Environmental Research 156 (2017) 39–46

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Sewage sludge disposal strategies for sustainable development

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ARTICLE INFO

Keywords:
Sewage sludge
Waste management
Wastewater treatment plants
LCA

ABSTRACT

The main objective of the present review is to compare the existing sewage sludge management solutions in terms of their environmental sustainability. The most commonly used strategies, that include treatment and disposal has been favored within the present state-of-art, considering existing legislation (at European and national level), characterization, ecotoxicology, waste management and actual routs used currently in particular European countries. Selected decision making tools, namely End-of-waste criteria and Life Cycle Assessment has been proposed in order to appropriately assess the possible environmental, economic and technical evaluation of different systems. Therefore, some basic criteria for the best suitable option selection has been described, in the circular economy "from waste to resources" sense. The importance of sewage sludge as a valuable source of matter and energy has been appreciated, as well as a potential risk related to the application of those strategies.

1. Introduction

As the global demand for renewable energy and organic matter increases, organic wastes, including sewage sludge, could be one of the available resources for this purpose. This substrate can be used as an energy resource for power and heat with conventional and emerging technologies. Moreover, sewage sludge can be considered as a substrate for soil fertilization and remediation if the applied technology allows to obtain the product of quality. Such re-uses of sewage sludge are economically viable and environmentally sustainable compared to waste handling and landfilling. Potential environmental improvements of existing solutions include reduction in greenhouse gas emissions, improvement of soil conditions and a reduction in fossil fuel use. The economic potential is found in offsetting costs related to traditional waste treatment methods, reduced health costs due to appropriate waste treatment and decreased energy costs by the usage of biogas and biofuels, which can partially replace traditional fuels.

To obtain these goals, wastewater treatment operations require careful management of sewage sludge, not only after removal from the treatment facility, but also during the treatment process. The new strategies shall fit into the eco-innovation trend in order to fulfill the main concept of European Commission "reduce, reuse, recycle" currently strategy understood as the most preferable waste management hierarchy. As an output of wastewater treatment plant, sewage sludge is a critical biologically active mixture of water, organic matter (derived from human wastes, food wastes, etc.), dead and alive microorganisms (including pathogens), and inorganic and organic toxic contaminants (e.g., metallic trace elements, PAHs). Some quantity of sludge is routinely recycled within the treatment facility process in order to optimize operations. However, huge quantities of sewage sludge need to be removed from wastewater treatment plants and thus managed. This "raw" sludge typically contains 97–98% of water. Therefore, to be utilized as a beneficial biosolid, it must be treated properly. The desired new/upgraded technologies shall allow for a full recycling of organic matter and reduction of the potential risk associated with the presence of pollutants. Moreover, in spite of the fact that sewage sludge represents a few percent of the total volume of processed wastewater, the costs associated with its processing accounts for 50% percent of the whole operating expenses at the wastewater treatment plant (U.S. EPA, 2008). This paper provides a summary overview of management strategies for economic and sustainable use of sewage sludge.

2. The laws and regulations of the European Union concerning sewage sludge disposal

The European Union legislation concerning the disposal of sewage waste is included in the Council Directive 86/278/EEC on environmental protection of 12 June 1986 (the so-called Sludge Directive)

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http://dx.doi.org/10.1016/j.envres.2017.03.010
Received 16 August 2016; Received in revised form 23 January 2017; Accepted 6 March 2017
0013-9351/

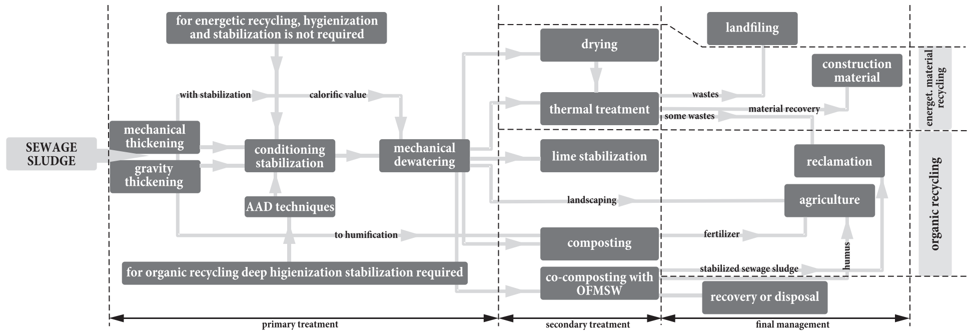

Fig. 1. The sewage sludge treatment processes at the WWTP.

(Directive, 1986). The Directive 2000/60/EC of the European Parliament and Council of Europe adopted on 23 October 2000 sets of the norms of joint Community action in the field of Water Policy (WFD, 2000). This Water Framework Directive (WFP) defines sludge not as a waste material, but as a ′product′ of sewage treatment. The operational directive of the WFD is the Directive 91/271/EEC adopted on 21 May 1991 concerning the treatment of municipal sewage (Directive, 1991) The Directive obliges to monitor and report municipal sewage treatment and final disposal of municipal sewage sludge for agglomerations. Article 14 of Council Directive 91/271/EEC refers to sludge produced in the course of sewage treatment and states that sewage sludge has to be reused in each appropriate case, to prevent adverse effect. Implementation of this Operational Directive till the end of 2015 increased the stream of sewage sludge, but on the other hand, it enabled other methods of sewage sludge reuse. Limits regarding storage of sewage sludge are introduced by the Directive 99/31/EC of 26 April 1999 on sludge storage, called the Landfill Directive (Directive, 1999).

Sewage sludge is the subject of European Parliament and Council Directive (2008)/98/EC of 19 November 2008 on waste (Commission, 2008) which is the Waste Framework Directive, that regulates recycling of wastes, including sewage sludge. According to the above- mentioned Directive, sewage sludge defined as waste is a subject to the procedure assigned for waste treatment. The Directive states that prevention of waste production is the first priority, the next being preparation of waste for reuse, recycling, or other forms of recovery and finally waste disposal. It is not possible to avoid the production of sewage sludge. Therefore, other steps of dealing with this specific waste are very important, i.e. preparation for reuse, understood as sludge reprocessing (including possible energy recovery or organic recycling).

Directive 2010/75/EC of 24 November 2010 (Comission, 2010) on industrial emission officially updates and combines other directives, including Directive (2008)/1/EC (Directive (2008) on integrated prevention of pollution and its control (IPPC), Directive (2001)/80/EC on the limitation of emission of certain pollutants into air from large combustion plants (Parliament and Union, 2001) and Directive 2000/76/EC of 4 December 2000 on incineration of waste (Parliament and Union, 2001) the so- called Incineration Directive which precises the norms and rules for incineration of waste and emission standards. Whereas the Directive of the European Parliament and Council 2009/28/EC of 28 April 2009 on the promotion of energy from renewable sources (Parliament, 2009) amends and as a consequence abates Directive (2001)/77/EC (Directive, 2001) and 2003/30/EC (Commission, 2003) indicating compulsory energy levels to be derived from renewable energy sources. Another document, the Technical Report for End-of-Waste Criteria on Biodegradable Waste Subject to Biological treatment, whereas the Third Working Document (IPTS and Comission, 2012) places sewage sludge on the positive waste list and allows “clean” sewage sludge to be used as fertilizer and gives way to qualify it as a waste product.

Analysis of these regulations gave highest importance to: the Landfill Directive, which will restrict the amount of sewage sludge and other organic wastes sent to landfills, and possible future local controls on pathogen content to ensure public acceptance. A broad range of national and sub-national legislations could influence the spreading of sewage sludge on land in the coming decade. Many other pieces of legislation will be important, from Registration, Evaluation and Authorization of Chemicals (REACH) – of which restrictions on chemicals may reduce contaminants in sludge and increase public confidence – to the new Directive on renewable energy, which could encourage the use of sewage sludge for biogas and other forms of energy recovery.

Commission Staff Working Document from 2 July 2014 concerning on the Ex-post evaluation of Five Waste Stream Directives, including Sewage Sludge Directive (SSD) is one of the oldest UE Directives, survived without any alteration, mainly due to the fact that no consensus could be reached about the right adjustment of limit values for heavy metals in sludge and soil. Additionally, in the opinion of European Commission, SSD has no recycling targets, the objective is rather to stimulate good environmental practice in increasing use of sewage sludge in agriculture. Moreover, several stakeholders stated that for assessing future relevance, it is important to assess links between the SSD and the Fertilizer Regulation, in particular how sewage sludge and sludge products will fit into the future Regulation.

3. Sludge processing

It is estimated that approximately 50% of the costs of operating secondary sewage treatment plants in Europe can be associated with sewage sludge treatment and disposal. Hence, not only the quality of the raw sewage sludge has influence on the final character of sewage sludge, but also several processes realized within sewage sludge treatment at Wastewater Treatment Plants (WWTP's) are involved in this process.

A typical process is summarized as follows (Fig. 1) (Metcalf et al., 2013; Wójtowicz et al., 2013).

- preliminary treatment (screening, comminuting),
- primary thickening (gravity, flotation, drainage, belt, centrifuges),
- liquid sludge stabilization (anaerobic digestion, aerobic digestion, lime addition),
- secondary thickening (gravity, flotation, drainage, belt, centrifuges),
- conditioning (elutriation, chemical, thermal),
- dewatering (plate press, belt press, centrifuge, drying bed),
- final treatment (composting, drying, line addition, incineration, wet oxidation, pyrolysis, disinfection),
- storage (liquid sludge, dry sludge, compost, ash),
- transportation (road, pipeline, sea),
- final destination (landfill, agriculture/horticulture, forest, land reclamation, land building, other uses).