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Polish experience in operation of sludge treatment reed beds

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ABSTRACT

Sludge Treatment Reed Beds (STRBs) is the technology of sludge treatment, which is based on natural processes occurring in the environment, in specially designed and operated facilities to achieve benefits for the environment. Integrated dewatering and stabilization occur in reed systems. For economic and environmental reasons it is an attractive solution, especially in rural areas where there are no appropriate facilities.

In the recent years many European countries like Denmark, France or Germany have applied this technology for sewage sludge management. Poland has also some experience in dewatering and stabilization of sewage sludge in STRB systems.

The objective of the paper is to present the current experience and lessons learned from the operation and to assess the quality of sewage sludge from STRBs in Poland.

The analyzed sewage sludge was treated in STRBs located in five wastewater treatment plants: Darżlubie, Swarzewo, Zambrów, Nadole and Gniewino, Poland. Two from the analyzed systems (Darżlubie and Swarzewo) worked only in a pilot scale and three of them (Darżlubie, Swarzewo and Nadole) did not work any longer. In the collected samples of sludge the evaluation of dewatering and stabilization processes, fertilizer properties, as well as heavy metals concentrations were determined.

The average dry matter content in sludge treated in Polish STRBs was from 11.2 to even 53.7%. The degree of mineralization in analyzed systems was from 31.4 to 68.6%. The average nutrient contents was for nitrogen from 1.0 to 10% DM and for phosphorus from 0.2 to 1.0% DM.

The conducted research confirms that sludge treated in STRBs is dewatered and stabilized, thus it could be used as a fertilizer in agriculture.

1. Introduction

Sewage sludge is a by-product of wastewater treatment processes. The systematic increase of sludge quantity has been observed for years (CSO, 2013). It is supposed that this trend will be maintained in the coming years due to the increased demand for the improvement of the quality of treated wastewater (NWMP, 2014). In the past in small and medium-sized WWTPs sewage sludge management was mostly limited to its storage. However, since 2016 this kind of management has been forbidden (MoE, 2015b).

In Poland in recent years 13 facilities for thermal utilization of sludge have been built. However, due to very high cost this method is available only for very big WWTPs (approximately 500,000 pe – person equivalent). It is recommended that valuable elements (for example nutrients) from sludge from small and medium-sized WWTPs should be reused in the environment (NWMP, 2014).

One of the methods of sludge utilization is composting. However, this method generates costs (connected with the purchase of structural material) which are often too high for small WWTPs. What is more, the quality of compost is very often not adequate for agricultural application and it can only be used for non-agricultural purposes. Then, the ratio of preparation of the material and the potential cost of the final product is not justified economically.

Another technology to treat sewage sludge is called Sludge Treatment Reed Beds (STRBs). Reed systems for sludge treatment stimulate natural processes occurring in the environment in specially designed and operated facilities to achieve benefits for the environment. Integrated dewatering and stabilization occur in reed systems.

STRBs are typically built as ground facilities with horizontal layers of gravel and sand, mostly planted with reed. It is very important to build the drainage system connected with ventilation chimneys. It prevents the formation of anaerobic conditions and provides proper conditions for dewatering and stabilization of sludge. During the operation of STRBs there are three periods (commissioning, full operation and emptying) (Kołecka and Obarska-Pempkowiak, 2008, 2013; Nielsen, 2003, 2011). During the first period of the operation –

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commissioning (which lasts for about 2 years), the dose of dry matter of sludge should be lower than the designed values (Nielsen, 2003). During operation reed systems are periodically irrigated with sewage sludge with low dry matter content (from 0.5% to 1.5%). The resting periods (breaks in sludge supply) may take several days, depending on the weather conditions, the age of the system and the dry matter content in sludge, as well as thickness of the accumulated sludge (Nielsen, 2003). Before emptying the bed should not be used for some time (preferably in summer) to increase the content of dry matter and improve its sanitary properties (Kołecka and Obarska-Pempkowiak, 2013; Nielsen, 2003; Troesch et al., 2009).

It is estimated that the maintenance cost of STRBs is only 10% of the cost of the traditional solution used for sludge management (Nielsen, 2015). Additionally, it is environmentally friendly technology which does not need the use of additional chemicals (e.g. coagulants or polyelectrolytes) and is characterized by low emission of gases (Brix et al., 2001; Kołecka and Obarska-Pempkowiak, 2013; Olsson et al., 2014; Uggetti et al., 2012). Therefore, it is an attractive solution for economic and environmental reasons, especially in rural areas.

STRBs have been used in many countries, for example about 105 reed systems were built in Denmark and 120 in France. These systems work also in Germany, Italy and Spain (Brix, 2017; Nielsen et al., 2014; Troesch et al., 2009; Uggetti et al., 2010). In Poland there is some experience in dewatering and stabilization of sewage sludge and septage in STRBs (Kołecka et al., 2017; Karolinczak and Dąbrowski, 2017; Obarska-Pempkowiak et al., 2003, 2015a,b; Pempkowiak and Obarska-Pempkowiak, 2002).

Based on years of research in Denmark, France, Spain, Italy and Poland (Kołecka and Obarska-Pempkowiak, 2008; Kołecka et al., 2017; Nielsen, 2003, 2011; Troesch et al., 2009; Uggetti et al., 2010, 2012) recommendations for the construction of STRBs were established. The main design factor is the sewage sludge loading rate (Uggetti, et al., 2010). This value for secondary sludge is approx. 60 kg DM (dry matter)·m^{-2}·$year^{-1}$. In case of sludge with high content of fat or fermented substances the recommended loading rate is lower and equal to 50 kg DM·m^{-2}·$year^{-1}$. To provide sufficient time for the transformations of accumulated sludge, the system of STRBs should consist of several beds. More beds ensure longer resting period between supplying sludge, which leads to the improvement of efficiency in dewatering and stabilization of sludge. Sludge is supplied until the system reaches its full capacity. The stabilization period is usually from 8 to 12 years.

The aim of the paper is to present the current state and experience of Polish STRBs. The main focus was on the quality of the achieved material and its fertilizing value. The novelty of the paper is presentation of entirety of experiences from Polish STRBs, which has not been elaborate yet. Based on carried out investigations and collected data, as well as experiences lessons learnt have been prepared.

2. Material and methods

The analyzed sewage sludge was dewatered and stabilized in STRBs located in the northern part of Poland. Some of them worked only in pilot scale. The characteristics of this system is presented in Table 1.

Three systems (located in Darżlubie, Swarzewo and Nadole) are not in operation any longer. In case of Darżlubie and Nadole the WWTPs were closed due to the modernization of wastewater treatment, namely the connection of the catchment area of the treatment plant to a larger plant. Wastewater from WWTP in Darżlubie was connected to the municipal sewage system and was discharged to the bigger WWTP located in Swarzewo. The same was in case of Nadole, where the wastewater was discharged to WWTP in Gniewino in 2010. In 1997 the layer of sludge of about 4.5 m high in Swarzewo was discharged to the reed system as a result of operation problems in WWTP. This extremely excessive load caused serious damage in reed and destroyed the system. The reed system was not reconstructed. Now sludge in Swarzewo is composted. Zambrów basin with reed is still in operation and this year WWTP is going to remove the sludge residue. The facility in Gniewino is also still in operation and the next new three beds planted with reed will be built to meet the requirements.

In the analyzed facilities the loading of sludge was below the recommended values or exceeded them insignificantly (Zambrów). Some operation problems in the pilot system were probably caused by a low number of beds. Additionally, at least 8–12 years of operation are needed to ensure right dewatering and stabilization. In the pilot systems the time of sludge treatment was much shorter.

In the paper the following properties of sludge were analyzed: dewatering and stabilization process, as well as the fertilizing potential. To estimate the above-mentioned properties, dry and organic matter content, as well as nitrogen, phosphorus and heavy metals concentrations were determined. The whole research was carried out according to Polish Standards (PN-C-04537-14, 1998; PN-EN 12879, 2004; PN-EN 16169, 2012; PN-EN 13657, 2006) and APHA (2005). The determinations of the selected heavy metals in the sludge were made by using atomic absorption after their mineralization.

The degree of mineralization was calculated as (Podedworna and Umiejewska, 2008):

$$M = 100 - \left(\frac{m.\,d.\,m_0 \cdot o.\,d.\,m_s}{o.\,d.\,m_0 \cdot m.\,d.\,m_s} \right) (\%)$$

where:

$o.d.m_0$ – organic dry matter at the beginning of the process, % DM
$o.d.m_s$ – organic dry matter after stabilisation, % DM
$m.d.m_0$ – mineral dry matter at the beginning of the process, % DM
$m.d.m_s$ – mineral dry matter after stabilisation, % DM

The quality of sludge from the three facilities (Darżlubie, Swarzewo, Zambrów) was presented based on the data from literature. Additionally, the quality of sludge treated in STRBs in Nadole and Gniewino was determined in the laboratory of Faculty of Civil and Environmental Engineering at Gdańsk University of Technology.

The samples of sludge from STRBs in Gniewino and Nadole were collected 3 times from the selected bed in six points by using of a special probe (Kołecka and Obarska-Pempkowiak, 2008, 2013). STRB in Gniewino treats sludge all the time while raw sludge was not discharged for 3 years in the facility in Nadole. Then the samples of sludge were averaged for analysis. In Gniewino and Darżlubie the samples of sludge were collected along the vertical profile. The profile was divided into the top and the bottom layer. Sludge from the bottom layer was treated longer than sludge from the top layer.

3. Results and discussion

3.1. Dewatering processes

In Poland, the average summer temperature is between 16 °C and 20 °C and between −6 °C and 0 °C in winter. The average annual air temperature is 7–9 °C (excluding mountain areas). The average rainfall is about 600 mm per year. The rainfall distribution is uneven throughout the year, 2/3 of annual precipitation is in summer (http://www.imgw.pl/). The climate conditions are similar to Denmark and they do not have any negative effect on the dewatering process.

In all analyzed STRBs the discharged sludge had high content of water, which amounted from 95 to 99%. The highest content of the dry matter was found in sludge from Nadole (Table 2). Effective dewatering, higher than from mechanical equipment, which is maximum 40%, has been obtained due to long time of operation. Also the time when sludge was not discharged has an impact on dewatering processes. The highest content of the dry matter (53.7%) was observed in Nadole, which has the longest resting period (3 years). The lower content of dry matter was found in the sludge from Gniewino (11.2%),