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Review

Review of sewage sludge management: standards, regulations and analytical methods

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ABSTRACT

This article presents the most popular methods of sewage sludge management and associated unit operations and processes referring to them. The most popular methods are: Reclamation and adaptation of lands to specific needs; plant cultivation not intended for consumption or for production of food; usage in agriculture; usage in building; recovery of phosphorus, rare earth metals or fats and usage in industry; producing combustible pellets, granulates or other usable materials such as absorbents; and storage on territory of treatment plant and landfills. Processing connected with stabilization leads to generation of materials which might be contaminated with variety of organic compounds. Since this type of management generally assumes introduction of processed sludge to the ground, it can cause soil contamination with unknown compounds of organic origin. However, thermal processing of raw sewage sludge essentially excludes such possibility. Majority of organic matter is transformed into simple, mineralized form. In this case the most problematic issue is sewage sludge ash contamination with heavy metals. Although, determination of heavy metals in ashes is much simpler than determination of organic compounds. Chemical analysis can be very useful to asses environmental safety of processed and managed sewage sludge. That is why there is a significant quantity of used analytical techniques which are likely to support the processes of designing and implementing new economically and environmentally reasonable ways of re-using sewage sludge. Further, the process of technological utilization of sewage sludge conducted in Wastewater Treatment Plant "Wschód" in Gdańsk is described. Recently technological line was upgraded. Now excessive sewage sludge is anaerobic digested with biogas recovery. Fermentation residues are incinerated in fluidized bed furnace. Ashes are cemented and land filled. Gdańska Infrastruktura Wodociągowo-Kanalizacyjna, which is owner of the treatment plant "Wschód" is planning development strategy for the implementation of a pro-ecological management method connected with production of light construction materials and phosphorus recovery. Management of thermal treated sewage sludge is simpler and cheaper than non-thermal management, especially in case of large amounts of treated sewage sludge like in Wastewater Treatment Plant "Wschód". Management in smaller installations of treatment plants collecting sewage sludge from less industrialized agglomerations is also less complicated. Sewage sludge management process should be developed separately for each treatment plant. Only then all management methods will be ecologically and economically justified.

1. Introduction

The management of sewage sludge is becoming an issue of growing importance. In all countries of the European Union, directives are introduced on the basis of which each member state has to create relevant. According to European regulations management methods involving storage are now being replaced by methods leading to waste stabilization and safe recycling. legislation, programs and developmental strategies. Their aim is, amongst

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other things, to promote pro-ecological management of sewage sludge. Management methods involving storage are now being replaced by methods leading to its stabilization and safe recycling. These methods may consequently lead to the recovery of valuable raw materials from potentially dangerous materials, processing them in order to enable their use in agriculture, various branches of industry or heat and energy recovery (Bartkiewicz and Pierścieniak, 2011). At each stage of sewage sludge processing, its characteristics change. During the disinfection process, the microflora of sludge is changed; the methane fermentation process leads to a decrease in overall carbon content, while thermal processing, depending on the temperature, may result in densification of sludge or even transformation of all organic matter into inorganic compounds. Therefore, many various kinds of processed sewage sludge are generated and each of them have a different chemical composition. They may also vary in the physical properties, consistency or even parameters such as toxicity or stability of pollutants. All those factors may decide whether the particular material will be classified as safe or unsafe. Determined values of parameters, mentioned above, may influence on changes in processing technology in order to develop other methods of management. Therefore, it is important that at every stage of processing of this type of waste, the resulting material should be subjected to a comprehensive chemical analysis. Due to their diversity, other methods and analytical techniques will be useful in each case. Therefore, the choice of a suitable analytical method depends on the planned method of sewage sludge management, which to some extent determines the technology used for processing them.

2. Methods and scope

This study focuses on describing sewage sludge management methods and showing advantages and disadvantages of many approaches. Analytical methods are described as powerful tool supporting management process. The review is based on literature from the entire world, and since the subject is still developing in some countries, and there is a great number of legislation including European Union directives and many countries ordinances, we have included not only management methods reported in peer-reviewed journals but also acts connected to raw and processed sludge management. Discussed legal aspects also recall maximum allowable concentration of contaminants and critical parameters.

Studies published in technical journals and books are also mentioned. As-build documentations, specifications and flow sheets were used to describe current applied technology in Sewage Sludge Treatment Plant "Wschód" in Gdańsk. This facility is used as an example of developing treatment plant, implementing modern technologies in order to create environmentally friendly and economically justified raw sewage sludge management methods.

3. Methods of sewage sludge management

Even today, there are situations in which raw sewage is discharged into bodies of water. This happens most often in small and less developed countries. The Federated States of Micronesia, where almost 30% of produced sewage goes into the waters of the Pacific Ocean without prior purification are good example here (Rouse, 2013). Problem is greater when countries are bigger, like India where only about 30% of the wastewater generated from major cities is being processed (Kapshe et al., 2013). Treated sewage, from which often only a part of the solid fraction has been removed, is also released into the water, which increases the carbon content in coastal waters and causes excessive growth of local fauna and flora. Fortunately, as the ocean is a large body of water and coastal waters mix with the waters from the ocean, eutrophication is not usually a big problem. The situation is different in bodies of water that do not have direct access to the ocean such as the Baltic Sea. It is separated from the Atlantic Ocean by two straits: Skagerrak and Kattegat, which prevent seawater from mixing freely water from the ocean. The introduction of raw sewage into such a relatively small body of water, would result in eutrophication progressing at a very fast pace. Therefore, it is very important to improve wastewater treatment processes so that sewage introduced into surface waters and then brought to lakes, marine and ocean waters is devoid of biogenic compounds such as phosphates. In order to limit environmental degradation caused by eutrophication and the introduction of harmful substances into the waters such as heavy metals, the European Union established relevant directives, such as the Council Directive of 21 May 1991 concerning municipal wastewater treatment. It assumes that in all areas sensitive to eutrophication, such as the Baltic Sea catchment area, it is required that wastewater should be treated more thoroughly (Council Directive, 1991; Winkler et al., 2013). This directive also applies to Poland, which is a member state of the European Union. As a result, more and more wastewater treatment plants are being built and the old ones are still being modernized. Regulations on the requirements for sewage discharged into water or soil are increasingly restrictive (Ordinance of Minister for the Environment on the conditions to be fulfilled while releasing sewage into water or soil & on substances particulary harmful to the environment, 2006). Thus, purification processes still need to be improved. An increasing amount of impurities, not only organic ones, is accumulated in excess sewage sludge. Therefore, its utilization is now becoming a greater problem. More than half a million tons of dry weight of sewage sludge was produced only in Poland in 2011. It should be taken into account that these sediments are usually hydrated in more than 90% so the problem of their management is very complex. Currently, on the areas of landfills and sewage treatment in Poland a two-year excess sludge is stored (Bartkiewicz and Pierścieniak, 2011), because until recently the storage method was the most frequently used way of its management. This is due to the fact that in order to be re-used for example for broadly understood agrochemical treatments, sewage sludge must meet restrictive standards. They will be different depending on the country and the specificity of the method of management. Moreover, according to Directive 2008/98/EC of The European Parliament and The European Council (Council Directive 91/271/EWG, 2008), all recycling and management methods should be preferred approaches involving the use of landfills. Landfilling must be reduced to 35% of biodegradable content by 2020 (Valderrama et al., 2013). Also, it is recommended that the best available technologies should be used to cope with all kinds of waste and with the production of new alternative products. Those products must meet all legal requirements for broadly understood environmental safety. Using them may not pose a risk to waters, soils, air, plants, animals and cannot generate odors or other kind of environmental pollutants.

3.1. The use of sludge in agriculture and soils reclamation

In 2012 over 10 million tons of dry solid sewage sludge was produced. About 40% of excess sludge was speeded on land for agriculture use. If sludge is used as a fertilizer for growing crops for both human consumption and feed production, a strong emphasis is placed on biological and chemical safety of this material (Roig et al., 2012). When waste is used for soils reclamation to the specific needs, its physical parameters may play a more important role. However, in both cases, you cannot afford to too large, uncontrolled amounts of potentially harmful chemicals seeping into the soil or groundwater (Houillon and Jolliet, 2005). Compounds such as