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Thermal utilization and agricultural use of sewage sludge in Poland

According to the Polish law, sewage sludge is regarded as a waste and in 95% is stored on a disposal sites after previous dewatering. Poland belongs to the group of European countries that hardly utilize sewage sludge as a resource. Only 0.5% of sewage sludge undergoes thermal treatment by incineration or co-incineration with other waste, of which sewage sludge comprises only a slight amount. Only 4.5% of sewage sludge is used as a valuable fertilizer to agricultural and natural purposes, which puts us at the bottom of the list of European countries in relation to utilization of such sludge as a valuable source of biogenic elements. In the paper the general characteristic of sewage sludge in the aspects of its potential thermal, agricultural and natural usage is presented. On the example of three wastewater treatment plants the final utilization of sewage sludge together with its thermal treatment and burning in one of the plants is characterized. Examinations of analyzed sludge from two wastewater treatment plants displayed the possibility of application of the sewage sludge to cultivation of non-comestible plants or reclamation of degraded land. High content of organic compounds and adequately low final hydration of sewage sludge from examined wastewater treatment plant created the possibility of its burning and co-burning, which is presented in the paper.

Keywords: **sewage sludge, thermal disposal of waste, management of natural deposits**

Introduction

Due to the diverse composition and properties, sewage sludge can be utilized and applied in number of ways. Currently, the most common application of sewage sludge is for agricultural and landscape purposes. Other alternative applications include incineration of sewage sludge. At present, there are several incineration facilities for utilization of sewage sludge in Poland.

The rising number of new wastewater treatment plants and the intensification of wastewater treatment processes result in the increase in the quantity of sewage sludge which are estimated at 1÷2% of the total volume of wastewater discharged to a wastewater treatment plant. In this context, sewage sludge is treated as a substrate of potential fertilizer or energy value allowing for partial cost recovery [1, 2].

Sewage sludge is characterized by the chemical composition of dry matter, organic and mineral matter content in dry matter, moisture content, and also technological properties (which derive from the chemical composition of sewage

sludge), i.e. calorific value, ability to dehydrate, rheological properties (including a possibility of sewage sludge transportation using pipelines) [3].
With reference to the composition, sewage sludge can be compared to organic fertilizers applied in agriculture, i.e. manure, fermented and unfermented liquid manure. The effect of organic fertilizers on soil properties was identified due to the following facts [4]:

- organic fertilizers are the important source of humus in soil, higher content of humus in soil results in the increase in the sorption capacity of soil,
- only organic fertilizers can improve other soil properties such as the structure, water capacity, etc.
- organic fertilizers are the source of nutrients and energy for soil microorganisms,
- organic fertilizers mitigate the negative effect of unbalanced mineral fertilization and strong acidification,
- organic fertilizers are almost the only source of microelements.

Table 1

The percentage of selected methods applied for the utilization of municipal waste in the EU countries and Poland

EU member countries UE - 15	Recycling and composting %	Landfilling %	Incineration	
			%	Number of incineration facilities
Austria	59	31	10	5
Belgium	52	13	35	18
Denmark	41	5	54	31
Finland	28	63	9	1
France	28	38	34	123
Greece	8	92	0	0
Spain	38	55	7	28
Holland	65	3	32	11
Ireland	31	69	0	0
Luksemburg	36	23	41	1
Germany	58	20	22	58
Portugal	3	75	22	3
Sweden	41	14	45	11
Great Britain	18	74	8	15
Italy	32	57	11	48
Poland	4,5	95	0,5	1

For many years sewage sludge was discharged to soil in uncontrolled manner disturbing the natural trophic chain. However, sewage sludge can be a valuable product with a number of well-defined properties if a proper and controlled application of sewage sludge to soil is ensured [5, 6].

Incineration facilities for utilization of sewage sludge are common in highly developed countries with high population density. This particularly applies to these countries which have large urban agglomerations. Incineration of sewage sludge is mainly applied by: Japan (55% of the total quantity of sewage sludge), Denmark and Canada (over 40%), France, Switzerland, Germany, the United States (over 30%). In Poland only 0.5% of sewage sludge is subjected to thermal utilization (Table 1) [7, 8].

1. Legal regulations for the application of sewage sludge for energy recovery and fertilization in Poland

The process of thermal conversion of waste has to fulfill specific requirements. With reference to the directive on waste from April 27, 2001 (Official Journal No. 62 item 628 from June 30, 2001), waste is defined as any substance or object classified into one of the categories listed in the appendix No. 1 which the owner disposes or intends to dispose or is obliged to dispose of. In terms of thermal conversion of waste this definition also applies to sewage sludge. The requirements for thermal conversion of waste are provided by the Decree of the Minister of Economy from March 21, 2002 on the requirements for thermal conversion of waste (Official Journal No. 37, item 339).

According to this decree during the process of thermal conversion of waste, herein referred to as "process", the minimal temperature in the incineration chamber can not be lower than:

- 1100°C - for waste containing more than 1% of chlorinated organic compounds (expressed as chlorine),
- 850°C - for waste containing up to 1% of chlorinated organic compounds (expressed as chlorine).

This process should be conducted in a manner to ensure that exhaust gases in the incineration chamber are kept for 2 s at the oxygen concentration of at least 6%.

Thermal conversion of waste should result in the adequate level of waste conversion expressed as the maximal content of unoxidized organic compounds. The indicators of unoxidized organic compounds include (according to the Polish Standards):

- the total content of organic carbon in slag and furnace ash not exceeding 3%,
- the percentage of flammable materials in slag and furnace ash not exceeding 5%.

With reference to the directive on waste from April 27, 2001 (Official Journal from 2001, No. 62, item 628 with later amendments) and the Decree of the Minister of Environment from August 1, 2002 on municipal sewage sludge (Official Journal from 2002, No. 134, item 1140), the following facts can be formulated:

a) Sewage sludge in Poland can be applied to soil with pH less than [5, 6]. The content of heavy metals in sewage sludge should not exceed the standards provided by the Decree of the Minister of Environment. Municipal sewage sludge should fulfill the sanitary standards provided by the above mentioned Decree.

b) Farmers who apply sewage sludge to soil should have a specific plan of fertilization with the quantities of nutrients contained in the proposed doses of sewage sludge intended for agricultural applications. This plan should also include the complete analysis of soil performed before sewage sludge was applied to soil.
c) The application of sewage sludge to soils with plants and crops intended for human consumption is forbidden.
d) Producers of sewage sludge should provide a detailed specification for the produced sewage sludge to farmers.

2. Technologies for thermal utilization of sewage sludge applied in Poland

According to Table 1, only 0.5% of waste in Poland is subjected to thermal conversion. Still, the most common method of the final utilization of sewage sludge is landfilling (95% of the total quantity of waste).

In Poland (despite small local incineration facilities such as the incineration plant for sewage sludge in 'Dębogóra' near Gdynia) there is only one incineration plant for municipal waste located in Warszawa and two incineration plants for hazardous waste located in Dąbrowa Górnicza i Płock. The Utilization Plant for Solid Municipal Waste (Zakład Unieszkodliwiania Stałych Odpadów Komunalnych - ZUSOK) in Warszawa provides thermal conversion and composting of waste. It is also the first power plant in Poland which is fired with municipal waste. Further more, this plant provides:

- segregation of waste with recycling of secondary materials,
- thermal conversion of waste not intended for recycling,
- composting of waste organic fractions,
- processing of slag and ash generated during the incineration process into aggregates harmless to the natural environment,

  production of electrical energy.

The plant receives about 110 000 Mg of solid municipal waste per year intended for total utilization. About 47 000 Mg of waste is incinerated. The integrated segregation lines process up to 375 Mg raw waste during two shifts. Incineration is conducted in a grate furnace where waste is neutralized in the temperature of 850÷1150°C [9].

The incineration plant for hazardous waste SARPI in Dąbrowa Górnicza is the most modern and largest incineration plant for hazardous waste and other waste in Poland. The plant provides complex services to industry, institutional and individual clients. The technological process is combined with the energy recovery which ensures ecological safety at all stages of waste utilization. The plant has been operating since 1993. However, the installation for thermal conversion was started in 2003. This installation allows for the utilization of over 800 waste categories including 339 categories of hazardous waste. The incineration process is conducted in the set of a rotary furnace and an after-burning chamber [10].

Started in 2008, the thermal installation for hazardous waste conversion ORLEN Eko in Płock is the most modern incineration plant with the capacity of 50 000 tones of dewatered sludge per year. Four types of sewage sludge are utilized there, i.e.: (1) oily sewage sludge from mechanical and physical-chemical treatment of refinery wastewater, (2) excessive sewage sludge from activated sludge chambers, (3) floating surface scum and (4) dried municipal sewage sludge provided by external suppliers. The mixture of dewatered sewage sludge in the decantation centrifuges is fed to two automated lines for incineration in furnaces with a fluidized bed. Each incineration line has the nominal capacity of 3110 kg of load per h. The installation for thermal conversion of hazardous waste using the technology of incineration in a fluidized furnace PYROFLUID™ is the first installation of that kind constructed and operated in Poland. It is also the most modern incineration plant for hazardous waste in Poland [11].

3. Application of sewage sludge for fertilization in Poland

The content of organic matter, nitrogen, phosphorous, microelements and also toxic substances present in sewage sludge determine the soil-forming and fertilization value of sewage sludge. Sewage sludge is considered a reservoir of organic matter and nutrients for plants [12, 13]. The most important nutrients are nitrogen and phosphorous. In most cases sewage sludge shows neutral or alkaline reaction which often results from high contents of calcium and magnesium. The acidification of soils in Poland is common, thus the presence of these elements is beneficial in terms of soil fertilization (Table 2) [14].

Table 2

The chemical composition of sewage sludge, % dry matter

Composition	According to the following authors		
	C. Maćkowiak [15]	J. Cebula [16]	E. Roszyk [14]
Organic matter	17÷74	43÷73	22÷87
Nitrogen	0.6÷3.9	0.6÷5.3	0.3÷2.3
Phosphorous	0.3÷1.7	0.3÷2.3	0.1÷5.0
Potassium	0.05÷0.57	0.03÷0.09	0.08÷0.37
Calcium	0.1÷2.9	0.6÷6.2	0.1÷5.1
Magnesium	0.4÷0.6	N/D	0.2÷5.1
pH	7÷8	6.0÷7.2	5.0÷8.4

The project proposal on ‘the Polish code for good agricultural practice’ assumes that the annual dose of nitrogen per hectare of cropland can not exceed 170 kg. This dose can be applied to soil annually providing that other fertilizers containing nitrogen are not applied. Due to the fact that sewage sludge is an organic fertilizer and similarly as manure can be applied once in 3 or 4 years.

The easiest method for utilization of stabilized sewage sludge is the application of sewage sludge to landscapes. However, the investigations on the fertilization efficiency of sewage sludge did not provide expected results. The fertilization efficiency of sewage sludge is low and the utilization of nutrients is also insufficient.
In Poland most sewage sludge after dewatering is landfilled. Only 4.5% of sewage sludge is recycled or composted. Insignificant application of sewage sludge to landscapes proves that sewage sludge is considered as waste not as a valuable fertilizer (Table 3).

Table 3

The comparison of agricultural value for sewage sludge and other organic fertilizers

Fertilizers	Average moisutre content %	Content (per dry matter) %				N:P_2O_5:K_2O ratio		
		Total N	N-NH_4^+	P_2O_5	K_2O	N	P_2O_5	K_2O
1. Fresh horse manure	71.3	2.02	0.48	0.98	1.85	2	1	1.9
2. Semi-fermented horse manure	77.0	2.39	0.04	1.08	3.04	2.12	1	2.8
3. Fresh cattle manure	77.5	2.0	--	1.02	2.22	2	1	2.2
4. Municipal waste	54	1.64	0.01	1.0	0.30	1.6	1	0.3
5. Screenings	77.0	3.1	0.08	2.9	--	1,1	1	--
6. Sewage from mechanical settling tanks	70.0	3.2	0.09	1.6	0.15	2	1	0.09
7. Fermented sewage sludge	70.0	3.2	0.02	2.4	0.20	1.3	1	0.08
8. Fresh activated sewage sludge	92.0	8.1	--	2.5	0.35	3.2	1	0.14

For example, sewage sludge obtained from the wastewater treatment plant "Repty" in Tarnowskie Góry (Silesia province) can be applied to amend soils for various purposes given in the waste management strategies, to cultivate plants intended for compost and plant not intended for human consumption and production of feed. Sewage sludge can also be used for reclamation of non agricultural land and also in agriculture for reclamation of arable soil. However, sewage sludge from the wastewater treatment plant "Miasteczko Śląskie" and "Leśna" in Tarnowskie Góry can be used to amend soils for particular purposes according to the waste management strategies, to cultivate plants intended for production of compost, to cultivate plants not intended for human consumption and production of feed, and also to reclamate non agricultural land. This sewage sludge can not be used for agricultural purposes and to reclamation arable soils as permissible values of cadmium stated in the Decree of the Minister of Environment from August 1, 2002 on municipal sewage sludge were exceeded. These wastewater treatment plants represent a small group of wastewater treatment plants in Poland which generate sewage sludge that can be used for agricultural and landscape purposes [17].

Summary

With view to the final method of utilization, sewage sludge should be subjected to adequate processing. Sewage sludge used for agricultural purposes must fulfill a number of requirements and the content of heavy metals can not exceed the standards provided in the Decree of the Minister of Environment from August 1, 2002 on the municipal sewage sludge.
Due to the possible occurrence of various contaminants, the utilization of sewage sludge has to be thoroughly controlled. Only complete control of the utilization process based on the physical-chemical and microbiological analysis of sewage sludge can assure that the application of sewage sludge to agricultural soils will not result in deterioration of the quality of soil, surface and underground water. Giving the properties and the composition, sewage sludge can be applied for agricultural and landscape purposes. This is observed for sewage sludge generated in the wastewater treatment plant in Tarnowskie Góry.

The number of incineration plants in Poland is insignificant. The most well-known incineration plant of sewage sludge is the incineration plant "Dębogóra" near Gdynia. The plant capacity is about 80 tones per day. The ash from the incineration process is landfilled in the wastewater treatment landfill with the area of 25 000 m^2. The area of the landfill is protected from the contamination of groundwater by two layers of geomembrane where the deposited ash is sprinkled with water to prevent from dusting [18].

At present, sewage sludge in Poland is more often treated as a substrate rather than waste. After thorough analysis of physical-chemical composition, sewage sludge can be considered a valuable source of nutrients and energy rather than waste deposited at landfills. Currently, other methods for the utilization of sewage sludge include composting as well as incineration and incineration combined with other energetic materials.

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Termiczna utylizacja i rolnicze wykorzystanie osadów ściekowych w Polsce

Osady ściekowe w Polsce, zgodnie z Ustawą o odpadach, traktowane są jako odpad i 95% po uprzednim odwodnieniu jest deponowane na składowiskach odpadów. Ten sposób unieszkodliwiania stawia nas w czołówce krajów europejskich, traktujących osady ściekowe jako bezużyteczny odpad. Tylko 0,5% odpadów w Polsce przekształcanych jest termicznie w wyniku procesu spalania czy też współspalania z innymi odpadami, z czego osady ściekowe stanowią znikomą ilość. Jako cenny nawóz osady ściekowe tylko w 4,5% wykorzystywane są w celach rolniczych i przyrodniczych, co również stawia nas w czołówce krajów europejskich pod względem niewykorzystania tego rodzaju odpadów jako cennego źródła pierwiastków biogennych.

W artykule przedstawiono ogólną charakterystykę osadów ściekowych pod kątem możliwości termicznego, rolniczego i przyrodniczego ich wykorzystania. Ponadto na przykładzie trzech oczyszczalni ścieków scharakteryzowano końcowe zagospodarowanie osadów z uwzględnieniem termicznej przeróbki i ich spalania w jednej z nich. Badania analizowanych osadów z dwóch oczyszczalni wykazały możliwość wykorzystania osadów ściekowych do uprawy roślin przeznaczonych do produkcji kompostu, uprawy roślin nieprzeznaczonych do spożycia oraz rekultywacji terenów zdegradowanych. Wysoka zawartość substancji organicznych oraz odpowiednie niskie uwodnienie końcowe osadów ściekowych z badanej oczyszczalni ścieków stwarza możliwość ich spalania i współspalania, co przedstawiono w artykule.

Słowa kluczowe: **osady ściekowe, termiczne unieszkodliwianie odpadów, przyrodnicze zagospodarowanie osadów**