

SEWAGE SLUDGE MANAGEMENT IN A SEWAGE TREATMENT PLANT

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Abstract

Sewage sludge produced in municipal sewage treatment plants, because of its physicochemical and sanitary properties, is a serious threat to the environment. In order to neutralize it, various methods of processing are used, which directly affect the quantity and quality of produced sewage sludge, which in the final stage can be used naturally. Properly managed sludge management is presented on the example of a sewage treatment plant, conducting the methane fermentation process with the production of biogas.

Keywords: sewage sludge, biogas, sewage treatment plant

1. INTRODUCTION

The indispensability of conducting sludge management in sewage treatment plants is closely related to their operation. Sewage sludge is formed as a product in the sewage treatment process and then undergoes appropriate treatment mechanisms. In the final stage, it must be properly disposed of or managed [6, 9]. One of the basic and cheapest forms of sewage sludge management is its agricultural use, because it has soil-forming and fertilizing features. Before being used, it must not be characterized by odour nuisance, the presence of pathogenic organisms and the unacceptable content of heavy metals for this purpose.

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The legal act that regulates the possibility of agricultural use of sewage sludge for the aforementioned properties is the Regulation of the Minister of the Environment of 6 February 2015 on municipal sewage sludge (Journal of Laws of 2015 item 257) [2, 4, 6, 10].

Effective stabilization, hygienisation and drainage of sludge depend strictly on the direction of sewage sludge neutralization. The most popular way is to conduct anaerobic stabilization in closed fermentation chambers. In addition to decomposition of organic compounds, the reduction of odour nuisance and the inactivation of pathogenic organisms, a parameter that significantly affects the universality of this method, can be done by the production of high-energy biogas. Appropriate processing of fermentation gas allows to significantly cover the energy demand of sewage treatment plants [1, 3, 6, 7, 8].

This article presents a process of treatment of sewage treatment plant sludge with methane fermentation along with the quantity and properties of primary, secondary, digestate and dehydrated sludge. The amount of biogas produced along with the amount of energy produced was also presented, which was used to prepare the energy balance. The properties of sludge classified in terms of the content of pathogenic organisms and heavy metals were also compared with the Regulation of the Minister of Environment of 6 February 2015 in order to determine the possibility of further use of sewage sludge in agriculture. Data refer to the period from 2015 to 2016 [10].

2. SEWAGE SLUDGE TREATMENT PROCES

Operation of sewage treatment plants includes clarification of municipal sewage in physical, chemical and biological processes. By adopting certain assumptions regarding the quantity and quality of raw sewage, a mechanical and biological treatment plant with increased biogen removal was selected and built. The sewage treatment process consists of a mechanical part consisting of elements such as grilles, an aerated sand trap with a grease trap and a longitudinal pre-settling tank as well as a biological part comprising a biological reactor and two secondary settling tanks. In addition to the sewage treatment process, there is also a sewage sludge treatment process. The scheme of sewage treatment and sewage sludge treatment is presented below (Fig.1).

After the processes of dephosphatation, nitrification and denitrification in the biological reactor (BR), part of the biological mass is sent back into the recirculation cycle and as the so-called recirculated sludge is subjected to mixing in the separation chamber before the biological reactor. The remaining amount of the biological mass is excluded from the process and as the so-called excess sludge is directed to further processing. Due to high hydration, excessive sludge is concentrated in mechanical sieve drums. Subsequently, it is mixed with the pre-

settling sludge coming from the settling tank, in the gravity pre-concentrator, and the so-called leachate (sludge supernatant) is directed to the process water tank. Next, the thickened raw sludge is sent back to the closed fermentation chamber (CFC) to reduce the amount of organic matter, the level of pathogenic organisms and the ability to rot. During the anaerobic digestion process (about 20 days), the sludge is stabilized, and biogas is also released, which is used to generate heat and electricity.

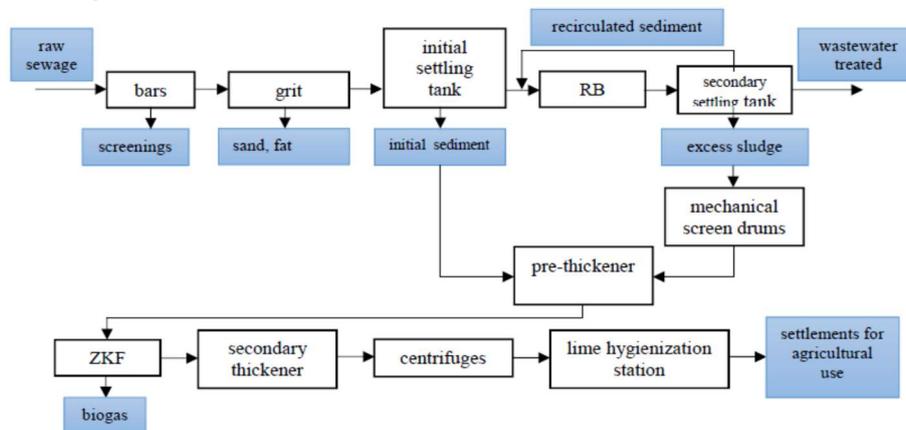


Fig. 1. A wastewater treatment sequence including treatment of sewage sludge

The fermented sewage sludge in the secondary gravity thickener is again compacted, and then dehydrated in two centrifuges. In the final section of the technological process of sludge processing, it is hygienized with highly reactive lime and directed to agricultural use.

3. QUANTITATIVE AND QUALITATIVE BALANCE OF SEWAGE SLUDGE

In sewage treatment plants, several types of sludge are formed with different properties after successive stages of sewage clarification, i.e. initial and excessive sludge, and during treatment and disposal of sewage, i.e. condensed excess sludge, fermented and dehydrated sludge. Their parameters are the percentage content of the organic part [%], and the value of the dry residue, expressed in kg/m^3 . Measurements were performed up to 3 times each month. The results of the quantity and quality of individual types of sewage sludge in 2015-2016 are presented in the tables below.

Table 1. The amount and quality of initial sludge in 2015 and 2016 [5]

Year	Quantity	Average (about)	The range of organic content	The range of dry residue
-	m ³	m ³ /d	%	kg/m ³
2015	23334	64	69-80	16-31
2016	20219	55	75-79	11.3-26.4

In 2016, 3115 m³ less initial sludge was created than in 2015. The monthly range of sludge produced ranged from 1728 to 2794 m³ (2015) and from 1299 to 1970 m³ (2016).

Table 2. Quantitative parameters of excessive sludge before and after compaction

Year	Excessive sludge		Concentrated excess sludge		The range of monthly volume reduction
	Quantity	Average (about)	Quantity	Average (about)	
-	m ³	m ³ /d	m ³	m ³ /d	%
2015	38335	105	12691	35	48-76
2016	49933	136	13906	38	55-80

Excessive sludge must be compacted in mechanical sieve drums due to the low dry matter content in order to mix it with the initial sludge. The results of sludge volume reduction before and after compaction are shown above.

In a sewage treatment plant, due to the presence of two secondary settling tanks, more excess sludge than initial sludge from one settler is produced. The monthly range of sludge produced ranged from 2000 to 5867 m³ (2015) and from 2023 to 6130 m³ (2016). For mechanically compacted sludge, these values oscillated successively from 837 to 1458 m³ (2015) and from 829 to 1744 m³ (2016).

In 2015, 11598 m³ less excess sludge and 1215 m³ less of mechanically compressed sludge was formed less than a year later. Dry residue oscillated in the range from 28 to 35 kg/m³ for excess sludge, and for compacted sludge from 33 to 48 kg/m³ in 2015. In 2016, it was successively between 28-33 kg/m³ and 31-54 kg/m³. The range of the organic content in 2015 for excess sludge was 70 to 78%, and for condensed one from 69 to 74%. The following year, it was successively in the ranges of 76-78% and 74-77%. The reduction process has little effect on the organic content percentage.

During the treatment of sludge, also fermented and dehydrated sludge is formed. After the anaerobic fermentation process, more specifically mesophilic fermentation, it is dehydrated with the effect of levelling the volume. The quantitative parameters are presented below.

Table 3. Quantitative parameters of fermented and dehydrated sludge with volume reduction

Year	Fermented sludge		Sludge is dehydrated		The range of monthly volume reduction
	Quantity	Average (about)	Quantity	Average (about)	
-	m ³	m ³ /d	m ³	m ³ /d	%
2015	41254	113	2306	6	93-97
2016	39682	108	2769	8	91-95

The monthly range of fermented sludge produced ranged from 2727 to 3995 m³ (2015) and from 2516 to 3826 m³ (2016), and for the dehydrated - 131-239 m³ (2015) and 179-284 m³ (2016). The dry residue remained in the range from 16.7 to 18.5 kg/m³ (2015) and from 16.8 to 19.4 kg/m³ (2016) for fermented sludge, and for dehydrated from 190 226 kg/m³ (2015) and from 183 to 211 kg/m³ (2016).

The value of dry residue in a given period for dehydrated sludge was from 10 to even 13 times higher than for fermented sludge. The process of treatment of sludge in the sewage treatment plant allows effective reduction of volume and hydration, while increasing the dry matter.

4. ENERGETIC EFFICIENCY

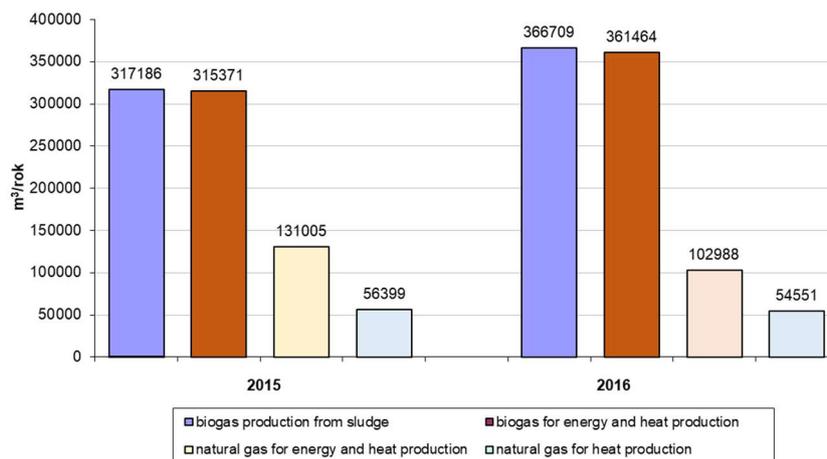


Fig. 2. The amount of biogas and natural gas [5]

During the process of anaerobic stabilization of sewage sludge taking place in a closed fermentation chamber, biogas is released. The receivers of the produced biogas are two combustion engines with a capacity of 230 kW (also using natural gas) and 220 kW, a central heating boiler and a torch for burning excess gas. In 2015, 317186 m³ was produced, and in 2016, in turn, 366709 m³ of biogas from fermenting sludge. The average amount of biogas produced in a given period was, in turn, approx. 869 m³/d and around 1002 m³/d. The figure below shows the amount of biogas and natural gas used in generating energy and heat.

In 2015, 1815 m³ of biogas was burnt in the torch and 5245 m³ in 2016. From the burnt biogas and natural gas, 1089568 kWh (2015) and 1112036 kWh (2016) of electricity and heat were produced respectively. These quantities have an impact on the energy balance of the sewage treatment plant (Figure 3). Energy self-sufficiency based on own production and purchased energy in relation to total electricity consumption, amounted to approx. 59% in 2015 and approx. 67% in 2016.

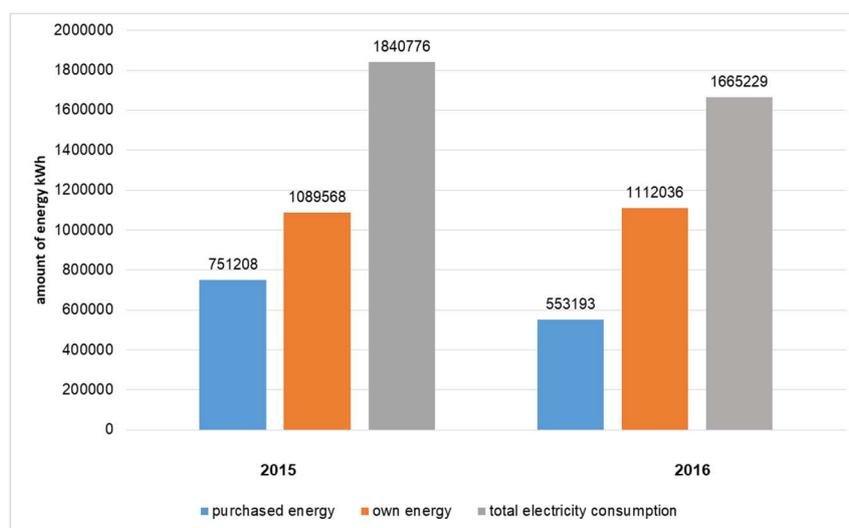


Fig. 3. Energy balance of sewage treatment plant in 2015-2016 [5]

5. THE FINAL MANAGEMENT OF SEWAGE SLUDGE

Sewage sludge, after the densification step, anaerobic stabilization and dehydration, is subjected in the final stage of hygienization with high-reactive lime. Through the use of this process, pathogenic organisms contained in sludge are destroyed. To be used for agricultural purposes, the produced sediments must be subjected to quality tests and therefore, their samples are subjected to analysis

in accredited laboratories. Tests in terms of physico-chemical properties and the presence of pathogenic organisms are carried out. The most important, however, are those concerning the content of heavy metals, the presence of pathogenic bacteria from the *Salmonella* genus and the number of living eggs of intestinal parasites *Ascaris* sp., *Trichuris* sp. and *Toxocara* sp. Their acceptable contents in sewage sludge for agricultural use are regulated by law and included in the Regulation of the Minister of the Environment of 6 February 2015 (Journal of Laws of 2015 item 257) on municipal sewage sludge. Quality tests were carried out once every 4 months. Their results relate to the period 2015-2016 and are presented below together with the admissible value.

Table 4. The results of measurements of heavy metals content in stagnant sediments [11]

Determined heavy metal	Unit	23.02. 2015	21.07. 2015	03.12. 2016	31.03. 2016	10.08. 2016	23.02. 2015	Permissible content
Cadmium	mg/kg d.m.	7.07	1.18	1.5	1.07	1.28	1.09	20
Copper	mg/kg d.m.	66.6	376	375	276	365	374	1000
Nickel	mg/kg d.m.	14.2	24	19.8	21.6	17.6	22.5	300
Lead	mg/kg d.m.	32.1	46.3	36.5	34.1	48.7	38.4	750
Zinc	mg/kg d.m.	595	1257	1241	1010	1320	1160	2500
Mercury	mg/kg d.m.	<0.05	0.93	0.77	0.65	0.68	2.05	16
Chrome	mg/kg d.m.	14.7	28.3	26.6	23.7	20.4	23.5	500

Salmonella bacteria were not isolated in the tested samples, and the total number of live intestinal parasitic eggs *Ascaris* sp., *Trichuris* sp., *Toxocara* sp. in 1 kg of dry matter amounted to 0. The results of measurements of other physico-chemical parameters of sewage sludge are presented below.

Table 5. Results of other physicochemical measurements [11]

Marked parameter	Unit	23.02. 2015	21.07. 2015	03.12. 2016	31.03. 2016	10.08. 2016	23.02. 2015
pH	-	8.4	11.8	8	8	7.6	7.9
dry weight	% d.m.	15.9	19.7	16.9	20.3	14.7	12.8
organic substance	% d.m.	72.4	66.2	68.5	73	66.3	65.6
general phosphorus	% d.m.	2.59	2.61	2.55	1.65	2.41	2.51

calcium	% d.m.	1.82	3.66	3.15	2.35	3.11	3.1
magnesium	% d.m.	0.59	0.5	0.51	0.4	0.57	0.66
content of ammonium nitrogen	% d.m.	0.59	0.61	0.56	0.8	0.4	0.7
total nitrogen content	% d.m.	5.32	5.3	4.92	5.62	4.65	5.23

Based on the results of the research, it was found that sewage sludge produced in the sewage treatment plant is safe in terms of physicochemistry and sanitation for use in agriculture, as well as for land reclamation. Sludge is not stored in any way, it occurs in the form of earth and is managed in the area of nearby villages.

6. FINAL CONCLUSIONS

Sludge treatment processes in sewage treatment plants reduce its mass and volume while increasing the dry matter content as well as reduce the amount of pathogenic organisms and the ability to emit odours.

The amount of biogas and natural gas produced in 2015 allowed for covering the level of total energy demand of the treatment plant at the level of 59%, and in 2016 at the level of 67%.

The analysis of the results of the physicochemical and sanitary parameters, in particular the content of heavy metals and pathogenic organisms in the sewage sludge, allowed to determine their compliance with the admissible values contained in the Regulation of the Minister of Environment of 6 February 2015 (Journal of Laws of 2015, item 257) in terms of the use of municipal sewage sludge in agriculture.

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