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Sewage Sludge Treatment in Europe – an Overview

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1. Introduction

Sewage sludge produced during municipal wastewater treatment has to be treated according to its final reuse or disposal options. European and most national legislation provide regulations for the safe reuse of sewage sludge as fertilizer in agriculture as well as requirements on landfilling and thermal processes. Following the principles of the Agenda 21, high-quality sewage sludge is supposed to be recycled instead of being disposed so that most commonly used treatment technologies are developed in order to comply with this principle. Nevertheless, recent discussions regarding changes of existing legal requirements for the reuse of sludge on EU and also national level have brought novel strategies in sludge management into focus, trying to combine maximum reuse of sludge valuables and minimum environmental impact. Therefore, this report provides a brief overview on treatment technologies and disposal options applied in EU member states as well as current and future trends in sludge management. The statistical data given in this report are mainly chosen from publicly available material and information provided by the member states to the European Commission (e.g. Eurostat, European Environmental Agency). A more comprehensive overview on sludge treatment, disposal and legislation in Europe is given in the report on *environmental, economic and social impacts of the use of sewage sludge on land* to the European Commission [8], which is related to recent considerations on revising the European Sludge Ordinance 86/278/EEC.

2. Sewage sludge production

With the implementation of the Urban Waste Water Treatment Directive 91/271/EEC, municipal sludge production has increased steadily in the EU during the last decade, although reduced water consumption and increased sludge treatment in some member states may have caused a stagnation or even slight decrease in sludge production (e.g. Germany, Austria, Sweden; [8]). Based on data provided to the European Commission for the

2002 – 2006 period, about 9.7 million Mg sludge solids are produced in the EU each year, 8.7 million Mg in EU-15 and an additional 1.0 million Mg in the new member states. Nearly 70 % of the total sludge mass is produced in Germany, UK, Italy, Spain and France. Until 2020, annual EU sludge production is expected to increase by 30 % up to 13 million Mg dried solids (Figure 1).

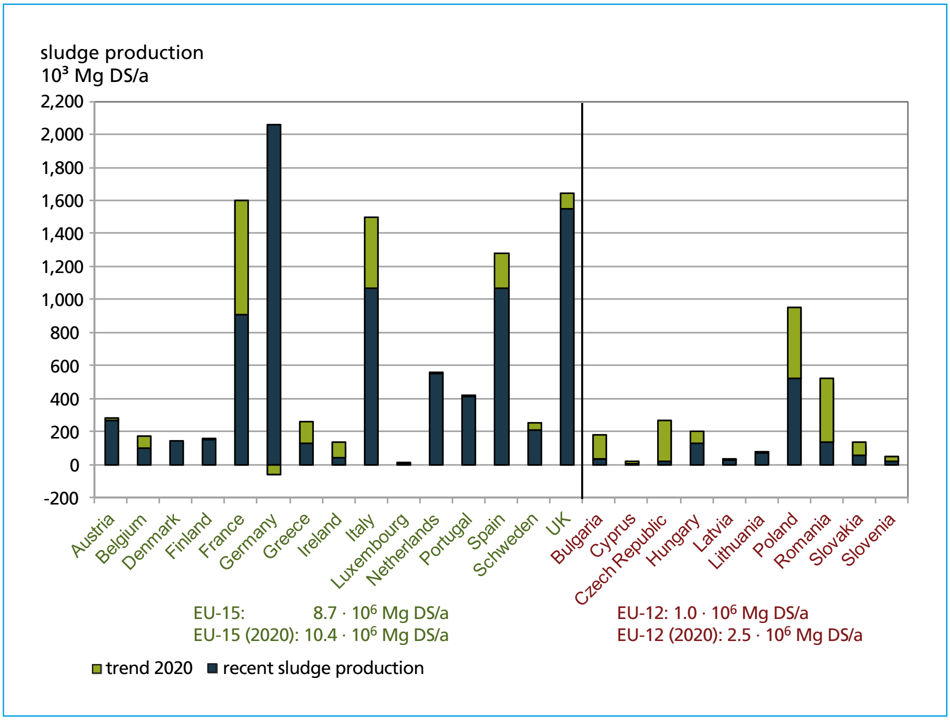

Figure 1: Recent sludge production in EU-15 and new member states EU-12 (data basis 2002 – 2006) and 2020 prospects

Source: Milieu Ltd.; WRc; RPA: Environmental, economic and social impacts of the use of sewage sludge on land. Final Report, Part III: Project Interim Reports. Report for the European Commission, DG Environment, Study Contract DG ENV.G.4/ETU/2008/0076r, 2010

Specific sludge production expressed as amount per capita and year shows large differences between the member states. According to Figure 2, recent average per capita sludge production amounts to 17 kg DS/a in EU-27 [8]. The differences are mainly due to variations in the percentage of population that is connected to wastewater infrastructure as well as the treatment technologies applied. According to data published by the European Environment Agency in 2010, 90 % of the population in Central Europe is connected to wastewater treatment systems, with about 70 % being connected to treatment plants with nutrient and organic matter removal in compliance with the Urban Waste Water Treatment Directive 91/271/EEC. In Eastern European countries, 65 % of the total population is connected to wastewater treatment systems, although most plants do not fulfill the EU treatment requirements yet [5, data basis 2006/2007]. With ongoing improvements, the per capita sludge production is expected to reach 25 kg DS/a in 2020 [8].

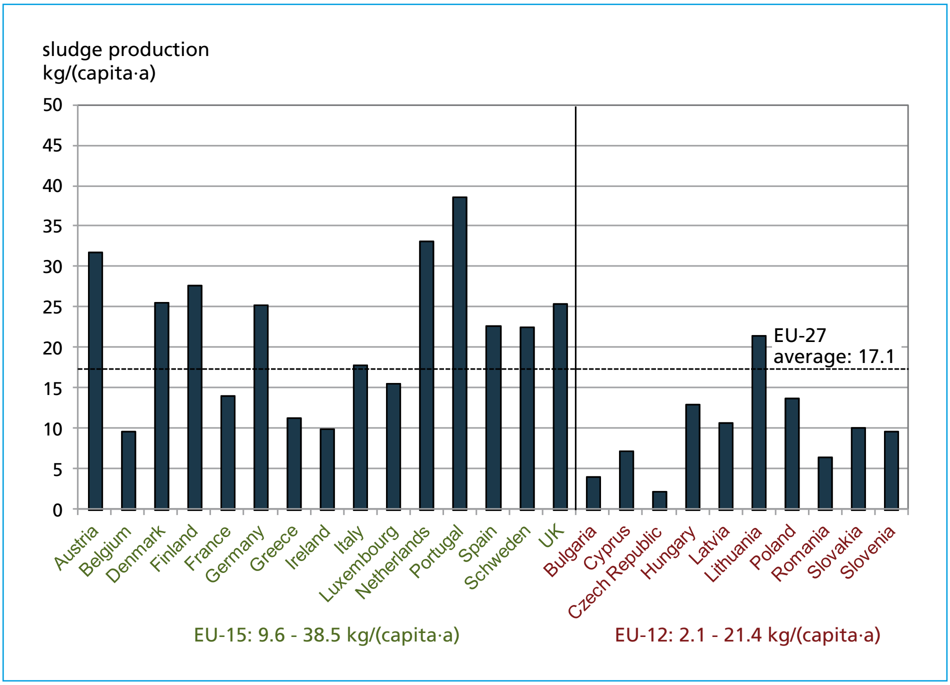

Figure 2: Recent per capita sludge production in urban wastewater treatment plants (data basis 2002 – 2006)

Source: Milieu Ltd.; WRc; RPA: Environmental, economic and social impacts of the use of sewage sludge on land. Final Report, Part III: Project Interim Reports. Report for the European Commission, DG Environment, Study Contract DG ENV.G.4/ETU/2008/0076r, 2010

3. Common treatment technologies

Before disposal, raw sewage sludge is usually treated in order to reduce its water content, to minimize further biological degradation and therefore emissions and to reduce pathogens. In general, sewage sludge treatment steps include thickening and dewatering, stabilization, drying and disinfection where required. The conversion of raw sludge into stabilized material is the most important step. Sludge stabilization technologies can be generally distinguished into biological, chemical and thermal processes. The different treatment pathways lead to different qualities of the treated sludge and either permit the reuse or the landfilling of the material. The applied treatment technology at a wastewater treatment plant is strongly related to the size of the plant and the final disposal option for the sludge.

Kelessidis and Stasinakis [9] recently published a review on sludge treatment methods applied in the EU, evaluating official data provided to the European Commission [2, 3] and previous studies [4, 8]. Their results can be summarized in Figure 3:

Of all stabilization methods available, anaerobic mesophilic/thermophilic and aerobic liquid sludge treatment are the most commonly used stabilization methods in EU-27. Figure 3 shows that the proportion of listings for aerobic processes including composting is higher in new member states in comparison to EU-15. Nevertheless, also in new member states, aerobic processes are predominantly applied at smaller wastewater treatment plants only.

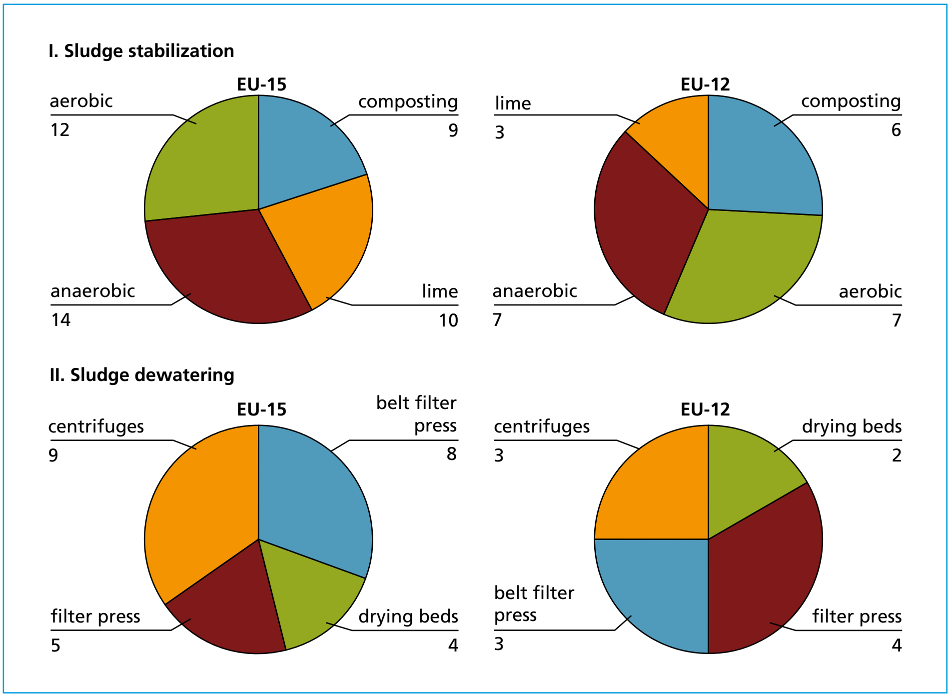

Figure 3: Number of listings for commonly and most commonly applied treatment technologies for sludge stabilization (I) and dewatering (II) in EU member states

Data evaluation according to: Kelessidis, A.; Stasinakis, A. S.: Comparative study of the methods used for treatment and final disposal of sewage sludge in European countries. In: Waste Management (2012), Vol. 32, pp. 1186-1195

At larger plants and therefore for the majority of total sludge volume, anaerobic processes are applied as in EU-15 states, using the economic benefits of energy production from biogas [3]. Due to Kelessidis and Stasinakis [9], the criterion for the application of aerobic or anaerobic processes varies between 5,000 p.e. (Czech Republic) and 50,000 p.e. (Italy, Austria) in member states.

Chemical treatment with quick or slaked lime are also commonly used methods at smaller wastewater treatment plants, often in combination with biological processes in order to realize higher pathogen reductions and are therefore listed by most member states.

Regarding dewatering equipment used in EU member states, mechanical dewatering plays a major role in sludge volume reduction in comparison to natural treatment options like drying beds. In the near future, a significant increase of the use of mechanical dewatering equipment is expected in north and eastern member states [6]).

Alternatives to the common biological and chemical stabilization processes are long term storage, cold fermentation and solar or thermal drying. According to Kelessidis and Stasinakis [9], the significance of thermal processes for sludge treatment is increasing steadily: The number of thermal drying plants in EU today has quadrupled since 1999 to 450, often being the first stage of combined drying and incineration plants. However, due to the authors' data collection, thermal drying has basically been applied in EU-15 states so far, mostly in Germany, Italy, UK and France (in decreasing order).

4. Disposal options

After treatment, there are mainly three different disposal routes possible: agricultural reuse as organic fertilizer, landfilling or incineration.

According to figures provided to the European Commission for the period 2000 to 2006, 37 % of the total sewage sludge produced is recycled in agriculture with large variations in final disposal options within the EU states (Figure 4) and even between different regions of the same country. For example, in France, Ireland, UK and Denmark, more than 50 % of the sludge is recycled, whereas in other countries, e.g. the Netherlands and Finland, agricultural reuse just plays a minor role or has even been banned due to growing concerns on the environmental effects of sludge application. In these countries, incineration is the main disposal route for sewage sludge.

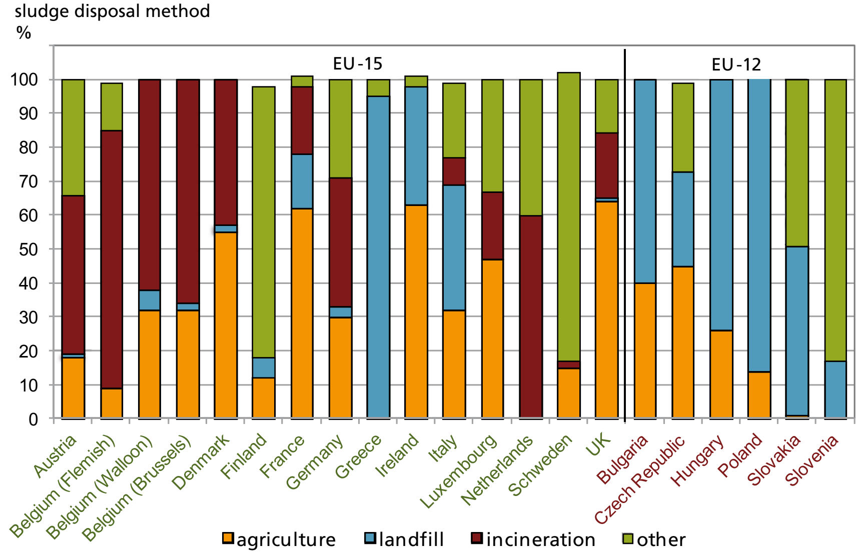

Figure 4: Sludge disposal methods (data basis 2000 – 2006)

Source: Milieu Ltd.; WRc; RPA: Environmental, economic and social impacts of the use of sewage sludge on land. Final Report, Part III: Project Interim Reports. Report for the European Commission, DG Environment, Study Contract DG ENV.G.4/ETU/2008/0076r, 2010

In general, variations in disposal behavior can be observed comparing EU-15 and EU-12 member states. Especially in new EU member states, large amounts of sludge are still dumped in landfills. Nevertheless, this proportion is supposed to decrease, as could already be observed in old member states during the last decade when Landfill Directive 99/31/EC had to be implemented setting limits to the dumping of biodegradable wastes.

About 24 % of the total EU sludge volume has been managed using alternative disposal routes including land reclamation, forestry or silviculture and export to other countries.

5. Novel treatment strategies

Especially agricultural reuse of sewage sludge is one of the most controversially discussed eco-political topics in EU member states. The high demand for stricter legal requirements on sludge recycling may reduce agricultural application of sludges further. Therefore, novel sludge treatment technologies gaining the most economic and ecological benefit of sludge valuables are getting more and more into focus. Several technologies for nutrient recovery have been developed in the last decade to recycle finite natural resources and/or to maximize energy output during anaerobic digestion. Especially the recovery of phosphorus has become one of the main targets in novel sludge management strategies. Research and pilot scale plants either focus on recycling phosphorus directly from waste activated or digested sludge, from sludge liquid or from ashes following sludge mono-incineration. Table 1 lists some of the presently examined and partly large-scale realized technologies on phosphorus recovery.

Table 1: Overview on technologies for phosphorus recovery

Process	Input Material	Characteristics
DHV Water BV Crystalactor, Kurita Fixed Bed, Sydney Water Board Reactor, Unitika Phosnix, CSIR Fluidized Bed	sludge liquid, waste activated sludge	precipitation and crystallisation with Ca or Mg, main stream or bypass
Aqua Reci Process	sewage sludge	sludge oxidation, alcaline pulping and precipitation as calcium phosphate
Cambi-Process	dewatered sludge	thermal hydrolysis, P-extraction with ammonia solution and MAP precipitation
LOPROX-Process (PHOXNAN-Project)	sewage sludge	wet oxidation, liquid separation and nanofiltration of P in sludge liquid
Phostrip-Process	activated sludge	enhanced phosphate remobilization and bypass calcium phosphate precipitation
PRISA-Process	sludge liquid	enhanced phosphate remobilization, filtration, MAP precipitation
P-RoC-Process	sludge liquid	flotation, crystallisation and precipitation as calcium phosphate
Seaborne-Technology	digested sludge	heavy metal precipitation and phosphate precipitation with magnesium
KREPRO-Process	sewage sludge	acid pulping, thermal hydrolysis, liquid separation and precipitation as ferric phosphate
KEMICOND-Process	digested sludge	acid pulping and oxidation, precipitation as ferric phosphate, conditioning and dewatering
BioCon-Process	sludge ash	acid pulping, ion exchanging for phosphoric acid separation
SEPHOS-Process	sludge ash	acid pulping, precipitation and separation of aluminium phosphate, alkaline pulping, precipitation as calcium phosphate
ASH DEC Umwelt AG	sludge ash	thermal treatment of ash, chlorides and acid, evaporation and separation of heavy metal chlorides
RuePa-Process	sludge ash	acid pulping, ion exchanging and liquid separation for heavy metal removal, precipitation of aluminium phosphate

Sources:

Dichtl, N.; Rogge, S.; Bauerfeld, K.: Novel strategies in sewage sludge treatment. In: Clean (2007), Vol. 35, pp. 473-479

Gethke, K.; Herbst, H.; Montag, D.; Pinnekamp, J.: Potentiale und Technologien zum Schließen von Nährstoffkreisläufen in Deutschland. 40. Essener Tagung für Wasser- und Abfallwirtschaft, Aachen, 14.03.-16.03.2007

Pinnekamp, J.; Montag, D.; Gethke, K.; Goebel, S.; Herbst, H.: Rückgewinnung eines schadstofffreien, mineralischen Kombinationsdüngers Magnesiumammoniumphosphat-MAP aus Abwasser und Klärschlamm. UBA Text 25/07, Dessau, 2007

Besides evolving nutrient recovery strategies, an increase in thermal treatment processes can be observed in some member states. If incineration is the favored disposable option, an effective sludge drying is essential to reduce costs for sludge transportation and to increase the heating value. In contrast to common stabilization processes, a maximum degradation of organic substances in sludge can even hinder incineration processes as heating value of the material is strongly related to the organic matter content. In this context, solar sludge drying has become an economic alternative to conventional drying processes, especially when using additional excess heat (e.g. from biogas plants or cogeneration units) in combination with solar radiation.

6. Conclusion

In the near future, sewage sludge production will reach more than 13 Mio. Mg DS/a, posing a huge challenge to political and environmental sustainable sludge management strategies. Recent developments in sludge treatment and disposal and its legal background reflect the growing concern on agricultural reuse of organic waste material. Therefore it is predictable that in some member states, larger amounts of sludge will be incinerated in order to minimize impacts on the environment and on public health. Where possible, future trends may go towards recycling of valuables, e.g. from sludge ash, provided that novel technologies get more efficient and cost-effective and political and economic conditions are put on track. Meanwhile, some member states, especially those with a strong reuse background, are heading towards comprehensive quality assurance systems for agricultural utilization of sludge in order to conserve a safer option for direct sewage sludge recycling with a minimum risk for the environment.

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