or longer harvesting intervals?

Q25 - Should formal risk management methods be consistent throughout the EU?

2.7 Other factors which could influence sludge recycling to land

A number of other factors which could influence sludge management in the future need to be further evaluated including their risks and opportunities for the recycling outlet. This will require further discussion with the Stakeholders during the consultation period. Some areas of uncertainties are listed below:

- Treatment technologies - Developments in sludge treatment will continue and there may be a move towards enhanced treatment for sludge going to land so that the product to be recycled is effectively odour and pathogen free.
- Another possible change is the opportunity to co- treat sludge with other materials such as municipal solid waste
- Public perceptions - Although overall it is predicted that 50 % of sludge is likely to be recycled to land, there are uncertainties about the future sustainability of this outlet due to public opinion and the competition for land with other organic wastes.
- Mineral fertilizers – sewage sludge represents only a very small amount of total nutrients spread on land, of which mineral fertilizers provide the largest share. The future demand and supply of mineral fertilizers could thus influence the use of sewage sludge..

Factor	Potential risk	Potential opportunity	Degree of uncertainty	Influence on future changes on spreading sewage sludge on land
Public opinion	Widespread rejection of sewage sludge use	Wider acceptance of land spreading as effective recycling	No major changes expected; but future opinion is uncertain	National level: stricter requirements or bans possible NGO and public opposition Farmers acceptance of sludge
Scientific research	Could identify new health risks. Ambiguous results could be interpreted as health risks	Could provide stronger evidence for a lack of health risks	No major changes expected	National level: stricter requirements or bans possible NGO and public opposition
Sludge treatment technology	Could be expensive compared with other outlets for sludge. Lower level of nutrients	Greatly reduced levels of odour and pathogens	Level of developments Proportion of sludge being treated	On the one hand, improve public acceptance; on the other, lower nutrient value
Mineral fertilizer	A fall in fertilizer prices could lead to lower demand for sludge.	Possible shortage of natural resources and higher prices could increase demand for sludge. Added conditioning value with sludge	Future availability	On a local basis only not nationally

2.7.1 Competition with inorganic fertilizers

In coming decades, global fertilizer consumption is predicted to increase steadily (see Figure 6). In industrialised countries such as the EU15, FAO forecasts that consumption will rise by about 20% from the late 1990s to 2030. Elsewhere, consumption will increase even higher. World fertilizer demand has been increasing to meet global plant nutrient requirements driven by a combination of population changes, increased crop production, and development of biofuel crops (Heffer and Prudhomme, 2008). The increased consumption has also been reported with forecast increases in consumption by the EEA and shown in Figure 6.

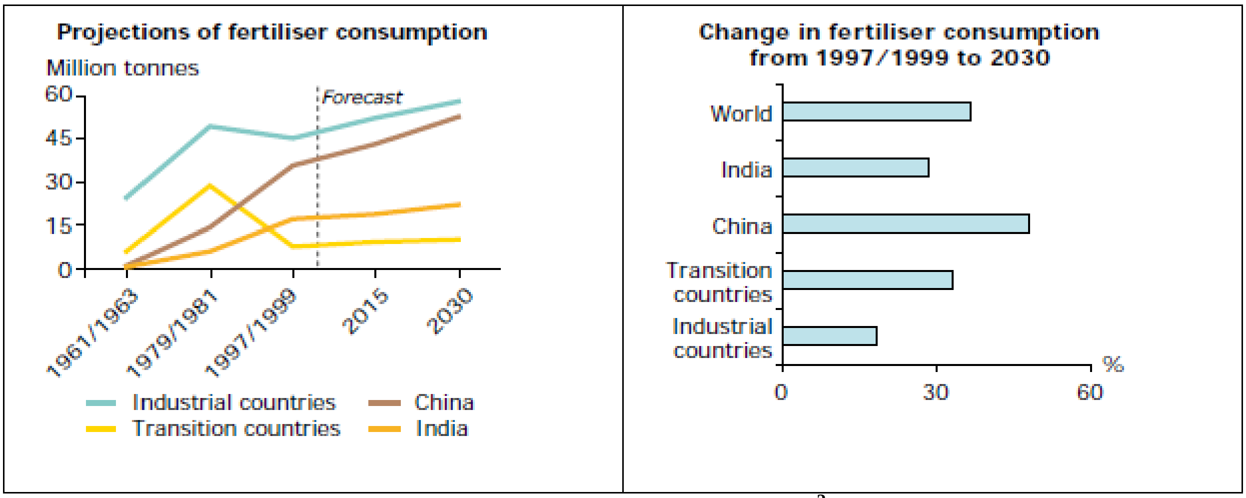

Figure 6 Forecast of world fertilizer requirements to 2030[2]

The increase in demand in the current decade has led to higher prices of the raw materials used in mineral fertilizers, as shown in Table 7. A possible shortage phosphate for use in fertilizer has been forecast for many years, and this could be a concern in the coming decade. Nonetheless, current forecasts of known extractable sources of phosphate rock indicate that at current rates of use reserves are available for almost three centuries.

More generally, the increased demand for fertilizer is now being matched by newly available supply, with further increases in supply of all components including phosphate expected from current extraction developments (Heffer & Prud'homme, 2008).

Table 7 Fertilizer component costs at source

	$/tonne	$/tonne
	2004	Jul 2007
Sulphur	60	110
MOP (Potassium brine)	110	200
NH_3 (ammonia)	250	240
Urea	150	270
DAP (Di ammonium Phosphate)	310	420

While sewage sludge – due to the much smaller volumes – can not be regarded as a significant alternative source of fertilizer components, a shortage of fertilizer would likely lead to higher demand

[2] http://www.eea.europa.eu/publications/technical_report_2008_8

for alternatives, including sewage sludge. Moreover, sludge may be a valuable alternative or supplemental source with its particular properties of soil conditioning and long release fertilizer components which may be particularly valuable in areas sensitive to high nitrate or phosphate loading. Whilst inorganic fertilizers remain available increases in transport and energy costs may make locally available sewage sludge a more desirable source of fertility.

Questions for consultation

If you disagree with our judgements of influences or effects of factors that include public opinion, financial pressures or materials availability, please correct them and provide explanations where possible using the following questions.

Q26 – Is sewage sludge likely to be used as a replacement for inorganic fertilizers? To what degree is the use of sewage sludge influenced by the market for inorganic fertilizers? Are the qualities of sewage sludge as a replacement for inorganic fertilizers sufficiently well understood to increase the demand for sewage sludge recycling onto agricultural land?

Q27 – How will public opinion in Member States that currently send high levels of sludge to landfills (e.g. EU12) react to greater use of sewage sludge on land?

Q28 – Will the co-treatment of sludge with municipal solid waste become an important path for the future?

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Annex 1 Sludge Treatment processes

Mesophilic Anaerobic Digestion (MAD) is a well established process for treating sewage sludge that operates in the mesophilic temperature range (30 – 38°C). The organic matter that can be converted to biogas within the sludge, referred to as volatile solids, is metabolised microbially, typically over a period of 12-15 days. The volatile solids are first broken down by acid-producing (acidogenic) bacteria and produce smaller, volatile fatty acids (VFA) compounds, which can then be used by methane-producing (methanogenic) bacteria to produce biogas.

In conventional MAD approximately 40-45% of the volatile solids can be converted to biogas. Biogas is approximately 65% methane (CH_4) and 35% carbon dioxide (CO_2) and will typically be burnt in a CHP engine to generate electricity and heat, a portion of which will be used to maintain the optimum temperature in the MAD. Conventional MAD may not always destroy pathogens to the required level and therefore a pasteurisation step is sometimes incorporated.

Acid Phase Digestion (APD) is a variation of the MAD process. Instead of the one reactor in a conventional MAD plant, APD uses two or more reactors, whereby the acidogenic phase and the methanogenic phase are separated. In the first reactor a large amount of volatile solids are added and the pH drops over 3-4 days as VFAs are produced. This material is then fed to the main digester where the methanogenic process occurs, producing biogas. In APD it has been estimated that 53% of the volatile solids is converted to biogas. Therefore, more biogas is produced in APD compared to a conventional MAD. The low pH of the acid stage leads to an increased destruction of pathogenic organisms.

The Thermal Hydrolysis Process (THP) is also a two stage process. In the first stage the sludge is treated in a reactor by injecting steam at high temperature (150°C – 170°C) and pressure (5 - 7 bar) for approximately 30 minutes. This essentially ‘pressure cooks’ the sludge, solubilising more of the organic material and making it easier to digest. It will also destroy pathogens. In the second stage, this residue is fed to an anaerobic digester where approximately 60% of the volatile solids can be converted to biogas. Therefore, more biogas is produced by THP than by either conventional MAD or APD. An additional benefit of THP is that higher concentrations of volatile solids can be added to a digester, meaning that a higher throughput of sludge is possible for a given volume of digester. Retrospectively fitting THP to a MAD plant can therefore increase the capacity of the plant.

The Wet Oxidation Process for sewage sludge involves the injection of air, or oxygen, into sewage sludge at high temperature and pressure. It was first used for sludge in the 1960’s but has not been widely installed for sludge treatment. It has some similarity to incineration in terms of the completeness of the conversion, but with a reduced risk of production of substances such as dioxins, furans, nitrogen oxides and dusts that could or are present in incinerator off-gases. The process has chiefly been used previously for strong and poorly degradable industrial effluents, with a reputation for being highly corrosive to equipment. The Athos® process (Veolia) uses conditions of 250°C temperature and 50 Bar pressure, injects pure oxygen and uses a copper sulphate catalyst, to achieve 85% COD removal, a residual solid that dewaters readily to 55% dry solids, and a liquid effluent rich in acetic acid that can be used to drive a biological phosphorus removal plant. Recently installed processes in France, Belgium and Italy treat sludge after anaerobic digestion to reduce the oxygen and energy demands,

Brief description of pyrolysis and gasification

Pyrolysis is the heating of a substrate such as coal, wood or sewage sludge at around 500°C. This drives off hydrocarbon vapours which on cooling produce a mixture of tar, oil and permanent gases. The residue left after pyrolysis is termed a char – coke and charcoal being examples. The char contains the ash that would be produced by incineration, together with non-volatile carbon compounds. It should be assumed that the environmental impact from char is greater than that of incinerator ash.

Gasification involves heating the substrate to 800°C or higher, sometimes with added steam. This enables the water gas or syngas reaction to take place, which produces a mixture of carbon monoxide and hydrogen. In principle this reaction can proceed to completion, leaving behind a mineral ash essentially the same as incinerator ash, though in practice it may retain some of the characteristics of a char.

The high temperatures are often obtained by introducing a limited supply of air, allowing combustion of part of the substrate. This will introduce CO_2 into the gas, reducing its calorific value. As sludge is heated up to gasification temperatures, a certain amount of pyrolysis will always take place. In practice there are a large number of process configurations which can be geared towards producing oil, hydrocarbon gas or syngas and which may produce char or ash as a solid residue. Sometimes the char is incinerated. In general, these processes have not been developed at any significant scale for sewage sludge, except for one large scale oil from sludge plant in Perth, Western Australia. Pyrolysis/gasification cannot yet be considered to be a developed process for sewage sludge.

Incineration or complete gasification with combustion of the gas both liberate essentially the same amounts of energy. Fluidised bed incinerators, however, require substantial amounts of electricity to run. While sludge gasifiers are at a much earlier stage of development, it is believed they will require much less energy to operate than an incinerator. As a result, the net electricity production from gasification should be considerably greater than from incineration.

Annex 2 – Country files

Reviews of individual EU countries are presented, with summary tables of annual sludge production and percentages to different disposal routes shown as Table 8 (1995 – 2005) and Table 9 (2010 – 2020).

Austria

The following description is based on information provided by Kroiss for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and a presentation given by Doujak in 2007.

In 2005, there were about 1500 municipal treatment plants in Austria with a treatment capacity of 18.6 million capita. Approximately 90% of the population was connected to a municipal treatment plant while 10% had in-house treatment plants (for example, septic tanks, cesspits).

The annual sludge generating rate is reported to vary between 11 to 32 kg DS per capita per year. In 2005, municipal sewage sludge production in Austria amounted to 266,100 tds including 28,000 tds of imported sludge; 47% was incinerated; 18% was recycled to agriculture, 1% sent to landfill and 34% disposed by other routes such as composting (77%); landscaping (12.3%), intermediate storage (2.4%) and unspecified.

It is expected that, by 2010, the connection rate will increase to 92% and annual sludge production will rise to 273,000 tds and that, by 2015, the connection rate will rise to 94% and sludge production is expected to have reached 280,000 tds pa. By 2020 the sludge production will stay at this level as 100% connection is not expected.

Region	Sludge production (tds/y)	Agriculture	Incineration	Landfill	Other (inc. composting, landscaping, intermediate storage and unknown)
Burgenland	10,700	5650	110		4910
Kärnten	11,800	830	2560		8410
Niederösterreich	41,000	13410	5690		21900
Oberöstereich	44,200	17550	23810		2810
Salsburg	12,800	1950	8320		2560
Steiermak	25,900	5430	4930	2850	12710
Tyrol	16,400	170	2460	990	12810
Voralberg	10,400	2200			8180
Vienna	64,900		62780		2160
Imports	28,000		12800		15200
Total	**266,100**	**47,190 (18%)**	**123,460 (47%)**	**3,840 (1%)**	**91,650 (34%)**

In addition, there was also 155,000 tds of sewage sludge from industries (mainly cellulose and paper industry) being produced in 2005, which was mainly incinerated (83%) or sent to landfill (13%), with 3% recycled to agriculture and 1% to other outlets.

Based on predictions presented by Doujak, for our baseline scenario, we have assumed that by 2020 in Austria, the proportion of municipal sewage sludge recycled to agriculture will decrease to 5% and that about 10% will be treated in MBT plants (mainly composted) to be recycled to land reclamation projects and that about 85% will be thermally treated (by either incineration and/or co-incineration). In addition, sludge from industries will be entirely thermally treated (100%).

The development of sludge disposal routes in Austria is strongly influenced by the regional regulatory framework for sludge and waste management.

There are stringent restrictions on the application of sewage sludge and compost on agricultural land specified in the regulations. These requirements vary according to the federal state: two of the 9 federal states have, for example, banned sewage sludge application in agriculture. Where it is allowed, sludge has to be treated and at least dewatered. At the treatment works, up to a half-year storage capacity is necessary to fulfil the requirement that sludge must not be applied during late autumn and winter. Direct application of sewage sludge on grass land has little relevance today in Austria. The use of sludge on forestry in Austria is forbidden by law.

There are additional restrictions imposed on the use of sewage sludge and compost in agriculture due to product quality requirements for different markets (for example, organic farming, eco-labelling, and retailer requirements).

As the legal prescriptions and the restrictions for use of sludge and compost for land reclamation or landscaping are much less stringent; an increasing part of sewage sludge, mainly after composting, is used for this purpose especially where the agricultural reuse is no longer accepted.

In recent years, there has been an increase of sludge-drying facilities with different processes (drum dryers, solar drying) to reduce storage volume and transport load. On a national scale this method still has low relevance. There is also an increase of adding other organic wastes into anaerobic sludge digestion to increase biogas production. Mechanical Biological Treatment plant (MBT) have been proposed as a suitable option for sewage sludge composting in combination with other organic materials.

While in the past 11% of sewage sludge was sent to landfill for disposal, since 2004, only material meeting the following criteria is permitted in landfill disposal:

- Less than 5 % TOC related to total dry solids
- Less than 6000 MJ/kg dry solids.

These criteria cannot be met by conventional sludge treatment and stabilization processes; only the ashes after incineration meet the requirements which means that sludge disposal on landfill sites is effectively banned and has no major role in Austria.

During the last 10 years, waste incineration capacity in Austria has increased. The overall capacity is still dominated by fluidized bed incineration plant on the site of the Vienna Main Treatment Plant where about 25% of the total sewage sludge production in Austria is incinerated. For the remaining, sludge is mainly co-incinerated with other wastes in coal-fired power plants and cement kilns.

The current debate in Austria on sludge disposal is dominated by soil and food protection from potentially hazardous organic micro-pollutants and sustainable phosphorus management.

In Austria there is general requirement for treatment plants > 1000 pe for P-removal which results in a ~80 to 85% transfer of P from waste water to sewage sludge. It has been estimated that the P-load in sewage sludge could replace up to ~40% of P-market fertilizer imports to Austria.

There are two clear options in the debate on sludge disposal. The first favours incineration as organic pollutants are destroyed. The second favours sludge application in agriculture as this is the least-cost solution for recycling phosphorus and favours mono-incineration of sewage sludge with P-recovery from the ashes. It does not favour co-incineration with cement coal and wastes as it interferes with P-recovery.

Under waste legislation, energy recovery from sewage sludge has a lower priority compared to nutrient and organic material recycling. But as the political discussion on sludge treatment and disposal is increasingly focussing on possible risks for soil and food due to application of sewage sludge that may contain organic micro-pollutants, public acceptance of incineration is increasing.

Belgium

The situation in Belgium has to be described separately for the 3 regions. The description below is based on information provided by DGRNE 2005, IRGT 2005 and from a presentation given by Leonard in 2008.

Wallonia

Since 2000, a public water management company (SPGE) has been coordinating and financing wastewater treatment in Wallonia. While in 1999, only 38% of wastewater could be treated in Wallonia, at the end of 2004, 137 UWWT plants with capacity of 2,000 p.e. or more were in service with a total treatment capacity of 2,500,000 pe or about 60% of the 2005 UWWT target (i.e. 4,215,775 pe). An additional (700,000 pe + 483,000 pe.) treatment capacity was constructed and had been commissioned, respectively, thus leaving about 11 % short of the target to be met. By 2007, treatment capacity had increased to 88 % of population, compared with 60% in 2005 and 38% in 1999. Treatment capacity is reported to be over scaled by 20% to allow for population and industrial growth. From 3,413,978 inhabitants in 2006, population is expected to grow up to 3,450,555 by 2011 and to 3,551,351 inhabitants by 2020.

About 80% of the population are located in agglomerations above 2,000 pe, about 9% are in agglomerations less than 2,000 pe with both connected to sewer while about 12% of the population (400,000 inhabitants) live in areas without municipal sewer and need to install an individual wastewater treatment system.

The whole territory has been designated as sensitive area which means that all the plants with a capacity of more than 10,000 pe have to have been equipped with tertiary treatment by 2008 at the latest. Ninety percent of the 137 plants in 2004 were small or medium-sized (less than 10,000 pe). Most treatment plants had secondary treatment and only 33 plants with a capacity above 10,000 pe had tertiary treatment.

From the latest figures submitted to the Commission, sludge production amounted to 18, 514 tds in 2001, 20,300 tds in 2002 and 23,520 tds in 2003. By 2005, sludge production was estimated to 30,000 tds and it is expected that by 2010, when Wallonia will have completed investment for the UWWT Directive, IRGT (2005) and Leonard (2008) estimated that sludge production will rise to 45,000 tds which is lower than our estimate of 80,000 tds based on 25kg per capita, 3.5 M inhabitants and 88% connection. For our baseline scenario, we have assumed that it will stay at that level until 2020 as population growth and industry expansion is expected to be limited.

In Wallonia, recycling to agriculture has traditionally been the preferred option although the proportions have decreased over the last 10 years from more than 70% in 1995, 88% in 1998, 65% in 2000 to about 50% in 2002 and 2003. It was reported by Leonard that, in 2006, about 32% was still recycled to agriculture. Quantities sent to landfill have first increased from 18% in 1998 to 45% in 1999, 34% in 2000 and 37% in 2001 but would only be around 5% in 2006. Proportions of sludge sent to MSW incinerators have dramatically increased since 1999 from 2% to more than 60% in 2006. The agriculture outlet should continue to play an important role in sludge management despite some fear and opposition from the population.

For our baseline scenario we have assumed that the proportion of sludge recycled to land will remain at the current level for the next 15 years, i.e. 30-35%.

Leonard reported the growing interest in drying facilities and methods to improve dewatering of sludge.

Flemish region

In the Flemish Region, in 1990, approximately 78 % of the wastewater from households was collected in sewer systems, but only 30 % was treated in a wastewater treatment plant. In 2002 the collection and treatment rates increased respectively up to 86% and 60%. By the end of 2005, treatment levels amounted to 64.4% (VMM, 2006) and by 2007 this figure was expected to have reached 80%.

From the figures submitted to the Commission, sludge production amounted to 81,351 tds in 2001, 82,871 tds in 2002 and 76,072 tds in 2003 (CEC 2006). From the latest reports (CEC 2009, personal communication), sludge production was reported to amount to 87,382 tds in 2004, 76,254 tds in 2005 with no figure available for 2006. According to IRGT (2005), it is expected that by 2010, when Flanders should have completed investment for the UWWT Directive, sludge quantities will increase by 43% compared with the 2002 figure amounting to about 118.000 tds which is lower than our estimates of 135,000 tds based on 25kg per capita, 6.1 M inhabitants and 88% connection.

Due to more stringent restrictions on PTEs, quantities of sludge recycled to agriculture have decreased sharply since 1998 from 22% down to 7% in 1999, 0% in 2000/2001, 2 % in 2002 and 3% in 2006. Quantities sent to landfill have also decreased steadily since 1998 from 35% down to 3 % in 2002 while quantities sent to incineration have risen steadily since 1998 from 43% to 95 % in 2002. For our baseline scenario we have assumed that there will be no longer any sludge recycled to agriculture in 2010 and in 2020 and that all sludge will be thermally treated.

Brussel region

In the Brussels region, it is currently estimated that 90% of inhabitants are connected to the sewage system. It is expected that, by the year 2015, 100% of inhabitants will be connected. The first (and only) wastewater treatment plant with a capacity of 360,000 pe started operation in 2000. The second UWWT plant with a capacity of 1.1 M pe started operating in 2008. Since 2009, sewage sludge is treated by thermal hydrolysis/anaerobic digestion followed by wet oxidation reducing sludge quantities by 99% and the final product will sent to landfill or used in construction materials.

Following the implementation of the UWWT Directive, sludge quantities are expected to increase by 300% by 2010 compared with 2002 figure of 2,792 tds. However with the wet oxidation treatment applied, the final quantities should not increase dramatically. In 2002, sludge produced at the first works was recycled to land (32%), sent to landfill (66%) and incinerated (2%). For our baseline scenario we have assumed that there will be no longer any sludge recycled to agriculture by 2010 but sludge will be treated by wet oxidation and disposed of for other uses and that the situation will not change by 2020.

Bulgaria

The following description is based on information provided by Paskalev for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and various other reports including MoEW 2003 and UNDP/GEF Danube Project 2004.

Bulgaria joined the EU only recently (January 2007) and has been granted an extended deadline until December 2014 to comply with the UWWT Directive.

The population in Bulgaria was around 8.1 M in 2000 and decreased to 7.8 M in 2002. The forecast is for continued decline: from 7,785,091 inhabitants in 2003 to 7,323,708 inhabitants in 2014 that is a 6% decrease of population (MoEW, 2003).

The transition period for implementing the Directive 91/271/EC in Bulgaria is as follows:

- By 1 January 2011 - construction of sewerage systems and WWTPs for settlements with more than 10000 pe;
- By 1 January 2015 - construction of sewerage systems and WWTPs for settlements with 2000-10000 pe.

In 2002, the proportion of population served by public sewer network and wastewater treatment was 68.4% and 38.6%, respectively. The number of WWTPs was 55, of which 43 plants had biological treatment while the remaining had only mechanical treatment. The total length of the network is around 9,000 km and is in poor condition and needs to be upgraded. The Government plans to build an additional 16,000 km of sewers to connect 2.4 million people as part of the plan to meet the EU directives. The plans of the Government are to treat wastewater generated by 85% of the population.

In 2002, about 500Mm^3 of urban wastewater was discharged annually into sewer; 21.7% is untreated, 2.5% is treated by primary treatment and 75.8% is treated by secondary biological treatment. In addition, 64Mm^3 is not collected. The existing WWTPs with biological treatment were under utilised by 44%.

About 1,000 new urban wastewater treatment plants are planned between 2003 and 2015 in Bulgaria for agglomerations with populations over 2,000 pe (MoEW 2003 reported by UNDP/GEF 2004).

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
New WWTPs >10,000 pe:	1	2	7	22	43	53	48	33	0	0	0	0	209
New WWTPs for 2,000-10,000 pe;	0	0	0	0	0	19	87	129	177	196	154	87	849
WWTP for completion	6	8	7	9	8	5	2	2	0	0	0	0	47
WWTPs for reconstruction and modernisation	6	16	18	29	30	32	20	23	4	2	0	0	180

Sludge production was reported to amount to 31,300 tds in 2004, 33,700 tds in 2005 and 30,000 tds in 2006 for a population of 7.5 million (CEC 2009, personal communication). Based on the above table, by the end of 2010, Bulgaria is expected to have completed 50% of construction of new WWT plants (mainly above 10,000 pe) and to have upgraded existing plants; and thus sludge production is expected to increase by 50% compared with 2004, amounting to around 47,000 tds. By 2020, compliance should be achieved and sludge production has been estimated to reach 151,000 tds (85% of 7.1 M * 25 kg/capita and per year).

In Bulgaria, there is a National Plan for sewage sludge. The Plan recommends development of a programme for recycling of sewage sludge in agriculture and forestry, as well as in land reclamation projects. The Plan requires that sludge be, at least, mechanically dewatered for WWTPs with more than 10,000 pe; and treated by anaerobic digestion for WWTPs with more than 150,000 pe. It is also planned to incinerate sludge in fluidized bed furnace units for WWTPs with more than 500,000 pe.

In Bulgaria, the majority of sludge is currently sent to landfill after stabilization. The most common method of stabilization of sludge from a treatment plant of this size (100,000 pe) is mesophilic anaerobic digestion, while aerobic digestion is rarely used. Recent practice for landfilling is to partition special cells for sludge at the landfills.

There is currently no incineration plant for municipal sewage sludge in Bulgaria. A project for incineration of waste produced in Sofia is under development. This could potentially also handle sewage sludge.

Although there was no experience of recycling sludge on land in Bulgaria in 2006, 40% of sludge was reported to be used in agriculture. There have been only a few cases of sludge recycling in land reclamation and it is considered in Sludge Management Plans. There are no special regulations for the use of sludge in land reclamation and there are other possibilities of reuse on non-agricultural land.

For our baseline scenario, we have assumed that in Bulgaria, by 2010, the current outlets for sludge will be the same as in 2006 but that recycling to agriculture will increase together with recycling to land reclamation; with the combination reaching around 80 % by the year 2020. Disposal of sludge to landfill will decrease to below 10% by 2020 and incineration and co-incineration will increase to about 10% by 2020.

Cyprus

The following description is mainly based on information provided from different presentations by Mesimeris in 2004 and Pantelis in 2005 both from the Ministry of Agriculture, National Resources and Environment (MANRE).

Cyprus joined the EU in May 2004 and has been granted an extended period until 2012 for full implementation of the requirements of the UWWT Directive. In 2005, the total load for rural and urban agglomerations was estimated at 675,000 pe (545,000 pe+130,000 pe, respectively). In 2005, overall 73% of urban agglomerations and only 9% of rural agglomerations were in compliance. However, it is expected that by 2012 Cyprus would have completed its implementation programme for wastewater connection and treatment. In 2007, wastewater treatment plants were in operation for the 4 largest agglomerations on the coast of Cyprus. Treated effluent is almost entirely reused for irrigation. There is no discharge of untreated wastewater (municipal or industrial) to the sea. Two of these treatment plants, e.g. the Limassol/ Amathousa STP and the Larnaca STP, periodically discharge tertiary treated effluent to the sea during the winter months. Two sensitive areas have been designated.

It was reported that previous to 2004, no data were available on sludge production and disposal routes but that only limited quantities were recycled to agriculture. The quantities produced and recycled to land reported to the Commission for 2004-2006 (CEC 2006) are presented below:

Year	**Total production Tds/annum**	**Agriculture Tds/annum**	**%**
2004	4,735	3,134	66%
2005	6,542	3,427	52%
2006	7,586	3,116	41%

The future sludge production estimated by Pantelis (2005) in Cyprus is presented in table below and will amount to about 9,000 tds. This gives a sludge production rate per pe of 24 kg pe per annum. For our baseline scenario, we have assumed that by 2010, the future sludge production will be similar to the figure reported in table below and that by 2020, sludge production will have increased to 16,000 tds when all effluent will be treated (24 kg/pe* 675,000 pe).

WWTP	**Design capacity (pe)**	**Future sludge production (tds/y)**
Vathia Gonia (1)	56,000	1,200
Limassol	76,000	1,600
Nicosia	150,000	3,000
Larnaca	32,000	700
Agia Napa/ Paralimni	54,000	1,100
Paphos	63,000	1,300
Total	377,000	8,900

Notes:

1) include imported sludge from smaller works

Some studies have considered alternative disposal outlets for sewage sludge such as an alternative fuel at cement kilns. Trials have started in Vassiliko Cement Plant (Cyprus) (Zabaniotou and Theofilou, 2008). Also reclamation of disturbed mine land with sewage sludge has been investigated (Kathijotes, 2004).

Czech Republic

The following description is based on information provided by Michalova, 2004 and Jenicek for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

The Czech Republic joined European Union in 2002. Sludge production has increased by about 50% from 146,000 tds in 1995 to 220,000 tds in 2006 (see table below based on data from Michalova, 2004, CEC 2006, CEC 2009, personal communication). Compliance with the UWWT Directive is expected to be achieved by 2010, and future sludge production is estimated to increase by about 20% by 2010 and to stabilise to that level (263,600 tds per annum) for the next 10 years as population growth is reported to be limited over that period.

Year	**Annual sludge production ($x10^3$ tds)**	**Quantities recycled to agriculture ($x10^3$ tds)**	**Quantities sent to landfill ($x10^3$tds)**
1995	150	35	60
1996	140	Ni	30
1997	180	Ni	40
1998	180	Ni	20
1999	190	Ni	40
2000	210	Ni	45
2001	146	70	40
2002	206	0.2	45
2003	211	0.3	25
2004	206	33	Ni
2005	211	35	Ni
2006	221	25	Ni
Ni – no information			

Historically, sludge was typically recycled to agriculture. Untreated sludge application to land has decreased in recent years due to stricter rules concerning sludge quality in terms of heavy metal and pathogens content. At the same time, application of composted sludge has increased. While in 2001, 42-48% of sewage sludge produced was reported to be recycled to agriculture, there was nearly no recycling in 2002 and 2003. From the latest report to the Commission (CEC 2009, personal communication), quantities recycled to agriculture have risen again to around 12% in 2006. However, it is reported that 66% of sewage sludge is ultimately recycled to agriculture, probably after composting.

The amount of sludge landfilled in the Czech Republic has steadily decreased over the last decade from 50% down to about 10-15 % of annual production.

A negligible amount of sludge is incinerated in the Czech Republic. At present, only one municipal wastewater treatment plant has such technology. The incineration of sludge in cement plants is also practiced. A slow increase in the market share of more expensive technologies, such as incineration or other thermal treatment methods can be expected. However, this increase will probably be lower than in Western Europe.

For our baseline scenario, we have considered that recycling of sludge to agriculture will remain high at about 75% mainly after composting and that by 2020, landfilling will only cover 5 to 10 % and thermal treatment will rise to 15-20 % of annual production.

Denmark

Denmark has achieved high level of compliance with the UWWT directive. By 2010, based on a sludge production of 25kg/capita, the increase in annual sludge production should be limited to 141,500 tds. As population growth is limited, sludge quantities should not change between 2010 and 2020.

No recent figures on sludge quantities have been submitted to the Commission for Denmark, but past records showed that sludge production has decreased significantly since 1995 from 167,000 tds down to around 140,000 tds in 2002. According to Eureau survey, sludge production amounts to 77,530 tds.

There is a target for 2008 for 50% recycling through agriculture, 45% incineration corresponding to 25% incineration with recycling of ashes in industrial processes and 20% “normal” incineration.

For our baseline scenario, these proportions have been estimated to be valid for 2010 and 2020.

Finland

The following description is based on information provided by Rantanen for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and data provided to the Commission.

In Finland, in 2005, around 4.4 M inhabitants lived in cities or smaller towns (Santala et al. 2006). Finland has achieved high level of compliance with the UWWT directive. The total amount of municipal sewage sludge produced in Finland was about 150,00 tds in 2004 and 2005 (see table below). Quantities seem to have decreased since 2002.

Although in 2003, 17% of sludge was recycled to agriculture, only 3 % of the sludge was used in agriculture by 2006. The rest was used in landscaping (Syke, 2007). Although the concentrations of heavy metals and nitrogen and phosphorus were well below the levels described in the Sludge Directive and also below the more stringent Finnish requirements, the proportion of sludge recycled to agriculture has diminished and has shifted to landscaping operations.

Future sludge production by 2010 is estimated to have a limited increase to 154,000 tds and proportions for the two main outlets to stay the same; that is less than 10% recycled to agriculture and 90% recycled to other land after composting.

	Total amount of municipal sewage sludge (tds per annum)	Sewage sludge used in agriculture	
		(tds per annum)	%
1995	141 000	47 000	33
1996	130 000	49 000	38
1997	136 000	53 000	39
1998	158 000	23 000	14
1999	160 000	23 000	14
2000	160 000	23 000	14
2001	159 900	25 000	16
2002	161 500	22 000	14
2003	150 000	26 000	17
2004	149 900	11 600	8
2005	147 700	4 200	3

In 2006, Finland passed a new legislation, Government Decree (539/2006), concerning the use of organic fertilizers including sludge. The Decree regulates potentially harmful elements, pathogens and pathogen indicators as limit values in products as well as rates of application. The amounts of nutrients are also regulated. The Decree also stipulates which treatment methods are suitable for producing products of high hygienic quality. The listed methods for sludge treatment are thermophilic anaerobic digestion, thermal drying, composting, lime stabilization, chemical treatment. Other methods can also be validated, that is, each new method has to demonstrate a product with a consistently good hygienic quality.

The old legislation, which is the national implementation of Sludge Directive, is still enforced. More can be found in *http://www.finlex.fi/fi/viranomaiset/normi/400001/28518* in Finnish and Swedish.

The most typical sludge treatment process in Finland is composting, which is done in windrows, reactors or both. According to a survey, 73 % of the wastewater treatment plants compost their sludges (Sänkiaho and Toivikko, 2005). Mesophilic anaerobic digestion is also common in the largest cities. Other methods that include lime stabilization, thermal drying, incineration, thermophilic digestion and chemical treatment are marginal.

France

In France, results from a national survey by the Agences de l'Eau in 2004, show that there were about 16,400 WWT plants with a treatment capacity of 90 M pe. There are regional differences (see table below) but overall the quantities of sludge produced amounted to 807,000 tds per annum; 62% recycled to agriculture, 20% disposed of to landfill, 16% to incineration and 3% to others. According to 2008 Eureau survey, 963,800 tds of sludge were produced.; 55% were recycled to agriculture; 24% sent to landfill; 17% tds were incinerated; and 3% to other outlets.

For our baseline scenario, we have considered that future sludge production will continue to increase and should amount to 1.6 million tds by 2010 and that quantities produced should stabilise to that level until 2020. The proportion of sludge recycling to agriculture will stabilise at around 60-65% over the next 15 years.

Region	Sludge production ($x10^3$ tds)	Agriculture (%)	Landfill (%)	Incineration (%)	Other (%)
Artois picardie	57	90	10	0	0
Rhin Meuse	82	46	23	24	7
Loire Bretagne	160	68	19	13	0
Seine Normandie	192	81	4	9	6
Adour Garonne	70	63	22	8	7
Rhone Mediterranee Corse	246	36	34	28	2
Total	**807**	**62**	**20**	**16**	**3**

Germany

The following description is based on information provided by Schulte for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

In 2008, about 10,000 municipal wastewater treatment plants were in operation in Germany; 250 of the biggest plants (with design capacities of more than 100,000 pe treat about 50% of the wastewater volume, while a further 7,000 small sewage works (with design capacities less than 5,000 pe) contribute less than 10 % of treatment capacity. About 94% of the wastewater volume is treated according to a high standard that comprises biological treatment with nutrient removal.

In 2003, about 2 million tonnes of sewage sludge (dry matter) were produced in Germany. A substantial increase in sewage production in the future is not expected due to the existing high connection rate to sewer and thus to wastewater treatment. Our baseline estimate for 2010 and 2020 is a sludge production of 2 million tds.

Over the past few years, thermal processes have gained greater importance for sludge management, at the expense of landfilling and recycling to land (agriculture and landscaping). This was primarily due to the following developments:

1. Since 2005, disposal of sludge to landfill is no longer possible in Germany, as materials with a total organic content (TOC) of more then 3% are banned from landfill; and

2. The political debate about sludge recycling to land which went on during the past few years in Germany caused a lot of uncertainty. These discussions proposed not only the possible introduction of higher requirements, but also the possibility of a complete ban on sludge recycling. In consequence, some operators of sewage treatment plants felt that sludge recycling to agriculture might not be a reliable disposal option in Germany and therefore viewed thermal treatment as more sustainable choice.

Even though the use of sewage sludge has been strictly regulated by the 1992 Federal Ordinance in terms of limit values for heavy metals and some organic compounds, many experts considered the maximum permissible values as too high, and in November 2007, the Federal Environment Ministry published a draft for a new sludge ordinance. The draft proposes a significant reduction of existing limit values for heavy metals and limit values for additional organic substances.

The proportions of sludge going to the different disposal outlets for sewage sludge in Germany in 2003 are presented in the table below.

Year	Agriculture	Landscaping	Mono-incineration	Thermal treatment - Co-incineration	Thermal treatment-special process	Landfill	Intermediae storage
2003	32	25	20	14	3	3	3

For our baseline scenario, for 2010 and 2020, the proportion of sludge recycled to agriculture may decrease slightly to around 25 to 30% and proportion being used for landscaping remains stable at around 25% and the proportion treated thermally increases to about 50%.

Greece

The following description is based on information provided in a presentation from Karamanos et al (2004) and information on implementation of UWWT Directive.

In 2004, it was estimated that about 95% of households were connected to a sewerage system and that about 60% of the permanent population was served by around 350 municipal wastewater treatment plants. The remaining population is in small villages and remote areas for which individual sanitation technologies should be used. According to the Commission, there are around 100 agglomerations above 2,000 pe in Greece with a total generated load of about 10 M pe; 600,000 pe in sensitive areas; 3.7 M pe. in normal areas and 5.5 M pe from large agglomerations.

Following the implementation of the UWWT Directive, large-scale sewage treatment plants have been constructed in recent years. However, by 2009, Greece has not yet fully complied with the UWWT Directive requirements. About 56% of generated load from agglomerations discharging into sensitive areas was in compliance while about 90% of generated load from agglomerations discharging into normal areas was in compliance

In Greece, sludge production is reported to have dramatically increased from 52,000 tds in 1995, 83,400 tds in 2004, 116,800 tds in 2005 to about 126,000 tds in 2006 (CEC 2006 and CEC 2009, personal communication). There are currently only small trials of recycling of sludge to agriculture (less than 100 tds per annum), the majority of sludge produced is sent to landfill. This is in agreement with figures provided from a recent Eureau survey (2008), which reported that sludge production amounted to about 126,000 tds; the majority being disposed of to landfill with only minor trials of sludge recycling to agriculture (100 tds).

For our baseline scenario, we have assumed that, by 2010, Greece will be complying with the UWWT Directive and thus that sludge production will have more than doubled to amount to 260,000 tds (25 kg * 95% of 11.1 M inhabitants). By 2010, recycling to agriculture will remain low to inexistent (5%) and landfilling will remain the main outlet at 95%. By 2020, sludge production will remain at around 260,000 tds but landfilling will have decreased to 55-60 % and be replaced by thermal treatment (35-40%) while agriculture will remain low at about 5%.

Hungary

The following description is based on information provided by Garai for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and from a presentation by Toth (2008).

Hungary joined the EU in May 2004. It has a population of around 10 million people and a total area of 93,000 km^2. Budapest has a population of 1.85 million with 96% connected to sewer but only 49% are served by one of the 2 existing wastewater treatment plants and thus untreated sewage is discharged into the Danube. A new plant (Central) has been commissioned and should be operational in 2010. In the rest of the country the situation is worse with only an estimated 68% of population connected to sewer and less than 1/3 of 3000 settlements having adequate wastewater treatment.

The priority is to tackle sewerage problems from industry and 10 large cities. There are smaller investments for settlements below 15,000 people and by 2015, it is planned that all agglomerations of more than 2,000 pe will have a modern sewage treatment system.

In Hungary, the most commonly applied wastewater treatment technology is activated sludge. Sewage sludge is usually dewatered by filter belt press or centrifuge to a typical dry solids content of 18-20%. At the largest treatment plant in Hungary (North-Budapest Wastewater Treatment Plant), membrane presses are operated and sludge dry content is between 36-38%. A small proportion is dried.

At the larger plants, sludge is usually treated by mesophilic anaerobic digestion. At some plants, electricity is produced by biogas engines.

According to a 2008 Eureau survey, the total sludge production in Hungary was about 119,000 tds per year. Sewage sludge was predominantly sent to landfill (72,000 tds, 69%) or recycled to agriculture (47,000 tds, 39%). The quantities produced in the latest Commission survey for 2004-2006 are reported to be slightly higher (128,400 tds in 2006) while a smaller proportion was recycled to agriculture (24%). Figures reported by Toth (2008) for 2005 also differ significantly from the ones reported in the Eureau and Commission surveys; quantities produced amounted to 105,000 tds; quantities recycled to land including recycling to agriculture and land reclamation directly and after composting amounted to 70,000 tds (67%) while quantities sent to landfill were only about 25,000 tds (24%) and about 10,000 tds to other/unknown outlets (9%).

According to Toth (2008), total sludge production will rise to 175,000 tds by 2010 and reach a plateau of 200,00 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 135,000 tds (77%) and then decrease to about 115,000 tds (58%) by 2020. Quantities sent to landfill will steadily decrease down to 20,000 tds in 2010 and 10,000 tds by 2020 while quantities sent for incineration will increase from 2010 until 2020 to reach about 60,000 tds per annum. The quantities sent to other/unknown will not change.

According to Garai (2008), the goal of the government is to decrease landfilling and increase the proportion of sludge being recycled to agricultural. By 2015, the proportion of landfilling is expected decrease to 33%.

Year	**Sludge production (tds per annum)**	**Agriculture (tds)**	**Forestry (tds)**	**Incineration (tds)**	**Landfill (tds)**	**Other (tds)**	**Ref**
2004	120,741	36,105					a)
2005	125,143	42,329					a)
2005	105,000	70,000			25,000	10,000	c)
2006	128,379	32,813					a)
2007	120,000	47,000	0	1,000	72,000	0	b)

References:

a) CEC 2009, personnel communication
b) Eureau survey 2008
c) Toth 2008

Agricultural recycling is controlled under two regulations: the first covers compost product and the second one is for use of sewage sludge in agriculture. Sewage sludge is allowed to be disposed in municipal waste landfill if it is treated, not contagious, and the dry content is at least 25% and complies with leaching tests**.**

There are no incinerators for sewage sludge in Hungary as the capacity of hazardous waste incinerators is not sufficient to receive significant amount of sewage sludge, and the price of processing is too high. Some cement factories are authorised for sludge incineration and trials have been performed, but it is not used on a regular basis (Garai 2008).

For our baseline scenario, we have used figures presented by Toth (2008). We have assumed that by 2010 sludge production would amount to 175,000 tds reaching 200,000 tds by 2020. The proportion of sludge recycled to agriculture will increase until 2010 up to 135,000 tds (77%) and then decrease to about 115,000 tds (58%) by 2020. This will include a certain proportion of composted sludge. Quantities sent to landfill will steadily decrease down to 20,000 tds in 2010 and 10,000 tds by 2020 while quantities sent for incineration will dramatically increase from 5,000 tds in 2010 until 60,000 tds by 2020. The quantities sent to other/unknown will not change over that period and remain at 10,000 tds.

Ireland

Information has been extracted from an EPA report on urban wastewater discharges in Ireland for 2004/2005 (EPA 2005).

In Ireland, there are 478 agglomerations with populations greater than 500 pe, which collectively represent a total of 5.6 M pe. It is reported that in 2004/2005, 11% of wastewater received no treatment; 7% of wastewater received preliminary or primary treatment; 70% of wastewater received secondary treatment; and 12% of wastewater received nutrient reduction in addition to secondary treatment.

By the 31st of December, 2005, secondary treatment was required for all agglomerations discharging to freshwaters and estuaries with a population equivalent of 2,000 or greater and for agglomerations with a population equivalent of 10,000 or greater discharging to coastal waters. There have been delays in providing the required treatment plants at a number of locations throughout the country. Of the 158 agglomerations requiring secondary treatment or better by 31st December 2005, the required level of treatment was not in place at 30 of these agglomerations. The level of compliance with discharge limits was 86% for agglomerations above 10,000 pe discharging into sensitive areas and 67% for agglomerations above 15,000 pe and 38% of plants between 2000 and 15,000 pe.

Sludge quantities produced and recycled to land have sharply increased over the last 10 years from 38,000 tds in 1997 to 42,000 tds in 2003. The proportion of sludge recycled to land has also increased dramatically over the same period from 11% to 63%. (CEC 2006). About 62,000 tds in 2004 and 60,000 tds in 2005 respectively were reported to have been produced nationally; 76% (45,5000 tds) was used in agriculture and 17% (10,300 tds) went to landfill and a small proportion (4,000 tds, 7%) was either recycled to forestry or composted (EPA 2005).

We have estimated that, by 2010, sludge quantities will continue to increase and reach up to twice the current amount with full implementation of the UWWT directive, and reach 135,000 tds and remain at that level until 2020. By 2010, we have assumed that proportions recycled to agriculture and disposed of to landfills and other outlets would be at the similar level as in 2005 – i.e. 75%, 15 % and 10%, respectively and that by 2020, while agriculture would still be the major outlet at about 65-70%, incineration would steadily increase to replace landfilling.

Italy

The following description is based on information provided by Spinoza and Canzian for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Sludge management in Italy varies widely as far as local disposal or reuse options are concerned due to different geographical, geological, technical, economic and social contexts. Some Italian Regions have undertaken the revision of the regional legislation on sludge utilisation in agriculture. For example, the Region Emilia-Romagna, in Northern Italy, published a new Regional Decree 2773 of December 30, 2004, modified and completed by Decree 285 of February 14, 2005.

In addition, as monitoring of sludge recycled in agriculture in Region Emilia-Romagna showed an almost constant occurrence of toluene and hydrocarbons, a research programme to define limits values for the above components was started in April 2007. Preliminary theoretical evaluations indicated possible safety limits of 500 mg/kg-ds for toluene and 10,000 mg/kg-ds for hydrocarbons.

In 2004, it was estimated that annual production of sewage sludge was about 4.3 Mt, corresponding to about 1 Mt of dry solids at a solids concentration of 25%, with an increase of about 10% with respect to years 2001-2003 (ONR, 2006). This is in line with the figures reported to the Commission for the period 2004-2006 which are presented in table below.

Year	**Sludge production (t DS per annum)**	**Agriculture**	
		(t DS per annum)	**%**
2004	970,235	195,161	20
2005	1,074644	215,742	20
2006	1,070,080	189,555	18

According to ONR (2006), disposal of sludge to landfill now accounts for only 24% of total quantities of sludge produced, and agricultural recycling, including co-composting and land reclamation, has increased to 69%. About 2% of sewage sludge is incinerated and 5% kept in temporary storage basins.

Sewage sludge is usually thickened and digested before being recycled to agriculture or sent to landfill. Sludge post-treatments, such as pasteurisation and thermal drying, are seldom practiced. Increasingly combined composting is performed by treating sewage sludge with other organic fractions, for example municipal solid wastes, food wastes, wood chips from broken pallets, cuttings from gardening and forest maintenance, and other similar materials.

When the quality of the compost is not good, mainly because of heavy metals exceeding the limits for unrestricted use, the resulting material can be used in land reclamation or as landfill cover. In 2005, wastes treated in composting plants amounted to about 3 million tons, with an increase of 125% with respect to 1999. Plant inflow consisted of 70 % of organic fraction deriving from separate collection and green wastes, 16% of sludge (+7% with respect to 2004) and 15% of other organic wastes, mainly from the food industry.

In some cases, sewage sludge is added in small amounts (up to 5%) to lime and clay in thermal processes to produce inert materials, such as expanded clay for construction.

Adoption of sludge thermal treatment in Italy is low, and accounts as already stated for a mere 6% at most. Incineration or co-incineration with municipal solid wastes is the most common thermal sludge disposal route in Italy. Sludge pyrolysis with gasification is currently under evaluation by a few water service companies.

In all cases, current management practices are influenced by both sludge characteristics and plant size.

In Italy, small WWTPs (those not exceeding 2,000 pe) usually treat domestic wastewater only, no primary sedimentation is usually provided and excess sludge is often already stabilized as deriving from extended aeration activated sludge processes. Alternatively, excess sludge is stabilized by separate aerobic digestion. Sludge is seldom treated on site, but is hauled to centralized plants for dewatering and final disposal or reuse.

In small to medium size plants (up to approx. 100,000 pe), anaerobic digesters are commonly used, and normally built to treat mixed primary and putrescible biological excess sludge However, in areas where eutrophication must be controlled, strict standards on nutrients require biological processes for nutrient removal, with long sludge retention times. Often, in these cases, primary settling is not present or it is by-passed to save internal organic carbon for denitrification. As a result, in these plants anaerobic digesters are no longer used and the sludge is stabilized aerobically. A typical example is the Milan Nosedo WWTP, serving over 1 million pe, that has been built without anaerobic digestion.

Thermal driers have seldom been used in medium-size WWTPs, as 100,000 pe is usually considered the minimum threshold for economic viability. However, recent regulatory restrictions on disposal to agriculture are favouring this technology, as dried sludge can be used as alternative fuel in cement kilns or for energy recovery in waste-to-energy plants. Especially for large size WWTPs, thermal treatment of sludge (drying, pyrolysis with gasification, incineration with energy recovery), is currently considered a feasible solution, as agriculture and landfilling will be no longer be viable disposal routes within few years.

Sludge composition is reported to be highly variable in Italy because almost all WWTPs serve urban areas where industrial activities contribute to the organic pollution load. Further, many medium and large size plants are located in industrial districts, such as (i) the wool district (Biella, Piedmont), (ii) the silk district (Como, Lombardy), (iii) other textile finishing district (Prato, Tuscany), (iv) tannery districts in Veneto and Tuscany, (v) metal surface finishing districts in Piedmont and Lombardy, and other minor districts.

In such cases, obviously, sludge characteristics strongly depend on the influent industrial wastewater, as, for example, it carries many organic recalcitrant compounds that are absorbed by the sludge (such as hydrocarbons and LAS) and contain heavy metals, which usually precipitate as metal hydroxides during treatment and accumulate in the sludge.

It is also worth noting that sludge deriving from textile finishing districts has often poor dewatering characteristics: it is very hard to reach values higher than 22% solids concentration by centrifugation, while belt-presses hardly reach 17-18%.

According to the Italian National Institute of Statistics (ISTAT, 2006), the total population equivalent (urban + industrial) in Italy is estimated to be around 175 million pe, of which the urban fraction is as much as 102 million pe (55.9% resident population, 14.9% tourists, 16.6% commercial sites, 12.6% crafts and small enterprises).

Based on an average annual production of dry solids per capita (after aerobic or anaerobic digestion) of 30 kg ds/annum/pe, the potential total sludge production in Italy can be estimated at around 5.25 million tds/annum, of which about 3 million tds/annum is linked to the urban population only. This is a three-fold potential increase compared with the current sludge production when all the population would be served by sewerage and subsequent appropriate treatment.

It is expected that, at least in Northern Italy, where co-management with municipal solid wastes due to the integration of public services (energy, waste and water), could become a real possibility for the future, anaerobic co-digestion of sludge and wet fraction deriving from separate collection of municipal solid wastes would increase. This is still a marginal practice in Italy but some examples of this type are listed below:

- Treviso: 3,500 t/annum of solid waste wet fraction and 30,000 t/annum of sewage sludge are co-digested.
- Cagliari: 40,000 t/annum of solid waste wet fraction and 15,000 t/annum of sewage sludge,
- Camposampiero: 12,000 t/annum and 12,000 t/annum, plus 25,000 t/annum from zootechnical wastewaters,
- Bassano: 16,000 t/annum of MSW and 3,000 t/annum of SS,

- Viareggio: 5,000 t/annum of MSW and 50,000 t/annum of SS.

The co-incineration of sewage sludge and solid wastes in incineration plants appears feasible if a drying step for sludge is introduced. Some trials are being carried out in Sesto San Giovanni, near Milan, involving the cooperation with two public companies and results are encouraging.

To meet requirements of the UWWT directive, Italy has had to put systems in place for adequately collecting and treating wastewater of agglomerations of more than 15,000 pe before 31 December 2000. Some 299 towns and cities have been listed as not yet being in compliance with EU standard. Discharges of untreated urban wastewater are the most significant source of pollution in coastal and inland waters and Italy faces the prospect of being brought before the European Court of Justice (ECJ).

For our baseline scenario, we have assumed that, by 2010, Italy will have complied with the UWWT Directive and that sludge production will have reached its maximum at about 1.5 M tds and remain at that level for the next 10 years. Sludge recycling to agriculture will increased to about 50% and a large proportion will also be recycled to land reclamation projects both totalising 70% of sludge produced. Most of the sludge recycled to land will be first co-composted.

Latvia

Information is mainly extracted from a report produced by GHK (2006).

Latvia is a small Baltic state with an area of 65,000 km^2 and 2.5M inhabitants. Agricultural land occupies 39% and forestry 44% of Latvia's territory. In the last decade, with the dismantling of collective farms, the area devoted to farming decreased dramatically - now farms are predominantly small. Latvia joined the Union in January 2007 but Latvia started a programme of improving wastewater treatment in 1995. The whole territory of Latvia has been classified as sensitive area under the UWWTD. In 2005, it was reported that overall 71 % of the population was connected to the sewer system (almost all connected to a WWTP). The availability of a centralised wastewater infrastructure varies from town to town. In towns with a population above 10,000 it typically reaches 70-85% of the population while in towns with a population below 10,000 it can be as low as 30% of the population.

Out of 71 agglomerations that have a wastewater treatment plant, only 7 are complying with the UWWTD standards while 64 have a WWT plant which is not fully compliant. All together, in the wastewater sector, numerous projects have been planned to be implemented during the time period from 2006 – 2015. By the end of 2008, Latvia should have finished improvements to the wastewater collection in the largest cities above 100,000 pe and investment will continue until 2015 to construct about 60 new WWT plants with a total capacity of 1.9 M pe and upgrade existing non-compliant WWT plants with a capacity of 1.17 M pe.

Most of wastewater treatment plants do not have adequate sludge treatment. The most common final disposal routes for sewage sludge are agriculture and compost.

Wastewater volumes have decreased by 2.2 times between 1990 and 2000 and thus the quantities of sewage sludge. It was estimated that about 20,000 tds were produced in 2000 and about 29% was recycled to agriculture, 38% stored (landfilled?), 26% for other uses and 7% was composted. No incineration was reported (EIL, 2002). Sludge production seems to have continued to decrease between 2004 and 2006 from 36,000 tds, 28,900 tds down to 24,000 tds (CEC, 2009, personal communication) and quantities recycled to agriculture have fluctuated from 7,700 tds (31%) in 2004, 6,500 tds (22%) in 2005 and nearly 9,000 tds (39%) in 2006. It was mentioned that the high level of heavy metals sometimes restrict the recycling of sludge to agriculture.

For our baseline scenario, we have assumed that by 2010, Latvia will not have finished installing new WWT capacity and thus that sludge quantities will not have increased substantially compared with

2006 figure while, by 2020, compliance with the UWWT directive will have been achieved and sludge quantities will have more than doubled to 55,000 tds. In 2010, we have considered that recycling to agriculture will remain at around 30 %, landfilling at 40% and 30% to other unspecified outlets and that, by 2020, while agriculture remains at around 30%, landfilling will have decreased to 20% and incineration will have increased at about 5 to 10% .

Lithuania

The following description is based on information provided from a presentation by Ciudariene in 2007 and Cepelè in 2008.

Lithuania has a population of 3.4 million inhabitants – its territory is divided in 10 counties and 61 municipalities with regional differences in economic development and treatment connection rates. It has joined the Union in May 2004. Lithuania has designed the whole territory as sensitive area under the UWWT Directive. It was granted until 31 December 2007 to provide collection of wastewater and more stringent treatment for agglomerations of more 10,000 pe (i.e. 38 agglomerations) and until 31 December 2009 to fully comply with the requirements of the UWWT Directive (collection and more stringent treatment for all agglomerations of more than 2,000 pe, i.e. 57 agglomerations). It is reported that there are about 95 agglomerations with more than 2,000 pe generating a total load of 3.34 M pe.

In 2006, 60% of the population was connected to a centralised wastewater treatment plant and at least 32% of wastewater received at least secondary treatment. Sewerage and wastewater treatment plants are reported to be in great need of upgrade and further investments have been identified for the period 2007 - 2013. From the latest Commission report on implementation of UWWT Directive (UBA 2009), in 2005/06, 93% of generated load of all agglomerations >2,000 pe were reported to be collected with 82% of the total generated load treated by secondary treatment and 61% with more stringent treatment.

Between 2004 and 2006, sludge production increased from 60,500 tds to about 71,000 tds per annum (see table below). Due to lack of digestion capacity, most sludge is only dewatered before being recycled to land (25%) or sent to landfill (75%).

Year	Total sludge production (tds/y)	Quantities recycled to agriculture	
		(tds)	%
2004	60,579	14,315	24
2005	65,680	16,240	25
2006	71,252	16,376	23

There is a national plan for strategic waste management which prioritises management of bio-waste with energy recovery (biogas production) and preservation of nutrients (composting). This is encouraging separate collection or MBT treatment.

The plan includes establishing 10 regional sludge treatment centres between 2007 and 2013, to include digestion, drying and composting plants. There are 2 existing centralised plants for anaerobic digestion of sewage sludge; 3 private composting plants including one for sewage sludge and 13 public regional waste composting plants. 76 additional composting plants are to be built between 2007 and 2013 using EU funding. There are currently no municipal waste incineration plants.

For our baseline scenario, we have assumed that Lithuania would have reached compliance with UWWTD by 2010 and that sludge production would reach its maximum by then and amount to 80,000 tds with no further change to 2020. In 2010, recycling to land may increase up to 30% as landfilling is increasingly restricted down to 70% of produced sludge and incineration capacity will not yet be available. By 2020, landfilling will have decreased further down to 30%, agricultural recycling up to 50-60 % and incineration and other thermal treatment up to 10-20% of produced sludge solids.

Luxembourg

According to the latest figures from the Commission (UBA 2009), the collection rate for wastewater in Luxembourg has reached 98% with 93% of generated load treated by secondary treatment and up to 80% to a more stringent level. Luxembourg has wastewater treatment capacities of for approximately 950,000 pe; 80% of the treatment is provided by 10 biological wastewater treatment plants with capacities > 10,000 pe. 5 out of these 10 WWTP's do not comply with the EU standards with regard to organic discharges and 6 out of 10 do not comply with the emission limits for nutrients.

Sludge quantities produced are reported to amount to 9,300 tds (2008 Eureau survey) and to be mainly recycled to agriculture 8,736 tds (95%). The remaining sludge is sent to incineration.

For our baseline, by 2010, we have assumed that there will be no change in the collection rate but that compliance with UWWT will have been reached for all the sewage and that sludge quantities would have risen by 7% to their maximum of 10,000 tds. The majority (95%) will still be recycled to agriculture including after composting and 5% thermally treated. In 2020, the proportion of composted sludge recycled to land will have increased. The proportion of sludge thermally treated either by incineration or co-incineration in cement plants will increase to at least 20% after a study found it to be the best environmentally option (CRTE).

Malta

No information is available, but it is believed that until 2004 there was only a very small amount of sludge produced as there was limited wastewater treatment (17% of generated load). Under the UWWT Directive, by 31 March 2007, all untreated wastewater (25 M m^3 per year) should have been collected and treated to relevant standards. Since 2006, 3 new wastewater treatment plants have been built or are under construction with the construction for the final one having started in January 2009.

For our baseline, by 2010, we have assumed that all urban wastewater will be collected and treated to the relevant standards and that sludge production will have risen to 10,000 tds (25 kg * 400,000 inhabitants). By 2010, agriculture will not an important outlet but all sludge will be landfilled. By 2020, a small proportion may be recycled to agriculture (up to 10%) while the rest is landfilled.

Netherlands

The following description is based on information provided by Kreunen for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Netherlands has already achieved high compliance with the UWWTD. Quantities of sewage sludge are not expected to increase over the next 15 years. There are 26 Water Boards providing wastewater services in the Netherlands. Recycling of sewage sludge in agriculture has been banned in the Netherlands since 1996. Increasingly stringent standards for the application of sludge to land in the late eighties led to this ban.

A private company - GMB Sludge Processing Company has two composting plants which process about 15% of the total (dewatered) sewage sludge produced by municipal sewage treatment plants in the Netherlands, which amounts to approximately 1.5 million tons per year (with a total plant capacity of 1,370,000 PE). Since 2004, this granular product has been used as a biofuel in power stations, both in Germany and the Netherlands. The granules are used by the power stations either as an additive or as a stand-alone biofuel.

Of the remaining amount, approximately 58% is incinerated and 27% thermally dried. The product resulting from these techniques (composting, incineration and thermal drying) still requires further (final) processing.

There is no support in the Netherlands for application of sewage sludge into or onto the soil, or in agriculture. In addition, the animal manure surplus means that the farming sector is more likely to demand the exclusion of sewage sludge.

Norway

The following description is based on information provided by Blytt for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Norway is a country with a long coastline and is dominated by forests and mountains. Arable land covers only 3% and is mostly located near bigger cities and at the bottom of the valleys. Norway has 4.5 million inhabitants. During the seventies and eighties there was a major increase in the number of wastewater treatment plants, especially in the parts of the country with discharges to inland waters and narrow fjords. There are currently about 1,400 treatment plants, of which most are very small.

The sludge from smaller plants is usually transported to larger treatment plants. In total, 62 treatment plants have registered their treated sludge to be regarded as a fertilizer product. Total quantities of sludge produced and disposal outlet are presented in tds in the table below:

Year	Total production	Total utilization	Agricultural	Green areas	Mixed soil products	Top layer on landfill	Land filled	Other
?	86,030	86,484	56,055	10,198	13,178	2,934	2,957	1,162

More than 90 % of Norwegian sludge is used for land application as a soil amendment product; where one-third goes to parks, sports fields, roadsides, the top cover of landfills, and two-thirds goes to arable land within the agricultural sector.

In order to achieve this high rate of land applied sludge, stringent standards have been set for the content of heavy metals and pathogens, and the control of the odour nuisance has been given high priority. In fact the Norwegian regulation concerning sludge is stricter than those of most of the countries in Europe. Towards the end of the 1990s', the policy to recycle organic waste increased, along with requirements to remove organic waste from landfills, in order to reduce emissions of methane and leachates. Applying sludge on arable land is considered by the Norwegian authorities to be the socio-economically acceptable and cost-effective way to utilise the sludge. This implies that farmers are willing to accept the use of sludge. The sewage sludge market is very sensitive to negative reports as farmers acceptance is influenced by many factors including opinions of retailers and consumers. Authorities and waste water treatment plants continuously work on risk communication. This helps to sort real facts from false and provides balanced information to the partners.

In the mid-seventies, a reform in the agricultural sector changed the agricultural production in the populated regions around Oslo and Trondheim from dairy farms with grassland to the production of cereals (barley, wheat, rye and oats) and oil seeds. Single-crop farming depletes organic material in the soil. Changes in the farm structure and land use are contributing factors to use of sludge on agricultural land. Sludge is not used in forests in Norway.

Several municipalities started to source separate kitchen waste for making compost. The ministries found it necessary to harmonize the parallel regulations for different types of recycled organic waste. In 2003 a new joint regulation *"Regulation on Fertilizers Materials of Organic Origin",* prepared by the Ministry of Agriculture and Food in cooperation with the Ministry of Environment and Ministry of Health was published. This covered all organic materials spread on land which was derived from materials such as farm waste, food processing waste, organic household wastes, garden waste and sludge. It was also believed that to promote and standardise waste such as sludge, higher treatment and quality control standards had to be implemented.

The 2003 regulation sets the following major requirements for organically derived fertilizers in general, with a few special requirements for sludge:

- All producers have to implement a quality assurance system.
- Quality criteria of the products include standards for heavy metal content, pathogens, weeds and impurities, in addition to a more general requirement of product stability (linked to odour emissions). There is a requirement for taking reasonable actions to limit and prevent contamination with organic micro-pollutants that may cause harm to health or the environment.
- Requirements on product registration and labelling before placement on the market;
- Special crop restrictions for sludge, including a prohibition on growing vegetables, potatoes, fruit and berries for three years, and on spreading sludge on grassland.
- Requirements for storage facilities before use. Cannot be spread on frozen soil – no later than November and not before 15 February. Sludge has to be mixed into the soil (ploughing) within 18 hours after application.
- Beside the limit values for heavy metals, the hygienic requirements are: no *Salmonella sp*. in 50 grams and no viable helminth ova. and less than 2,500 fecal coliforms per gram dry solids.

A farmer has to make a plan for all fertilizers to be spread on his fields, including sludge. The municipality has to be notified of sludge use at least three weeks before it is locally stored or spread. The wastewater treatment plant or the sludge transport company often helps the farmer with this notification. A farmer cannot apply sludge more frequently than every 10 years on the same field, but that will depend on to the sludge quantity and amount he uses.

Markets for sludge within the landscaping sector are increasing. New markets for green energy may enhance cultivation for energy crops. This may increase sludge application on these types of arable land. There are ongoing experiments and pilot trials making synthetic diesel from sludge and organic waste. It is becoming more common to co-digest sludge and food waste in order to increase the production of biogas (methane). This will lead to a sludge quality with lower metal content, but higher nutrient content.

Poland

The following description is based on information provided from a presentation by Twardowska in 2006 and a paper by Przewrocki et al 2004.

In 2001, 51.5% of population were connected to a sewage treatment plant in Poland. No recent update to this information has been supplied to the Commission.

Sludge production has steadily increased from 340,040 tds in 1998, 397,216 tds in 2001, 476,000 tds in 2004, 495675 tds in 2005 and 523,674 tds in 2006 (CEC 2006 and 2009). Compared with the 2001 figure, a doubling of sludge quantities is expected by 2015 and an amelioration of the quality of the sludge due to reduction of industrial pollutants discharged into sewers. Almost all of sludge is stabilised by anaerobic digestion or by a natural drying method,

The recycling of sewage sludge to agriculture has increased since 1998 from 8%, 14% in 2000, down to 12% in 2001 and up again to 17% in 2006 (44,819 tds in 2004, 42,558 tds in 2005 and 44,284 tds in 2006). Between 2000 - 2001 the amount of composted sludge increased from 25,528 tds to 27,591 tds (7%) while recycling to agriculture dropped slightly from 50,628 tds (14%) to 49,302 tds (12%). Industrial use (not specified) of sewage sludge increased from 19,815 tds (5%) in 1998 to 28,274 tds (7%) in 2000 and then fell to 24,220 tds in 2001 (6%). Quantities of sewage sludge sent to landfill have dropped from 191,600 tds in 1998 (56%) to 151, 618 t ds in 2000 and rose again to 198,630 tds in 2001 (50%). Quantities incinerated dropped between 1998 and 2001 from 14,389 tds (4%) to 6,937 tds (<2%).

According to a 2008 Eureau survey, sludge production in 2005 amounted to 790,900 tds; 147,000 tds (18%) sent to landfill; 80,600 tds recycled to agriculture (10%); 4,500 tds incinerated and 558,700 to other outlets (not specified).

The forecasts for sludge management routes prepared by the Ministry of the Environment are presented below:

- Proportion of municipal sewage sludge disposed of to landfill will rise to 45% in 2010 but will decrease to 39% in 2015.
- Proportion of sewage sludge incinerated should rise from 1.6% in 2001 to 5% in 2010 and to 8% in 2015. This will depend on new investments in incineration plants.
- Composting is the preferred method of sewage sludge treatment. It is estimated that 20% of sewage sludge could be composted; however, this requires building sufficient capacity of composting plants.
- Another route will be recycling to agriculture. The introduction of more effective and stringent regulations will limit the increase of sewage sludge to agriculture. In 2015, it is predicted that about 26% of sewage sludge will be recycled via this route. Sewage sludge use as fertilizers will reach 46%, including composted sludge.

Portugal

The following description is based on information provided by Duarte for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

In Portugal, there are wide regional differences in sludge production and sludge management as the number of inhabitants and the development of wastewater treatment varies greatly and soil and climatic conditions differ. Since the implementation of the UWWT Directive, there have been major upgrades of existing wastewater treatment plants (WWTP) and construction of new ones, leading to an increase in sludge production. However, by 2005, only 65% (6,572,000 inhabitants) of the total population of Portugal was served by a WWTP mainly with secondary treatment (43%); 24% had also tertiary treatment. The Southern regions (Algarve Alentejo and Lisboa e Vale do Tejo) had about 76% of the population served by a treatment plant and the Northern regions (Centro and Norte) about 58%. There are also industries discharging to these WWTPs producing a load of 50% and 70% respectively in the Southern and in the Northern regions where industry is more important. The generated load was estimated to be about 10,650,000 pe.

The available information on sludge production is scarce and dispersed. Based on field studies carried out in two different Portuguese regions: Algarve (2005) and Center Alentejo (2006), the amount of sludge produced has been estimated and is reported in the table below.

Region	**pe**	**Daily sludge production ratio (g DM/pe.day)**	**Sludge production (tds/year)**
Norte	3,500,300	80	102,209
Centro	2,404,800	50	43,888
Lisboa e Vale do Tejo	3,441,600	50	62,809
Alentejo	802,500	70	20,504
Algarve	499,500	40	7,293
TOTAL	**10,648,700**	**60**	**236,703**

The range assumed for the sludge range (40 – 80 g DM/pe.day) depends, mainly, on the sludge treatment process. For example, if the sludge is digested and if lime is added the upper limit is for non-digested sludge with lime addition and the lower limit is for digested sludge without lime addition. Quantities reported to the Commission are presented below:

Year	Sludge production	Quantities recycled to land	
	tds	tds	%
1995	145,855	44,000	30
1996	177,100	53,130	30
1997	214,200	64,260	30
1998	121,138	41,413	34
1999	374,147	66,547	18
2000	238,680	37,176	16
2001	209,014	69,853	33
2002	408,710	189,758	46

Until recent years, the most common disposal outlet for sewage sludge was landfill. However, this disposal option is becoming more restricted as regulations limit disposal of organic matter and the cost of landfilling is increasing. However, public opinion is against incineration and protest actions have taken place every time a waste incineration plant project has been presented. Thus agricultural use of sludge could play a major role in the future in Portugal. This is especially the case in the Centre and Southern regions of the country where soils are deficient in organic matter. Increasing numbers of operators have started to transport and apply sludge in agricultural and forest land. The main agricultural crop receiving sludge in Portugal is maize, followed by vineyards and orchards. Some sporadic applications occur in forage areas and in forestry after forest fires.

At the same time, other industries and activities such as agro-industries, municipal solid waste (MSW), manure and slurry from intensive livestock production are also relying on agricultural land for the disposal of their waste and are thus competing with sewage sludge for available land. This is especially the case in the Northern and Central regions where operators have more difficulties in recycling sludge to land for three main reasons:

- these are more populated areas, thus WWTP produce more sludge;
- the available agricultural area is reduced;
- more intensive livestock production occurs and thus production of manure and slurry competes for available agricultural land.

Future development does not support an indefinite increased of sludge recycling to agriculture, as continuous reduction of the cultivated area is happening, with wider areas devoted to forest or fallow land and consumers demanding more quality controls on agricultural products, reducing the desire in agricultural producers to use sewage sludge on agricultural land.

For our baseline scenario, we have assumed that by 2010, compliance with UWWT Directive will be achieved and that sludge production would have risen to a maximum of 420,000 tds and that recycling to agriculture will have reached 50%. The remaining sludge will be thermally treated (30%) and landfilled (20%) depending on treatment capacity. The situation is not expected to change by 2020.

Romania

Romania joined the EU in January 2007 and has been granted an extended period to comply with the UWWTD up to 2019. In 2005, 47% of generated load was collected but only 28% was treated by secondary treatment. Current sludge production has been reported to decrease between 2004 and 2006.

Year	Total production (tds/y)
2004	164,969
2005	134,322
2006	137,146

While there is currently no recycling of sludge to agriculture, it has been considered as an option for future management together with co-incineration in cement plants (Crac, 200?).

For our baseline scenario, we have assumed that by 2010, the situation in Romania will have not changed compared with 2006. We have assumed however that full compliance will be achieved by 2020 and that by 2020, sludge quantities will have risen dramatically to 520,000 tds (25*21 M inhabitants). By 2020, a significant proportion could be recycled to agriculture (at least 40%) while landfilling would be the second option unless thermal treatment capacity has been built.

Slovakia

The following description is based on information provided by Sumná for the latest version Global Atlas (Alabaster and LeBlanc, 2008).

Following the implementation of the UWWT Directive, it is estimated that sludge production will increase by approx. 20-40 % in Slovakia. During the period 2004-2006, about 55,000 tds of sludge was generated per annum.

Sewage sludge production (tds per annum) and disposal outlets in the years 2004 – 2006 (CEC 2009) is presented in table below.

Year	Total	Incineration	Agriculture 1)	Landfill 2)	Forestry	Other
2004	53,114	0	41,116	10,581	0	1,417
2005	56,360	0	34,784	17,236	0	4,340
2006	54,780	0	33,630	15,375	0	5,775

Notes:
1) While sludge was directly applied into the agriculture in 2004 and 2005, it was no longer the case by 2006 when large quantities were diverted for the production of compost.
2) Landfill also includes quantities of the sludge that were temporarily stored.

About 90 % of monitored sewage sludge production in Slovakia meets the limit values for PTEs as a result of reduction programmes for pollution due to industrial discharges to public sewers that has been implemented in Slovakia.

Recycling of sewage sludge to agriculture is the preferred option in Slovakia not only because it was relatively the cheapest option but also because it was recognised as the best environmental option for sustainable development. Direct application of sludge into agricultural land is regulated according to the Act on Sewage Sludge Application into Agricultural Land. This determines the conditions for sewage sludge application into agricultural and forest land without affecting soil properties, plants, water, or health of humans and animals. The Act authorises, under specific conditions, applications to arable land and permanent grass land and forestry (only soil in forest nurseries, in plantations with Christmas trees, fast-growing wood plants, energetic and intensive growths). It does not deal with the application to non-agricultural land or use of sludge in land reclamation.

Application of compost or soil supporting substance or growing media is regulated by the Act on Fertilizers. In this case, the product made on the basis of sludge is subject to certification and assessment whether properties of such fertilizer and its technical documentation are in line with related technical standards and generally binding legal regulations.

There are currently no suitable incineration capacities for sludge incineration. However, the national waste management plan for the year 2005-2010 is planning to increase these capacities and to promote energy recovery from waste. The capacity for waste co-incineration in two cement plants (others do not comply with the conditions of the Act on Air Protection) exists in the Slovak Republic, but currently it is reserved for the handling of industrial waste and co-incineration of animal waste. However with the decreasing production of animal waste, sludge could be considered as an alternative in the future in these facilities.

Disposal of sludge to landfill is the least favoured option for sludge management by the Slovak Government. However, due to lack of incineration capacity, it is the only alternative option for sludge disposal. It is expected that the proportion of organic waste disposed at landfills will be limited in line with the requirements of the EC Landfill Directive.

The aim of the Waste Management Programme of the Slovak Republic is to decrease the amount of landfilled waste to 13% out of the total amount of waste being generated in the SR, by the year 2010. Among the measures to be used to reach this are decreasing the quantities of sewage sludge disposed of into landfills and to increase the costs of landfill disposal of all materials.

For our baseline we have estimated sludge quantities by 2020 to amount to 135,000 tds. The proportion of sludge recycling to agriculture as compost to be 50% or more, landfilling will decrease down to 5% or less depending on the thermal treatment capacity, which could treat up to 40% of sewage sludge.

Slovenia

The following description is based on information provided by Grilc and Zupancic for the latest version Global Atlas (Alabaster and LeBlanc, 2008), a presentation given by Mayr and Zugman in 2005 and by Medved in 2006 and a paper from Vukadin and Podakar (from Environmental Agency) in 2007.

Slovenia was a part of former Yugoslavia until 1991 and in May 2004 it became a member of the EU. Wastewater treatment capacity has increased steadily since 2000 when Slovenia entered the process of accession to the EU. It is reported that, in 2005, only 53% of population was connected to a WWT plant but that 73% of generated load from agglomerations above 2,000 pe were collected; 51 % was treated by secondary treatment and 19% by more stringent treatment. Nearly 250 municipal wastewater treatment plants are now in operation, but only 10 % of them are larger than 10,000 pe capacity, (and only 5 larger than 100,000pe capacity). Their total capacity is about 2 million pe (similar to the the population of Slovenia), but part of the capacity is used to treat industrial effluents.

Sewage sludge quantities have increased from 15,000 tds in 2001 to 47,000 tds in 2006. The quantities reported by the Environmental Agency are much lower and were estimated to amount to only 20,000 tds in 2006 (see tables below).

	Gril and Zupancic, 2008	**CEC, 2006**	
Year	**Sewage sludge production (tds/y)**	**Sludge production (tds)**	**Quantities recycled to agriculture (tds)**
2001		8,200	500 (6%)
2002	14,767	7,000	1100 (16%)
2003	20,140	9,400	800 (9%)
2004	26,747	9,687	125
2005	39,366	13,580	71
2006	46,744	19,435	27

Figures from the Environmental Agency of the Republic of Slovenia (2007) are reported below:

Year	Sewage sludge production (tds/y)	Use in agriculture	Composted	Landfill	other	export
2000	8,800	300	1,000	7,500	Na	
2001	8,200	500	900	6,800	Na	
2002	7,000	1,100	900	5,000	Na	
2003	8,800	500	0	7,000	1,400	
2004	12,900	100	0	9,000	3,700	
2005	16,900	100	100	9,500	7,200	
2006	20,100	0	0	9,200	5,600	5,200

These figures show that the quantities of sewage sludge have increased steadily and have more than doubled over the last 4 years. The rate of increase will level off in the next few years as the construction of the largest plants is almost completed. It has been reported that by 2010, sludge production in Slovenia would amount to 40,000 tds per year.

Anaerobic digestion of sludge is relatively rare (10 plants only), mainly at larger plants, where biogas production contributes to the reduction of treatment costs. Some plants use combined input; that is, fresh sewage sludge and separately collected biodegradable municipal waste, food waste, and other similar materials. Filter presses and belt filters are mainly used at small plants, whereas continuous centrifuges are used at large plants.

Some wastewater companies dispose of the sludge on site (internally) (about 14% of total sludge produced). The main ‘internal’ outlets for dehydrated sewage sludge are land application and recycling after composting on the premises of treatment plants or of their operators (mainly non-arable land). This can only be performed sporadically. Composting is practiced on site at a small scale usually together with other types of municipal waste. The compost produced is used for maintenance of green areas around the treatment plants. Limited amounts of sludge are temporary stored, before the most appropriate (or cheap) method is found.

Disposal Methods	Internally		Externally	
	Quantities (tonnes DS/y)	%	Quantities (tonnes DS/y)	%
Temporary storage	321	<1	589	1
Recycling/Composting	2,831	6	4,030	8.5
Land use	3,288	7	0	0
Landfill disposal			13,967	30
Export (to incineration)			21,916	47
Other disposal types			123	2
				47,065

In 2006, the largest amount of sludge (47%) was exported abroad in granulated dry form for incineration. The reason for this method is the absence of proper incineration facilities in the country and tightening of the landfill requirements. The existing industrial thermal processes have not yet obtained permits to co-incinerate dry sludge as an alternative fuel. Co incineration in cement kilns is however not considered particularly attractive in Slovenia due to its relatively low calorific value (about 11-12 MJ/kg at 90% DM.). Sludge export for incineration abroad should, however, only be a temporary solution as new thermal treatment facilities for wastes and sludge are currently under construction.

Landfill disposal of dehydrated sludge has been the most traditional way of disposal and, is still the second route for disposal of sludge in Slovenia (30%). From 2008, sludge landfilling will decrease due to stricter waste acceptance criteria for landfilling such as total organic carbon content of less 18% DM and calorific value less than 6 MJ/kg. In particular the required TOC/DOC limit values are difficult to reach by conventional digestion/composting stabilization processes.

Composting of dehydrated sewage sludge is most often performed in combination with biodegradable municipal waste and other structural materials (bark, corn stalks). Compost is used in non-agricultural applications: for recultivation of landfill sites and land reclamation of degraded areas, public parks maintenance and other similar locations.

Agricultural use is almost inexistent due to the high content of PTEs in sludge, especially zinc, copper, chromium and lead. The available arable land in Slovenia is limited to 36% as 60% of the country is covered with forests and woods. Application of sewage sludge in forestry is prohibited.

For our baseline, the situation in 2010 will remain the same as in 2006 while by 2020 quantities produced are expected to increase to amount to 50,000tds. Over the next 10 years, the proportion of sludge being recycled to land will increase as sludge quality improves but will stay relatively low at around 15%, landfilling will also decrease to 5% while thermal treatment will remain the preferred option.

Sweden

The following description is based on information provided by Hultman et al (1999).

Sweden has a population of about 9.2 million people. The proportion of people living in urban, rural or in sparsely populated areas is about 85%, 5% and 15%, respectively. There are approximately 2,000 municipal wastewater treatment plants and 95% of the population in towns and agglomerations with more than 200 inhabitants are served by plants with tertiary treatment. Full compliance with the UWWT Directive is already achieved.

Sweden has gradually strengthened its rules concerning limiting values of metal concentrations in sludge. In addition there are also limit values for organic substances (nonyl-phenol, toluene, total PAH and total PCB).

There are also legal restrictions on disposal to landfill and, since 2005, organic wastes including sludge from wastewater treatment plants have effectively been banned from landfills. In addition, since 1 January 2000, a landfill tax has to be paid when sludge is disposed of to landfill.

Centrifuges are the most common by used dewatering equipment followed by belt presses. Other conditioning methods are used such as the KREPRO process which uses sludge conditioning by use of acids and heat. There is a growing interest to more efficiently use natural and biological dewatering methods, for example, by use of reed beds.

All large treatment plants use anaerobic digestion, while the other methods are used at small and medium-sized plants. There are also some examples of thermal drying.

Co-treatment of sewage sludge with solid wastes has been investigated in Sweden at different scales such as:

- Sludge incineration together with municipal solid wastes
- Anaerobic digestion of sludge together with other organic materials
- Large-scale composting of sludge together with other organic materials.

Sludge production has been relatively stable for the last 10 years at around 210,000 tds per annum (CEC 2006 and 2009) while quantities recycled to agriculture have fluctuated due to debate over the safety of the outlet but it seems to have reached a stable level at around 10 -15 %.

At the end of the 1980s, sludge disposal outlets in Sweden were agriculture (35%), landfill (50%), land reclamation (15%) and others (5%). Ten years later (1998) the agricultural use had declined to 25% and disposal to landfill had increased to 46 %. In 2006, the agriculture and landfill outlets had further been reduced to 15%, and 4%, respectively while other outlets (land reclamation, green spaces, co combustion, etc) were reported to have reached 81% (Eureau, 2008).

The reasons for the decrease in sludge recycling to agriculture were that, in 1990, the Federation of Swedish Farmers (LRF) recommended its members not to use sludge. A national consultation group was formed between LRF, the Swedish Water and Waste Water Works Association (VAV) and the Swedish Environment Protection Agency (SEPA) which reached agreements concerning agricultural use. However, at the beginning of 2000, LRF argued that agricultural spreading should be suspended because of the presence of brominated flame retardants in sludge and their possible negative effects on soils and organisms.

About five years ago VAV ordered a product certification system from the Swedish Testing and Research Institute (SP). The food industry requires that sludge be quality assured by a certification system. This however offers no guarantee that the sludge will be accepted for use in agriculture. A quality assurance system (ReVAQ) has been designed together by the concerned parties, water companies, farmers, nature conservation and the food industry but the future of agricultural use of sludge is still uncertain. Future use of sludges in agriculture may, however, decrease due to concerns of the food industries and the public. This is the most difficult to predict.

Landfilling had increased due to recommendations to avoid sludge in agriculture, but has now decreased to below 5% by 2005 due the legal restrictions on organic wastes going to land, the introduction of a landfill tax and the difficulties to find new land areas or getting permits for the disposal.

Incineration is a well established method in Sweden for solid waste treatment but not for sewage sludge. Co-incineration with solid wastes may be an interesting alternative to mono-incineration although it seems that most existing incineration plants for solid wastes do not have excess capacity to also burn sludge. Therefore, attention has been directed towards co-incineration with biofuels (wood, peat etc), coal power plants or plants producing building materials at high temperatures (cement, brick etc). Two factors will influence the use of incineration of sludge in Sweden: the potential introduction of a tax on incineration and the potential requirement that phosphorus must be recovered either before or after the incineration.

Other land uses of sewage sludge represent about 10-15% of sludge production in Sweden. Sludge based products and soil conditioners can be used on reclaimed land, parks, golf courses, green areas etc (there are about 400,000 hectares of green areas in Sweden). Sludge can also be used as landfill cover material. Sludge used in forestry has received some attention from forest companies. Sludge can be spread as dried sludge in pellet form on mineral soil to compensate for nitrogen losses due to soil acidification and intensive forestry.

Increased interest has been devoted to extraction of products from sludge. Two commercial systems are mainly under consideration in Sweden, namely the KREPRO and Cambi processes. The Cambi and KREPRO processes aim to see the dissolved substances as resources, either through improved methane production in the digester (Cambi) or by reuse of precipitation chemicals, production of a fertilizer (ferric phosphate), and separate removal of heavy metals in a small stream (KREPRO).

For the baseline study, sludge quantities are expected to increase slightly mainly due to population growth. By 2010, sludge quantities will remain at about 210,000 - 220,000 tds increasing to 250,000 tds by 2020. Over the next 10 years, the proportion of sludge recycled to agriculture will stay at 15% - 20% while recycling to other land uses is expected to be around 70-75%, landfilling reduced to 1% and 5%-10% for co-combustion.

United Kingdom

The following description is based on information provided by Matthews for the latest version Global Atlas (Alabaster and LeBlanc, 2008) and relates mainly to the situation in the England and Wales.

About 96% of the UK population is connected to sewers leading to sewage treatment works (DEFRA, 2002). Most of the remainder are served by small private treatment works, cesspits or septic tanks.

Sludge quantities have increased steadily over the last 15 years (see table below) to amount to 1.6 M tds in 2006. Historically, about a quarter of sludge was either dumped at sea or discharged to surface waters. This was banned from 1998 under the UWWT Directive because it was considered environmentally unacceptable.

Sludge recycling to land is encouraged in England and Wales as a contribution to the environment by recycling valuable nutrients and organic matter. It is recognised by the Government as the BPEO in most circumstances. Requirements are defined in the 1989 Sludge Regulations (derived from the sewage sludge directive) and the associated Code of Practice, and have been made more stringent by the agreement – the Safe Sludge Matrix - between the British Retail Consortium, Water UK (which represents the UK Water Utilities), and ADAS (the Agricultural Development and Advisory Service), with the support of the Environment Agency.

The most common option in England and Wales and in the UK overall for sludge disposal is recycling to agricultural land at around 70% in 2006 (see figures reported by CEC 2006 and 2009 in Table below) followed by incineration with subsequent disposal of ash to landfill. Landfill, which was always the less preferable option, is now used less due to increasing restrictions from the 1999 Landfill Directive, lack of site availability and costs. Liquid sludges can no longer be disposed of into landfill sites. In Scotland and Northern Ireland, incineration is the most preferred option treating respectively 51,000 tds in 2005 in Scotland and 22,000 tds in 2004 in NI.

	CEC 2006, 2009	**DEFRA web page**			
Year	**Sludge production (x10^3 tds)**	**UK sludge**	**England and Wales(x10^3 tds)**	**Scotland(x10^3 tds)**	**Northern Ireland(x10^3 tds)**
1995	1,120	1,124	993	93	34
1998	1,045	1,058	936	97	25
2001	1,187		1,137	-	-
2002	1,303	1,390	1,249	113	28
2003	1,360	1,422	1,280	113	29
2004	1,445	1,368	1,221	113	34
2005	1,511		1,369	140	. .
2006	1,545				

Year	Quantities recycled to agriculture		Incineration		Landfill		Sea		Power generation		Land reclamation		Other	
	(x10^3 tds)	%	**(x10^3 tds)**	%	**(x10^3 tds)**		**(x10^3 tds)**	%	**(x10^3 tds)**	%	**(x10^3 tds)**	%	**(x10^3 tds)**	%
1995	550	49	82	7	115		254	22	-		-		125	11
1998	504	48	185	17	115		150	14	-		-		105	9
2001	709	60					0		-		-			
2002	761	58	232	17	65		0		52	4	84	6	196	14
2003	824	61	227	16	38		0		50	4	106	7	177	12
2004	878	62	265	19	15		0		0	0	150	11	60	4
2005	1,056	70	NI		NI		0						NI	
2006	1,050	68	NI		NI		0						NI	

Untreated sludge is no longer applied in agriculture. The extent of dewatering and stabilisation varies from site to site. A variety of treatment methods might be used depending on the local treatment facilities. There is no set treatment requirement and many factors are taken into account to meet the required treated sludge quality.

A common method of treating sludge at present is anaerobic digestion to standards that meet the terms of the Matrix. After a period of doubt in the 1990's about the future of anaerobic digestion, the process now has a secure central place in sludge strategies and design and operation of plants has developed significantly. The process has been extended to higher levels of efficacy and effectiveness to meet the terms of the Matrix by the use of additional stages. These can also have the advantage improving product quality (that is, releasing ammonia, improving consistency, and reducing smell), producing gas and reducing volume. When digestion is used, the value of the energy created from the methane in the sludge gas is becoming increasingly important. Most sludges are now dewatered using centrifuges or belt presses. There continues to be an interest in other thermal processes, such as pyrolysis and gasification, but these are not currently available.

The application rate onto agricultural land depends on the crops, which can be a cereal, but on a local basis could be maize, rape, or sugar beet, (uses for growing potatoes and other root vegetable have become much less frequent in recent years). A typical application rate would be 6-8 dry tonnes/ha/year.

In the past, small quantities of sludge have been supplied to the domestic and horticultural market. The practice has not been widely encouraged for the domestic market due to the difficulties of effecting realistic controls over application and the disproportionate costs. One opportunity to supply a product would be as compost, which incorporated sludge with other materials. Investigation of this continues but, so far, products including a straw-based compost have not proved to be an attractive or cost effective product. If such products are supplied, there is a move towards the much tighter standards produced by the British Standards Institution, such as PAS 100, for composts, and details can be found on the SORP website.

Only a small amount of sludge is used in forestry and this will probably not increase in the future. Untreated sludge is no longer used for any part of the forestry cycle.

Sludge has also been applied on energy crops such as willow and poplar or miscanthus in short rotation plantations. The harvested wood can be used for a number of purposes, including use as a fuel source. The use of untreated sludge is permitted for these crops.

It is unlikely that the use of sludge on conservation and in recreational land would ever constitute more than a small fraction of the disposal of sludge. This market might be bigger than that at present if sludges were composted or dried and pelletised. The soil criteria for agricultural land apply, and it is likely that only fully treated sludge would be used, particularly on recreational land.

There is some use of sludge for land reclamation (i.e. capping landfill sites and creation of woodland on brownfield sites) However, these tend to be opportunistic and will probably never constitute a significant outlet for sludge.

In the future for our baseline scenario, the two main options will continue to be recycling to agricultural land and thermal treatment. The issues of energy consumption/production and carbon footprint will become important in assessing the sustainability of operations.

The UK is in the process of reviewing sludge use legislation. The UK Government has proposed the incorporation of the Safe Sludge Matrix into Regulations and could incorporate further changes to reflect any developments of knowledge and attitudes. If implemented, the Regulations would make many of the restrictions explicitly mandatory, rather than placed in a Code context. However as yet there are no firm indications as to when the law will be changed. Nevertheless the Companies are incorporating the principles in their operations. There is a clear awareness of the issues of risk management and accredited quality assurance programmes and many schemes have been registered under ISO 14000 or 9000.

Some of the changes to the Regulations would be:

- Use of untreated sludge would be banned
- Treatment will be in accordance with definitions of conventional treatment and
- enhanced treatment
    - Conventional treatment is 99% (2 log) reduction of E. Coli and an MAC of 100,000 per gram DS
    - Enhanced treatment is 99.9999% (6 log) reduction of E. Coli and an MAC of 1000 per gram DS and an absence of Salmonellae sp
- Ban the use of conventional sludge on grassland unless it is incorporated
- Restrict access for harvesting or grazing for conventional sludge to 12-month intervals for field vegetables and 30 months for vegetables eaten raw
- Max limit for lead lowered to 200mg/kgDS
- Max limit for zinc in soils pH 5.5-7.0 would be 200mg/kgDS and for pH values above 7 with a calcium carbonate content more than 5% would be 300mg/kgDS

For our baseline, sludge production is not expected to increase over the next 10 years from the 2006 level of 1.6 million tds. Recycling to agricultural land will also stay at a similar high level at around 65-70% over the next 10 years; incineration may increase to 20-25%; land reclamation will increase to 15-20% and landfill will remain low at about 1%.

Country	1995 total sludge	1995 agriculture	1995 incineration	1995 landfill	1995 other	2000 total sludge	2000 agriculture	2000 incineration	2000 landfill	2000 other	2005 total sludge	2005 agriculture	2005 incineration	2005 landfill	2005 other
	tds/a	%	%	%	%	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	20,000	40		60		20,000	40		60		33,700	40	0	60	
Cyprus	7,000	10				7,000	10				7,586	47		50	
Czech Republic	146,000	20		50	40	210,000	45		30	25	220,700	10	10	10	60
Estonia												10			
Hungary	30,000					30,000					128,380	37	1	44	15
Latvia	20,000					20,000	37		38	33	23,942	37		38	33
Lithuania	48,000			90		48,000	10		90		71,252	23	0	77	
Malta															
Poland	340,040	8	8	56		397,216	14	6	50		523,674	14	1	18	70
Romania											137,145	0	2	98	
Slovakia								0			54,780	39	0	28	16
Slovenia											19,434	0	47	30	15
Austria	390,000	12	5	11		401,867	10	10	11	60	266,100	17	43	5	39.814
Belgium	87,636	32	34	32		98,936	13	76	14		102,566	12	81	3	14
Denmark	166,584	67	25			155,621	60	43	2		140,021	59	40		
Finland	141,000	33			66	160,000	15		6	80	147,000	3			90
France	750,000	66	15	20		855,000	65	15	20		910,255	58	16	20	3
Germany	2,248,647	42	30		30	2,297,460	37	34	3	20	2,059,351	30	38	2	29
Greece	51,624	0		95		66,335	0		95		125,977	0		95	
Ireland	38,290	11				35,039	40				62,147	63		17	20
Italy	609,256	26		30		850,504	26		30		1,070,080	26	7	31	40
Luxembourg	7,000	80			15	7,000	80			15	7,750	45	20		33
Netherland	550,000	0	100			550,000	0	100			550,000	0	100		
Portugal	145,855	30	0	70		238,680	16	0	84		408,710	46	0	54	
Spain	685,669	46				853,482	53				1,064,972	65			
Sweden	230,000	29		50	20	220,000	25		46	20	210,000	14	2	4	86.5
United Kingdom	1,120,000	49	7	35	9	1,066,176	55	21	5	16	1,544,919	66	19	1	15
EU12 % of total EU	8	1	0	4	1	9	2	0	4	1	12	2	0	4	5
EU15 % of total EU	92	36	19	14	12	91	34	22	11	12	88	36	21	9	18
EU27 % of total EU	100	37	20	18	12	100	36	22	15	13	100	38	22	14	23

Table 8 Estimates of annual sewage sludge production and percentages to disposal routes, 1995 – 2005 (from data in this report)

Country	2010 total sludge	2010 agriculture	2010 incineration	2010 landfill	2010 other	2020 total sludge	2020 agriculture	2020 incineration	2020 landfill	2020 other
	tds/a	%	%	%	%	tds/a	%	%	%	%
Bulgaria	47,000	50		30	20	180,000	60	10	10	20
Cyprus	8,000	50		40	10	16,000	50	10	30	10
Czech Republic	260,000	55	27.5	10	25	260,000	75	20	5	5
Estonia	33,000					33,000				
Hungary	175,000	77	5	11	5	200,000	58	30	5	5
Latvia	25,000	30		40	30	50,000	30	10	20	30
Lithuania	80,000	30	0	70		80,000	55	15	30	
Malta	10,000			100		10,000	10		90	
Poland	520,000	38	5	45	12	950,000	26	10	18	46
Romania	165,000	0	2	98		520,000	40	10	50	
Slovakia	55,000	50	5	5	10	135,000	50	40	5	5
Slovenia	40,000	10	50	20	15	50,000	15	70	10	5
Austria	273,000	5	64	1	25	280,000	5	85	1	10
Belgium	170,000	9	90	0		170,000	9	90	0	
Denmark	140,000	50	45			140,000	50	45		
Finland	155,000	5			90	155,000	5			90
France	1,600,000	60	17	24	3	1,600,000	65	17	15	3
Germany	2,000,000	30	50	0	20	2,000,000	30	50	0	20
Greece	260,000	10		95		260,000	5	40	55	
Ireland	135,000	75		15	10	135,000	70	10	5	10
Italy	1,500,000	50	10		20	1,500,000	70	15		20
Luxembourg	10,000	90	5			10,000	80	20		
Netherland	560,000	0	100			560,000	0	100		
Portugal	420,000	50	30	20		420,000	50	30	20	
Spain	1,280,000	70				1,280,000	70			
Sweden	250,000	10	15	4	81	250,000	15	10	1	74
United Kingdom	1,640,000	65	25	5	5	1,640,000	65	25	5	5
EU12 % of total EU	12	5	1	5	1	19	8	3	4	4
EU15 % of total EU	88	40	25	7	11	81	40	25	4	9
EU27 % of total EU	100	45	26	12	12	100	48	28	8	13

Table 9 Estimates of annual sewage sludge production, and percentages to disposal routes, 2010 - 2020 (from data in this report)