Evolution of sewage sludge regulations in Europe

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Abstract The shape of sewage sludge regulation in Europe is outlined as it undergoes a period of rapid evolution. The overall governing policy is embodied in European Directive ED91/156, the Waste Basis Directive, which sets general parameters for waste management. Descriptions are given of the terms of the more specific directives that apply to the major routes for sludge management: land application, composting incineration, and landfill.

Keywords European Directives; incineration; land application; landfill; regulation; sludge management

Introduction
Within the field of waste management, the European Union (EU) promulgates many Directives that constitute the basis for the development of the waste regulations to be applied by each member country.

The European Directive 91/156 on wastes, also designated as the Waste Basis Directive, is of outstanding significance as it is always to be observed even with the application of the other listed regulations. This Directive contains general principles for:
- methods to utilize and dispose of wastes,
- development of waste management plans,
- approval and monitoring procedures.

This means that the particular requirements deriving from other Directives addressed to particular waste groups, like in the case of sewage sludge, apply additionally to the regulations of the Waste Basis Directive. In particular, sewage sludge must fulfill the requirements imposed by specific normatives, such as the Directive on the treatment of urban wastewaters and those for the incineration of wastes, when applicable.

The available and well known practices for the management of wastewater treatment sludge are:
- land application, including spreading on agricultural and forest land, disturbed soils for reclamation, dedicated beneficial use sites, etc.;
- composting;
- incineration;
- landfilling.

Therefore, for the convenience of the audience, in the following the European legislation is discussed considering above options through which sewage sludge is generally managed.

At the time of writing, the European legislation applicable to sludge is in rapid evolution. In particular, a new Directive on land application is at the stage of its third draft, a first proposal on the biological treatment of biodegradable wastes (composting) has recently appeared, and a new Directive on incineration was issued in December 2000.

Land application and composting
Land application is likely to remain as a major option for sewage sludge disposal, especially for sludges produced by small to medium size treatment works, less contami-
nated by toxic compounds, and located close to the disposal site.

The most important regulations at European level concerning sewage sludge are without doubt those reported in the Directive 86/278 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture. All member countries regarded the Directive as a first step towards the harmonization of sewage sludge utilization at Community level. Accordingly, the Directive contains only minimum requirements and permits stricter national measures.

The main rules that must be observed when applying sludge to soil are:

- (i) the concentrations of heavy metals in soil; (ii) those in sludge, and (iii) the maximum annual quantities of such heavy metals which may be introduced into the soil must comply with the limits given in three Annexes;
- sludge must be treated before being used in agriculture, i.e. it must be submitted to biological, chemical or heat treatment, long-term storage or any other appropriate process, so as significantly to reduce its fermentability and any health hazard (but no specific treatment conditions were given);
- sludge shall be used taking primarily into account the nutrient needs for plant growth, and that the quality of the soil and the surface- and ground-waters is not impaired;
- where sludge is used on soils with pH<6, the increased mobility and availability to the crop of heavy metals has to be taken into account by reducing, if necessary, the limit values.

Application of sludge is further limited in some situations, and in particular it is prohibited on:

- grassland or forage crops, if the crops are to be harvested before a certain period has elapsed;
- soil in which fruit and vegetable crops are growing, with the exception of fruit trees;
- ground intended for the cultivation of fruit and vegetable crops which are normally in direct contact with the soil and normally eaten raw, for a period of 10 months preceding the harvest of the crops.

The Directive also lists the analyses to be carried out and indicates the reference methods for sampling and analysis. Member states have also to ensure that up-to-date records are kept.

As already stated, this Directive is currently being amended and a new one will be promulgated shortly. This new Directive revises the previous one almost completely: the most important new aspects deal with the requirement of exactly defined: (i) advanced, or (ii) conventional treatments, mainly addressed to sludge hygienization and odour reduction.

The advanced treatments include:

- thermal drying ensuring that the temperature of the sludge particles is higher than 80 °C with a reduction of water content to less than 10%;
- thermophilic aerobic stabilization, as a batch, at 55 °C for 20 hours;
- thermophilic anaerobic digestion as a batch at 53 °C for 20 hours;
- pasteurization of liquid sludge at 70 °C for 30 minutes, followed by mesophilic anaerobic digestion at 35 °C for 12 days;
- chemical stabilization with lime at pH equal or above 12, maintaining the temperature at 55 °C for 2 hours;
- chemical stabilization with lime at pH equal or above 12 for 3 months.

The treated sludge shall not contain *Salmonella* spp in 50 g (wet weight), and achieve at least a 6 log10 reduction in *Escherichia coli* to less than 5×10^2 CFU/g.

Conventional treatments include:

- thermophilic aerobic stabilization at a temperature of at least 55 °C with a mean retention time of 20 days;
• thermophilic anaerobic digestion at a temperature of at least 53 °C with a mean retention time of 20 days;
• mesophilic anaerobic digestion at a temperature of 35 °C for 15 days;
• chemical stabilization with lime at pH equal or above 12 for 24 hours;
• extended aeration at ambient temperature, as a batch (time length to be defined locally depending on climate conditions);
• simultaneous aerobic stabilization at ambient temperature (time length to be defined locally depending on climate conditions);
• storage in liquid form at ambient temperature, as a batch, provided that a $2 \log_{10}$ reduction in *Escherichia coli* is achieved.

After advanced treatments sludge can be used on pastureland, forage crops, arable land, fruit and vegetable crops in contact with the ground which are eaten raw, fruit trees, vineyards, tree plantations and re-afforestations, parks, green areas, city gardens, all urban areas where the general public has access, and land reclamation.

The conventionally treated sludge can be used for such purposes only if applied by deep injection and provided that temporal limitations regarding grazing time, harvesting and public access are respected. In any case, its use on parks, green areas and city gardens is forbidden, as well as any use on forests.

Limit values for heavy metals are considerably stricter than in the past and new values are proposed with reference to the P content. Differently from previous Directives, new values are also proposed with regard to organic micropollutants, such as AOX, LAS, DEHP, NPE, PAH, PCB and dioxins.

Table 1 shows the proposed limit values of heavy metals in sludge for use on land, and Table 2 those of organic compounds and dioxins.

It seems clear that the limitations imposed by this new Directive will make it more and more difficult to use sludge in agriculture and that considerable investments will be needed to fulfill the new requirements.

The disposal option offered by the use in agriculture is subjected to a great variability over time, depending on crop type and weather conditions, while sludge production is continuous. Therefore, sludge composting is in some cases a preferred option, mainly because it has the advantage of producing a material which can be more easily stored, transported and used at times and sites different from those of production. Composting also involves the production of a more safe and hygienic product. Additionally, the more constant and controlled quality of compost, in comparison to what happens in direct agricultural utilization of sewage sludge, is of major interest.

To promote the biological treatment of biodegradable waste, included composting of sewage sludge, by harmonising the national measures concerning its management in order

<table>
<thead>
<tr>
<th>Metal</th>
<th>Limit values (mg/kg-dry matter)</th>
<th>Limit values (mg/kg P)</th>
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<tbody>
<tr>
<td></td>
<td>Directive 86/278</td>
<td>Proposed</td>
</tr>
<tr>
<td>Cd</td>
<td>20–40</td>
<td>10</td>
</tr>
<tr>
<td>Cr</td>
<td>–</td>
<td>1,000</td>
</tr>
<tr>
<td>Cu</td>
<td>1,000–1,750</td>
<td>1,000</td>
</tr>
<tr>
<td>Hg</td>
<td>16–25</td>
<td>10</td>
</tr>
<tr>
<td>Ni</td>
<td>300–400</td>
<td>300</td>
</tr>
<tr>
<td>Pb</td>
<td>750–1,200</td>
<td>750</td>
</tr>
<tr>
<td>Zn</td>
<td>2,500–4,000</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Note: The sludge producer may choose to observe either the dry matter related or the phosphorus related limit values.
to prevent or reduce any impact thereof on the environment, thus providing a high level of environmental production, a working document in view of a Directive in this field has been recently drafted by the EU.

General principles included into the first draft are, among others:

- the prevention or reduction of biodegradable waste production (e.g. sewage sludge) and its contamination by polluting substances and impurities;
- the composting or anaerobic digestion of separately collected biodegradable waste that is not recovered into the original material;
- the mechanical/biological stabilization of unsorted biodegradable waste;
- the use of biodegradable waste as a source for generating energy.

Member States are requested to encourage: (i) home and on-site composting whenever there are viable outlets for the resulting compost, such as private gardens, community allotments, public parks and farmland, and (ii) setting up of community composting facilities as a way of involving the general public in the management of their own waste, reducing transport of waste and increasing awareness of waste recycling practices.

According to this proposal, the composting process has to be carried out in such a way that a thermophilic temperature range, a high level of biological activity under favourable conditions with regard to humidity and nutrients, as well as an optimum structure and optimum air conduction are guaranteed over a period of several weeks. In particular, in the course of the composting process the entire biodegradable material has to be mixed and exposed to a temperature equal to or above 55 °C for at least 2 weeks or equal to or above 65 °C for at least 1 week (the temperature is reduced to 60 °C in the case of in-vessel composting).

Compost is deemed to be sanitized if *Salmonella streptococci* is absent in a 50 g sample and *Clostridium perfringens* in 1 g. Different limits for heavy metals (Cd, Cr, Cu, Hg, Ni, Pb, Zn), organic compounds (PCBs, PAHs) and impurities are imposed depending on the compost class.

Requirements on location of treatment plants, management of wastewater and leachate, control of odours, minimization of nuisance and hazards are also included in the proposal.

**Incineration**

Sludge incineration requires that economics be carefully evaluated, but it is a cost-effective solution in large urban areas, where the distance to agricultural land or landfill sites

<table>
<thead>
<tr>
<th>Compound</th>
<th>Limit values (mg/kg-dry matter)</th>
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<tbody>
<tr>
<td>AOX</td>
<td>500</td>
</tr>
<tr>
<td>LAS</td>
<td>2,600</td>
</tr>
<tr>
<td>DEHP</td>
<td>100</td>
</tr>
<tr>
<td>NPE</td>
<td>50</td>
</tr>
<tr>
<td>PAH</td>
<td>6</td>
</tr>
<tr>
<td>PCB</td>
<td>0.8</td>
</tr>
<tr>
<td>PCDD/F</td>
<td>(ng-TE/kg-dry matter)</td>
</tr>
<tr>
<td>(polychlorinated dibenzodioxin/dibenzofur)</td>
<td>100</td>
</tr>
</tbody>
</table>
makes transportation prohibitively expensive. Thermal treatments can usefully deal with materials which do not meet beneficial use requirements and/or recovery and also represent a consistent year round solution with a limited need of storage facilities during poor weather periods.

Potential advantages of high temperature processes include: (i) reduction of volume and weight of waste, (ii) destruction of toxic organic compounds, and (iii) recovery of energy.

Good performance by an incineration plant also depends upon the provision of proper auxiliary equipment and devices, which include receiving and storage systems, pre-treatment equipment, feeding system, flue gas cleaning, heat recovery, ash handling, wastewater disposal and process monitoring.

Regulations on incineration are in evolution in Europe. The general philosophy behind the European Directives is to fix limits for the emission for different pollutants. Main European Directives on incineration are:

• Directive 89/369, regarding the prevention of the atmospheric pollution deriving from new incineration plants of urban wastes;
• Directive 94/67, regarding the incineration of hazardous wastes;
• Directive 00/76 (issued in December 2000) on the incineration of wastes.

The first two European Directives above reported do not fix limits for nitrogen oxides (NOx) and PAHs. Moreover, Directive 89/369 does not include limits for dioxins (PCDD) and furans (PCDF) because it was considered sufficient to prescribe gases be submitted to a temperature of 850 °C for 2 seconds after the last air insufflation to adequately control their emission. The same prescription is contained in Directive 94/67, with the addition that the temperature must be increased to 1,100 °C when wastes containing more than 1% of halogen organic substances are incinerated.

With regard to the last European Directive on incineration of waste, some of the operating conditions are, among others, the following:
• a level of incineration such that the slag and bottom ashes TOC content shall be less than 3% or their loss on ignition less than 5% of the dry weight of the material must be achieved;
• the gas resulting from the process must reach, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, the temperature of 850 °C (elevated to 1,100 °C for hazardous wastes with a content of over 1% of halogenated organic substances), as measured near the inner wall or at another representative point of the combustion chamber as authorised by the competent authority, for 2 seconds;
• an automatic system to prevent waste feed must be operated when temperatures are below the above values;
• any heat generated by the incineration process shall be recovered as far as practicable.

The air emission limits to be fulfilled are reported in Table 3.

Limits are also given for: (i) water discharges from the cleaning of exhaust gases, and (ii) residues which must be recycled, where appropriate, directly in the plant or outside in accordance with relevant Community legislation.

Landfilling

Landfilling of municipal solid wastes is a well known and consolidated practice. It is a convenient solution where enough space is locally available at reasonable disposal fees. However, landfilling of wastewater treatment sludge involves several difficulties, mainly due to the sludge’s physical consistency. Generally, solids concentrations of at least 20–25% are required, but higher values up to 30–35% are often necessary because the corresponding physical consistency could be too low to support the cover material.
In all cases, a landfill is the necessary support to all other waste handling systems for the final disposal of materials no longer eligible for reutilization and during shutdown periods for maintenance and/or emergency.

Organic matter deposited in a landfill is not available for plant growth and also the production of landfill gas (biogas) is allowed. Biogas, if not captured, contributes considerably to the greenhouse effect, because it is mainly composed of methane, which is about 20 times more powerful than carbon dioxide in terms of climate change effects.

In addition, by keeping sludge away from landfill sites, the available landfill capacity can be used over a longer period of time and this capacity can be used for materials for which treatment or reuse is not possible.

These motivations are the most important ones behind the European Directive 99/31 that introduced targets for the reduction of biodegradable municipal waste to be landfilled as follows:

- reduction by 2006 to 75% of total biodegradable municipal waste produced in 1995;
- reduction by 2009 to 50%;
- reduction by 2016 to 35%.

Three classes of landfills, i.e. for hazardous wastes, non-hazardous wastes and inert wastes, are defined. Liquid wastes, wastes that in the conditions of landfill are explosive, corrosive, oxidizing, flammable, hospital and other clinical wastes, whole used tyres and other wastes not fulfilling the acceptance criteria are not accepted.

Wastes must be subjected to treatment before landfilling, where treatment means the physical, thermal, chemical or biological processes, including sorting, that change the characteristics of the waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery. In particular, a waste is considered as inert when it does not undergo any “significant” physical, chemical or biological transformations, but indications on the meaning of the term significant are not given.

General requirements for all classes of landfills include considerations on plant location, measures to be taken for water control, management of leachate and protection of soil and water. To this end, landfill base and sides shall consist of a mineral layer which satisfies the following permeability and thickness requirements:

- $K$ equal or below $10^{-9}$ m/s and equal or above 5 m for hazardous wastes;
- $K$ equal or below $10^{-8}$ m/s and equal or above 2 m for non-hazardous wastes;
- $K$ equal or below $10^{-7}$ m/s and equal or above 1 m for inert wastes.

### Table 3

Air emission limits for incineration plants (mean daily values) (referred to 11% O$_2$ concentration)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit value (mg/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>10</td>
</tr>
<tr>
<td>TOC</td>
<td>10</td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
</tr>
<tr>
<td>HF</td>
<td>1</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>50</td>
</tr>
<tr>
<td>NO$_2$ as NO$_2$ (existing plants $&gt;$ 3 t/h and new plants)</td>
<td>200</td>
</tr>
<tr>
<td>NO$_2$ as NO$_2$ (existing plants $&lt;$ 3 t/h)</td>
<td>400</td>
</tr>
<tr>
<td>* Cd+Tl</td>
<td>0.05</td>
</tr>
<tr>
<td>* Hg</td>
<td>0.05</td>
</tr>
<tr>
<td>* As+Pb+Cr+Co+Cu+Mn+Ni+V+Sb</td>
<td>0.5</td>
</tr>
<tr>
<td>** PCDD+PCDF (TE)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* mean values measured in a sampling period (min. 30 minutes, max. 8 h)
** mean values measured in a sampling period (min. 6 h, max. 8 h)
• K equal or below $10^{-9}$ m/s and equal or above 1 m for non-hazardous wastes;
• K equal or below $10^{-7}$ m/s and equal or above 1 m for inert wastes.

Recommendations for the surface sealing are as reported in Table 4.

Landfill gas must be treated and used to produce energy, otherwise it must be flared.

Member States are obliged to take measures for controlling and monitoring procedures in the operational phase, and for closure and post-closure procedures.

In conclusion, the general perception is that European environmental politics are pushing towards recycling, but often unjustified restrictions are imposed thus rendering very difficult the application of this possibility. Stringent limits are also imposed on other disposal methods with the consequence that the costs associated with sludge use/disposal are rapidly increasing.

Analytical and operational procedures

As seen, a number of requirements, such as guide and/or limit values, are contained in the European Directives, but methods for the determination of the respective parameters are often not available or described. Standard analytical procedures are recognized to be key components of the European market, because consistent, objective, transparent regulation supported by standardized methods of test would build stakeholder and public confidence.

In the particular case of sludges, to properly perform their utilization and disposal, and correctly fulfill the requirements imposed by legislation and regulations, the development of standardized testing methods and procedures for the chemical, biological and physical characterization of sludge is necessary. This will also make possible objective comparison and consistency of application.

For this reason the European Committee for Standardization (CEN) established in 1993 the Technical Committee 308 (TC308) whose objectives and strategic directions are to:
• elaborate documents (standards or reports) on terminology, methods of analysis and characterization, on good practice for different methods of sludge use and disposal, and on operational practices for preparing sludges. The aim is to harmonise the technical language, methods and practices for the sludges within its scope across Europe;
• write a report to describe the actual production and market situation of sludges and to propose future applications;
• enable compliance with legislation through the application of consistent analytical methods;
• promote and enable sustainable development through good practice for the conservation of organic matter and completion of nutrient cycles;
• contribute to improvements in public and environmental health and food safety through promoting and disseminating good practice;
• support and contribute to the production and revision of European Directives relevant to sludges;
• regulate the work programme to meet the needs of the European market;
• co-ordinate with, and build on the work done by the other CEN/TCs involved in the environment;
• support European stakeholders in sludge management (legislators, public and private companies, control agencies, etc.);
• give orientation to producers and users on how to meet legislation requirements in relation to areas of growing interest, like safety, health, environment protection, etc.;
• give a larger diffusion to the standards, thus favouring the global market.

The results of this activity will enable the European parties to make sound environmental choices for the final destination of sludges, including treatment, use, incineration, landfill, land restoration, etc.