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DIRECTIONS OF MANAGEMENT OF MUNICIPAL SEWAGE SLUDGE IN THE EUROPEAN UNION

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ABSTRACT: The purpose of this article is to compare sludge management trends between selected EU-15 and EU-12 countries on the basis of statistical data to determine trends and formulate conclusions for countries adopted after 2004. The analysis relied on the analysis of changes in legal regulations, international literature and the analysis of statistical data from EUROSTAT. Unfortunately, incomplete statistical data limited the number of analyzed countries, however, it was possible to draw conclusions.

Sludge management is an extremely complex issue, affects not only water and sewage management and waste management, but also concerns the issues of agriculture (fertilizers) and energy. A very important part of the issues is technological progress, and therefore research and development. Improper management of sewage sludge will in the long run lead to increasing costs of wastewater treatment, while modern technologies allow for the recovery of both energy and raw materials. The law in principle ruled out the possibility of storage and limited the agricultural use of unprocessed sewage sludge, thus one should choose the optimal development directions of the sector. Possible areas of action are burning with recovery of energy and raw materials from ashes or organic recycling, i.e. composting with recovery of energy and heat and using the resulting fertilizer.

KEY WORDS: sewage sludge, wastewater treatment, sewage sludge management, sewage sludge regulations

Introduction

The basic EU regulation regarding sewage sludge and its use in agriculture was adopted over thirty years ago. Since then, knowledge about the environmental and health effects of natural use of sewage sludge has been improved, technologies for wastewater treatment have changed, as well as, thanks to technical progress, more effective methods of dealing with sewage sludge are available in terms of neutralizing dangerous substances and pathogens. The progress of knowledge indicates the need to take action in the field of monitoring and handling substances present in wastewater and sewage sludge, which have not been the subject of interest so far.

The implementation of sewage management requirements in the countries adopted after 2004 (EU-12) will affect the increase in sewage sludge production, and the cheapest methods of handling them – that is storage and agricultural and natural use – are currently banned or very limited. These countries face the challenge of choosing a strategy for dealing with sewage sludge. One can and should take a look at the directions chosen by the countries of the "Old Union" – that is, adopted until 1995 (EU-15) and on this basis build recommendations for EU-12 countries.

The aim of the article is to indicate possible directions for sewage sludge management in Poland and selected newest member countries on the basis of observed trends in management of sewage sludge selected in the countries of the "Old Union". The adopted research method is the analysis of source documents and statistical data of Eurostat.

Legal foundations defining the directions of sewage sludge management in the European Union – an overview of the literature

Waste management obligations arise, for example, from the Helsinki Convention (EU 1994:156) and recommendation "Sewage Sludge Handling" approved on 17 March, 2017 indicating in the scope of handling sewage sludge to the highest possible level of recycling and recovery of phosphorus, and for other methods absolute compliance with standards. ("HELCOM 38/1", 2017).

The issues of production and management of sewage sludge are regulated by numerous regulations in the field of waste management and sewage management. However, also acts from other seemingly distant areas have a significant impact on the way they are managed – such as the issue of bio-

mass and the recognition of it as a zero-emission energy source (the most important directives are included in table 1).

The most important and the oldest EU legal act in the field of sewage sludge is Directive 86/278/EEC concerning the agricultural use of sewage sludge. Its purpose is to regulate the use of sewage sludge in agriculture in such a way as to prevent its harmful effects on soil, vegetation, animals and people, while encouraging the correct use of sludge. However, it clearly indicates that different regulations in individual countries can not pose a threat to the common market. It points out that although sewage sludge can be a rich fertilizer for agriculture, it can also contain heavy metals and other dangerous pathogens (EU, 1986). The Directive introduces limit values of heavy metal concentrations in soil on which sewage sludge is distributed, in sewage sludges itself and annual maximum amounts of heavy metals that can be introduced into the soil intended for agricultural purposes. At the same time, it prohibits the use of sludge if the concentration of even one heavy metal is exceeded. It also introduces the need for monitoring and reporting obligations for Member States (EU, 1986, Article 4). In this way, the possibility of agricultural and natural use of sewage sludge was significantly reduced (Bień et al., 2014, p. 9). The subsequent directives influence the creation and treatment of sewage sludge, although they are not directly devoted to them. Directive 91/271/EEC, called the Urban Waste Water Treatment directive, which aims to reduce the pollution of surface waters with municipal sewage and some industrial wastes. Its proper implementation will affect the increase in the amount of generated sewage sludge. It is important that, according to the Commission communication on the list of wastes, sewage sludge is not classified as hazardous waste, which significantly affects the way it is handled (EU, 2001, Chapter 19-20). On the other hand, Directive 1999/31/EC on landfill restricts, and in principle prevents the disposal of sewage sludge in landfills, and Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources results in limited areas on which sewage sludge can be used for agricultural purposes. Table 1 indicates the most important directives and the scope of their possible impact on the management of sewage sludge. Particularly important in addition to the waste directive, establishing a hierarchy of waste management (EU, 1998b) are: Directive 2009/28/EC on the promotion of the use of energy from renewable sources and Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control). The first recognizes energy from biomass, gas from landfills and sewage treatment plants as a renewable energy source, and the second does not prohibit the incineration and co-combustion of sewage sludge, while naturally maintaining all environmental standards. Both of these directives together with the aforemen-

tioned ones, which limit the agricultural and natural use and storage of sewage sludge, determine the desirable directions of this waste.

Table 1. Selected directives affecting the management of sewage sludge

Type	Document name	The most important records
Regulations regarding waste management	Directive 86/278/EEC on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture	- definition of sewage sludge - limits of concentrations of heavy metals in sewage sludge - the concentrations of soils in soils - monitoring obligation - reporting obligations
	Directive 1999/31/EC on the landfill of waste	- limits the possibility of liquid waste storage - limits the possibility of storage of biodegradable waste - does not include the spreading of sewage sludge on the soil surface for fertilization or fertilization
	Directive 2008/98/EC on waste and repealing certain Directives	- hierarchy of dealing with waste - the production of waste is avoided - treatment of waste as a resource
Regulations regarding water management	Directive 2000/60/EC establishing a framework for Community action in the field of water policy	- qualify the entire territory of Poland for the sensitive area (limitation of P and N discharge and biodegradable compounds to waters) due to the eutrophication of the Baltic Sea
	Directive 91/271/EEC concerning urban waste water treatment	- indicates the need to reuse sewage sludge (recycling) - resignation from the discharge of sewage sludge to surface waters - the necessity to monitor the removal of sewage sludge - its implementation will increase the amount of sewage sludge
	Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources	- can limit the amount of land on which fertilizers can be used
	Directive2006/118/ EEC on the protection of groundwater against pollution and deterioration	- possible limitations of organic recycling
	Directive 2008/105/EC on environmental quality standards in the field of water policy	- environmental quality standards in the field of water policy
	Directive 2008/56/EC establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)	- as a result of implementation, it is possible to increase the amount of chemical deposits (phosphorus precipitation)
Regulations regarding renewable energy	Directive 2009/28/EC on the promotion of the use of energy from renewable sources	- energy for biomass, gas from landfills and sewage treatment plants and from biological sources for renewable energy sources - Biodegradable part of the biodegradable parts of industrial and municipal waste

Type	Document name	The most important records
Regulations regarding industrial emissions	Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)	- disposal of sludge in any part of the water - not prohibit the combustion and co-incineration of sewage sludge - significantly reduces emissions from energy installations, including incineration and co-incineration of waste and sewage sludge)
	Directive 2004/35/CE on environmental liability with regard to the prevention and remedying of environmental damage	- responsibility for the environment - polluter pays

Source: authors own work based on Bień et al., 2014, p. 9-11; Radecki, 2016, p. 355-362; Górski, 2018, p. 393-484; Kelessidis, Stasinakis, 2012, p. 1187-1188.

Research methods

The research aimed at determining the directions of sewage sludge management in selected European Union countries in the context of legal changes being introduced, and comparing these changes with actions taken in countries admitted to the EU after 2004.

The conducted research was based on the analysis of source materials and statistical data published by Eurostat. The analyzes in the article are divided into two groups of countries. Three EU-15 countries (Germany, France and Austria) and five EU-12 countries were selected for analysis: three adopted in 2004 (Poland, the Czech Republic and Hungary) and two later (Bulgaria and Romania). The selection of these countries was determined both by their significance or representativeness, but also by the completeness of the available data, for example, data on composting for Spain, Sweden, Belgium and England are not available at a satisfactory level.

Since statistics on water and wastewater in Eurostat are published for the resident and not in terms of the equivalent number of inhabitants (PE) (Eurostat, 2018f), all data are reported and converted in such units. The analysis is made in 2018, the latest available data is from 2015 (Eurostat, 2018b), and for some specific data for 2013, nevertheless, interesting conclusions can be drawn. The 10-year period for this sector seems sufficient to capture certain regularities and, on this basis, formulate conclusions for other countries under the same legal regime.

Changes in the management of sewage sludge reflected in statistical data for selected European Union countries adopted before 1996

In the middle of the first decade of the 21st century, a significant review of waste policy directions was made, combining more closely with environmental and energy issues. As part of the conducted analyzes, which resulted in increased requirements, inter alia, in waste management issues, the sludge was also focused on.

At first glance, there is a huge disproportion in the amount of sewage sludge produced, firstly between the EU-15 and EU-12 countries, and secondly in the EU-12 countries surveyed. The volume of sewage produced in Germany is decreasing by 20%, in France by almost 12% and in Austria by over 20%, in EU-12 it is growing by 20% in Poland, by 17% in the Czech Republic and in Romania it has more than tripled, or maintains as in Hungary and Bulgaria – similar production levels are recorded (minimum drops) (table 2 and figure 1). The amount of generated sewage sludge is mainly affected by the amount of treated municipal sewage (the number of residents served, the amount of rainwater, the state of the sewage system – seepage of groundwater) and the technologies used for wastewater treatment. So let's look at these factors. One important point to pay attention to is the definition of sewage sludge in individual countries and when they become waste and when they lose their waste status. How are sludge treated in the sewage treatment plant classified, and how it is exported to other installations. This data may affect the generally reported amount of sewage sludge.

It should be noted that in Germany, 97% of residents were connected to sewage treatment plants, 100% in 2010, 95.8% and 100% in France, and 100% in Austria in 2004 (Eurostat, 2018b). Out of the EU-15 countries surveyed, only Germany suffered a decrease in the population (Eurostat, 2018a).

In the years 2004-2013, the number of sewage treatment plants decreased in Germany and France, with total capacity decreasing in Germany (expressed in BOD_5 [t. O_2/24h]), but for treatment plants with increased nutrient removal remained constant. It can be concluded that old sewage treatment plants with lower cleaning parameters were closed. In France, a colossal drop in the number of sewage treatment plants is noticeable with a significant increase in capacity, especially for treatment plants with increased biogen removal, which may inform about the liquidation of numerous small wastewater treatment plants with low technical parameters for modern large enterprises. In Austria, all the analyzed indicators increased (table 2), but the amount of generated sewage sludge decreased (table 4), which may inform about the growing technological potential.

Table 2. Change in the number of sewage treatment plants, their capacity in Germany, Austria and France in 2004 and 2013 [in pcs]

Country	Unit	Number of wastewater treatment plants			Including increased biogen removal		
		2004	2013	change	2004	2013	change
Germany	pcs	9 994	9 636	-358	5534	5180**	-354
Austria	pcs	1579	1841*	262	783	1049**	266
France	pcs	16889	3275	-13 614	2393	2605	212
		The capacity of the sewage treatment plant			Including increased biogen removal		
Germany	BOD5 [t. O2/24h]	9 283,7	9238,1	-449,6	9008,8	9003,9**	-4,9
Austria	BOD5 [t. O2/24h]	1 217,7	1 290,5*	72,8	1 156,6	1275,6**	119,0
France	BOD5 [t. O2/24h]	5 289,1	5 323	33,9	2 909	4 360	1 451,0
Germany	population equivalent (p.e.)	154 728 333	153 968 333	-7 493 333	150 146 667	150 065 000**	-81 667
Austria	population equivalent (p.e.)	20 295 000	21 508 333*	1 213 333	19 276 667	21 260 000**	1 983 333
France	population equivalent (p.e.)	88 151 667	88 716 667	565 000	48 483 333	72 666 667	24 183 333

* for 2006 ** for 2010

Source: author's own work based on Eurostat, 2018d; Eurostat, 2018c.

In nominal terms, Germany produces the most sewage sludge. The decrease in sewage sludge production between 2004-2015 is also the most visible in them (by 20%). It is caused by both a decrease in the number of inhabitants and technological factors in the form of abandoning the use of calcium / iron chloride in favor of polymers and the use of optimized processes during industrial wastewater treatment (Podewils, 2016). France produces on average half as much sewage sludge than Germany (table 3, figure 1). However, Austria has the highest production of sewage sludge per capita, followed by Germany. All three surveyed EU countries report a decrease in the volume of generated sewage sludge (Germany by almost 20%, France by 10%, and Austria by over 21%), as well as per capita, however Austria is the largest drop in this indicator in the period under study (figure 2). With a general decrease in the amount of generated sewage sludge in Germany, the amount of sludge burned increases from 711.2 to 1148.7 thousand tonnes of d.s. which is an increase from 36.2% to 63.7%. Storage was practically limited. The second most common way of utilizing sewage sludge is agricultural utilization with the share of nearly 24%.

In France, however, agricultural use dominates, but it remains at a similar level during the period under review with a downward trend of 420,000 t.d.s. today. The amount of sludge subjected to composting increased from 166.6 to 305.1 thousand t.d.s. together, composting and agricultural use gives almost 78% of the sludge used. The share and the amount of sludge stored fell. In Austria, both in 2004 and in 2014, combustion is dominating and almost half of sewage sludge is utilized in this method. The composting share increased from nearly 21% to 32.5%, but in nominal terms it increased from 63.4 to 77.7 t.d.s., as there is generally a significant decrease in the quantity of produced sewage sludge.

In the countries studied, we can see a decrease in the amount of generated sewage sludge, while in Austria and France the throughput increases. In Germany, the process of reducing it was visible, but the country registered a reduction in population, and the capacity of the treatment plant with the highest degree of treatment remained unchanged. In all countries operated by sewage treatment plants is the entire population. With the exception of Germany, the reason for the decrease in the amount of sewage sludge is not a reduction in the number of inhabitants, and possible reasons include: greater savings in water consumption, better sewage treatment technologies (smaller amount of excessive sludge) and in reducing the inflow of rainwater carrying significant amounts of sludge and other residuals. Following the industry literature, it can be confirmed that the development of modern technologies in wastewater management can contribute to reducing the amount of sewage sludge production (Makisha, 2016; Raghuvanshi et al., 2017; Grace, Clifford, Healy, 2016). Great technological progress is also observed in sewage sludge management methods, especially those related to energy recovery (Pająk, 2013; Fijałkowwski et al., 2017; Raheem et al., 2018; Kelessidis, Stasinakis, 2012).

The countries discussed have chosen different strategies for the management of sewage sludge. Both in Germany and Austria, its burning prevails, and in France, agricultural use, with the growing role of composting. In all the discussed countries, storage is disappearing, Austria has the most effective way to reduce it. It also confirms the effectiveness of the EU regulations that limit the possibility of sludge storage.

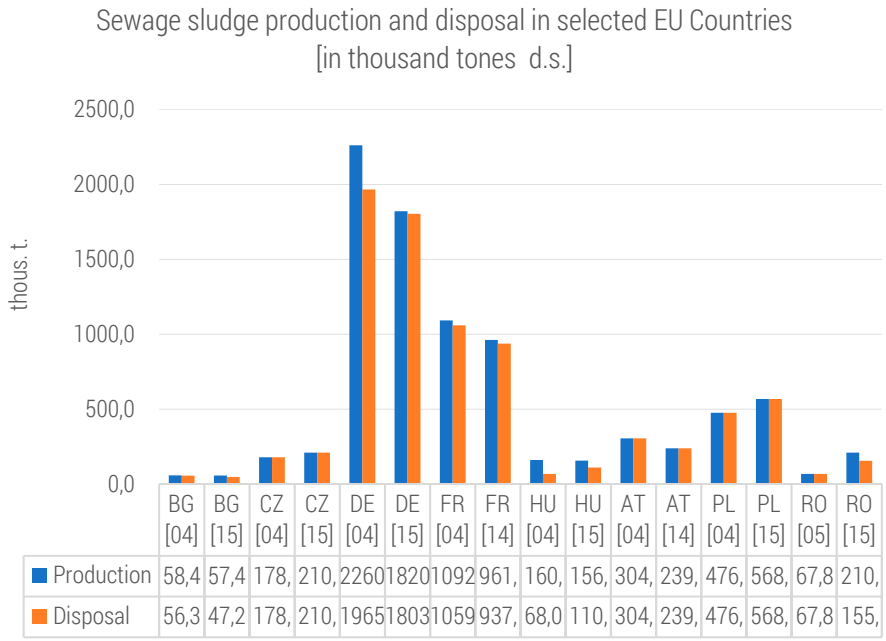


Figure 1. Sewage sludge production and disposal in selected EU Countries [in thousand tones d.s.]

Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e.

Table 3. Production and use of sewage sludge in selected European Union countries in thous. tonnes of dry matter in 2004 and 2015

Country	Production	Disposal						Share of sludge used in total
		Total	In agri-culture	Com-posting	Landfill disposal	Com-bustion	Other	
Bulgaria [2004]	58.4	56.3	0.0	0.1	51.2	0.0	5.0	96.4
Bulgaria [2015]	57.4	47.2	30.4	3.4	8.5	0.0	4.8	82.2
Czech Republic [2004]	178.8	178.8	29.1	87.5	25.5	0.0	36.7	100.0
Czech Republic [2015]	210.2	210.2	101.6	72.9	21.5	14.2	16.6	100.0
Germany [2004]	2260.9	1965.9	628.0	547.7	79.1	711.2	79.1	87.0
Germany [2015]	1820.6	1803.1	427.7	223.7	0.0	1148.7	3.0	99.0
France [2004]	1059.2	1059.2	465.3	166.6	222.1	178.4	26.8	100.0
France [2014]	961.5	937.1	421.3	305.1	31.1	170.6	8.9	97.5

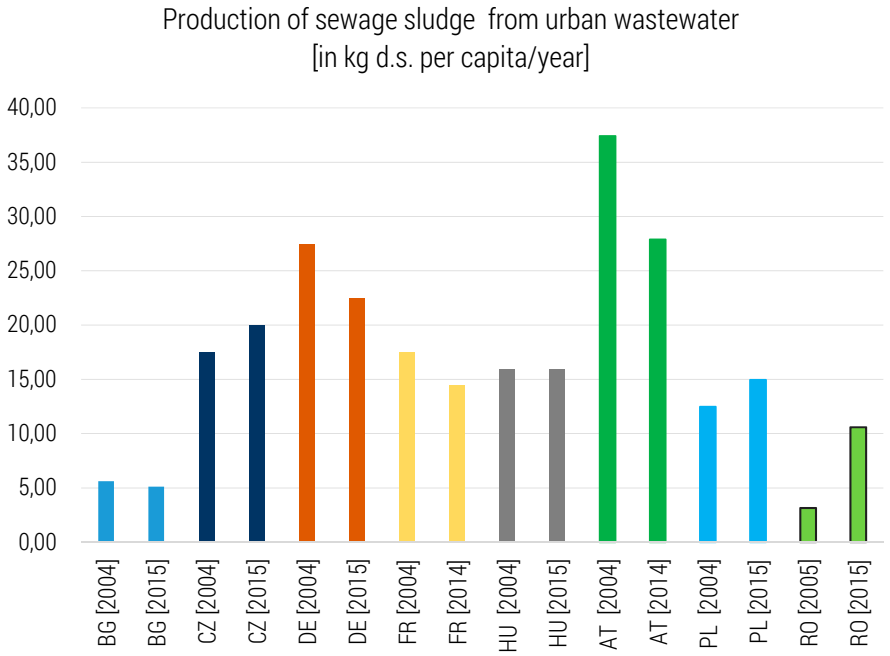
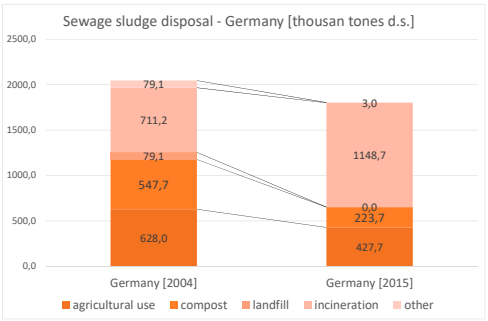


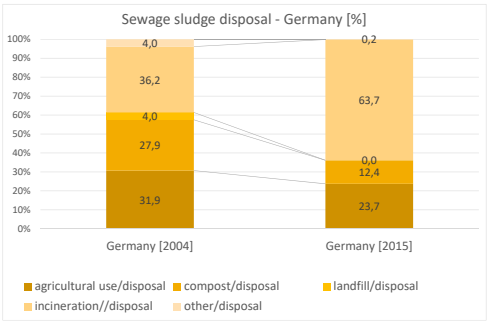
Figure 2. Sewage sludge production from urban wastewater per capita in selected EU Countries [in kg d.s. per capita/year]

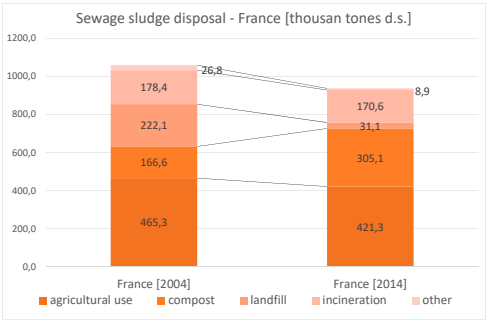
Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e; Eurostat, 2018a.

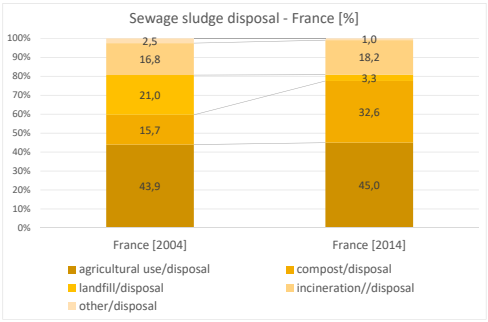
Hungary [2004]	160.9	68.0	33.2	8.7	19.3	4.4	2.5	42.3
Hungary [2015]	156.9	110.9	9.4	83.7	5.1	12.7	1.3	70.7
Austria [2004]	304.6	304.6	37.6	63.4	29.8	151.3	22.5	100.0
Austria [2014]	239.0	239.0	39.6	77.7	3.2	118.5	0.0	100.0
Poland [2004]	476.1	476.1	66.9	29.7	162.7	1.4	215.3	100.0
Poland [2015]	568.0	568.0	107.5	47.1	40.5	79.3	293.6	100.0
Romania [2005]	67.8	67.8	0.7	4.7	55.9	0.0	6.6	100.0
Romania [2015]	210.5	155.8	10.6	0.2	104.2	0.5	40.9	74.0

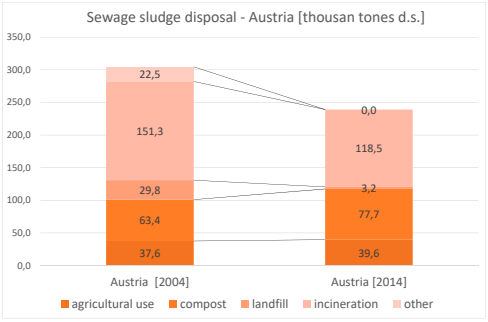
Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e.











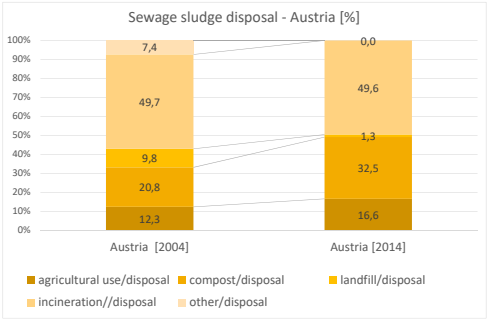
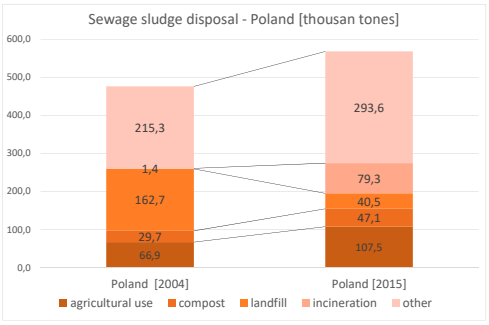
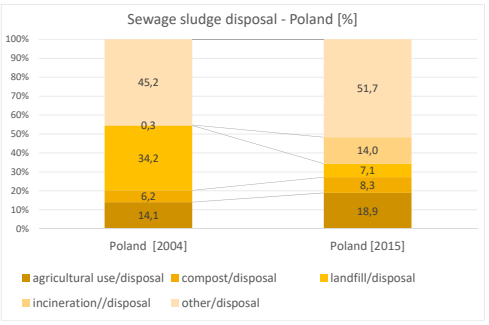
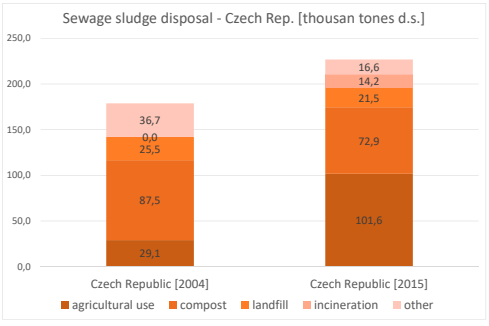


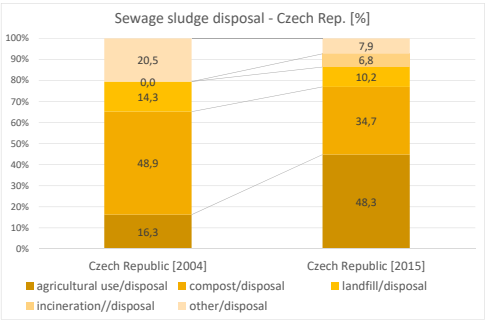
Figure 3. Sewage sludge disposal in selected EU-15 countries [in thousand thones d.s. and in percentage]

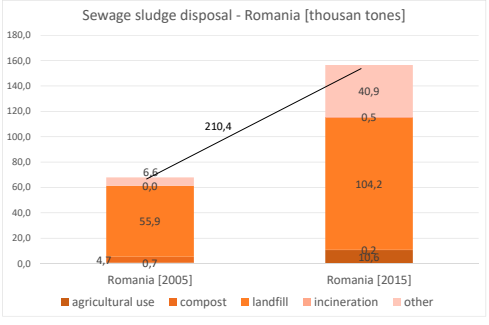
Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e.











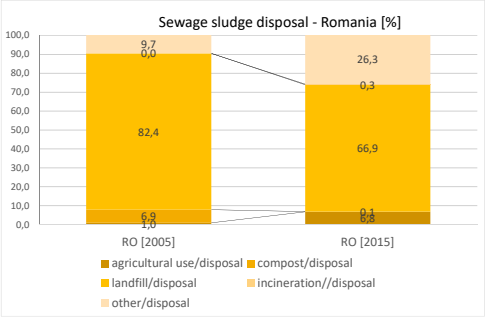


Figure 4/1. Sewage sludge disposal in selected EU-12 countries [in thousand thones d.s. and in percentage]

Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e.

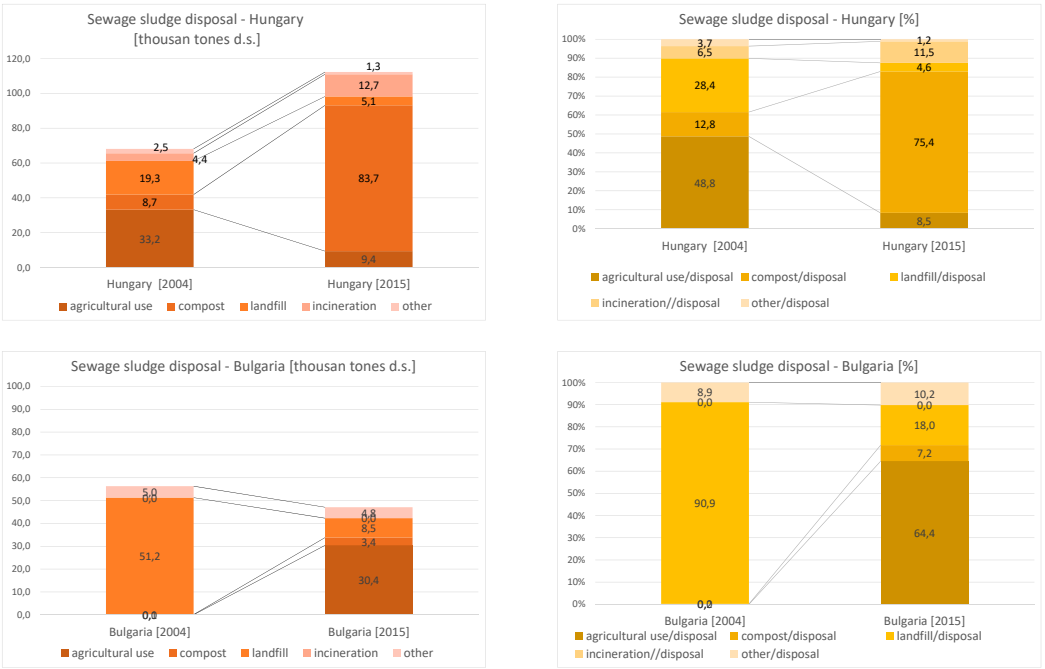


Figure 4/2. Sewage sludge disposal in selected EU-12 countries [in thousand thones d.s. and in percentage]

Source: author's own work based on Eurostat, 2018b; Eurostat, 2018e.

Directions for managing sewage sludge in selected countries admitted to the European Union after 2004

In the countries admitted to the EU after 2004, there is a completely different situation than in the EU-15 countries. The amount of produced sewage sludge is disproportionately smaller. In comparison to Germany, Poland produces only 30% of sewage sludge and Bulgaria 3%. Of the analyzed countries, only Hungary produces a comparable amount of sewage sludge as France (table 2, figure 1). In the studied EU-12 countries, the amount of generated sewage sludge increases due to the growing sewage treatment and increasing share of population with access to sewage treatment plants, improving the quality of treatment (table 4) and the growing share of residents with access to waterworks and lifestyle change resulting in increased consumption of tap water (increased water consumption is, however, hampered by rising water prices).

The number of people connected to sewage treatment plants is increasing, which increases the amount of sewage and sewage sludge produced. The share of people with access to sewage treatment plants increased: in Poland

from 84.5% in 2004 to 94.2% in 2015, in the Czech Republic from 73.5% to 81% respectively, and in Hungary from 72.1-76.8%. Even bigger changes occur in the countries adopted after 2007, and in Romania the increase of population connected to sewage treatment plants increased from 27.8 to 47.8%, in Bulgaria from 71.8 to 86.8% in 2004 and 2015 respectively (Eurostat, 2018b). It can be seen that especially in the last two countries there is still a large potential for growth in connecting residents to the sewerage system. At the same time, in all EU12 countries discussed, with the exception of the Czech Republic, there was a decrease in the number of inhabitants (Eurostat, 2018a).

In all EU-12 countries discussed, with the exception of Hungary, there was an increase in the number of sewage treatment plants, including increased biogen removal – table 4. This is clearly visible especially in Poland and the Czech Republic. In Poland, the capacity of sewage treatment plants increased by 11%, but in 2004, the purification plants with the highest degree of treatment constituted 58% of the available capacity, and in 2013 – already 82%. With the increase in the number of residents served, these are probably two main factors affecting the increase in the amount of sewage sludge (table 4, figure 4). Bulgaria and Romania are far behind although there has been a threefold increase in the production of sewage sludge in Romania during the period considered, Bulgaria and the Czech Republic can be compared due to a similar population (and these two countries have a population between 7-10 thousand inhabitants) and this shows how much still needs to be done in Bulgaria. The Czech Republic currently produces nearly four times more sewage sludge than Bulgaria.

In Hungary, the total number of sewage treatment plants decreased, but their throughput increased, and the number and capacity of the treatment plants with the highest degree of purification increased – resulting in an increase in sewage sludge (table 3 and table 4, figure 4). The number of sewage treatment plants in Poland increased, including the largest increase in the capacity of sewage treatment plants with increased biogen removal. Only in Bulgaria, the amount of generated sewage sludge and throughput decreased, despite the increase in the number of sewage treatment plants (table 5). It can be seen from the data that the processes of adaptation to the requirements of the Sewage Directive do not go as dynamically as in Romania. The total amount of generated sewage sludge in Bulgaria is only 10% of what is in Poland and slightly more than a quarter of what in the Czech Republic.

In Poland, the amount of generated sewage sludge increased from 476 to 568 thousand t.d.s. and the amount of managed sewage sludge has also increased. In Poland, the Czech Republic and Romania, the amount of gener-

Table 4. Change in the number of sewage treatment plants, their capacity in Bulgaria, the Czech Republic, Poland, Romania and Hungary in 2004 and 2013 [in pcs]

Specification	Unit	Number of wastewater treatment plants			Including with increased biogen removal		
		2004	2013	change	2004	2013	change
Bulgaria	pcs	56	90	34	0	26	26
Czech Republic	pcs	2006	2636	630	766	1272	506
Poland	pcs	2875	3264	389	689	820	131
Romania	pcs	467*	481**	14	:	74**	74
Hungary	pcs	864	739	-125	170	451	281
		The capacity of the sewage treatment plant			Including with increased biogen removal		
Bulgaria	BOD5 [t. O2/24h]	415.1*	464	48.9	:	223.7	223.7
Czech Republic	BOD5 [t. O2/24h]	862.2	981.7	119.5	705.2	864.7	159.5
Poland	BOD5 [t. O2/24h]	2 549.5	2 848.9	299.4	1 477.8	2 336.5	858.7
Romania	BOD5 [t. O2/24h]	793*	724.5	-68.5	:	293.4	293.4
Hungary	BOD5 [t. O2/24h]	661.9	946	284.1	240	692.6	452.6
Bulgaria	population equivalent (p.e.)	6 918 333	7 733 333	815 000	-	3 728 333	3 728 333
Czech Republic	population equivalent (p.e.)	14 370 000	16 361 667	1 991 667	11 753 333	14 411 667	2 658 333
Poland	population equivalent (p.e.)	42 491 667	47 481 667	4 990 000	24 630 000	38 941 667	14 311 667
Romania	population equivalent (p.e.)	13 216 667	12 075 000	-1 141 667	-	4 890 000	4 890 000
Hungary	population equivalent (p.e.)	11 031 667	15 766 667	4 735 000	4 000 000	11 543 333	7 543 333

* 2005 ** 2014

Source: author's own work based on Eurostat, 2018d; Eurostat, 2018c.

ated sewage sludge per capita is growing, in Hungary and Bulgaria it is stabilized or decreasing. However, it remains far lower than in Austria or Germany. Only France has a comparable production per capita as Poland or Hungary, and lower than the Czech Republic (figure 2).

The structure of utilization of sewage sludge is slowly changing in Poland. The share of incineration increased from a share of 0.3 to 14%. The share of the "other" category is very large. Of all the countries surveyed, the share of this category is the highest for Poland and growing. In response to the

Author's query to the CSO, an explanation was given that the category "other" includes:

- transfer of sludge to other authorized bodies for their development,
- the use of sludge for the cultivation of plants not intended for direct consumption,
- use of sludge in R3 processes, ie recycling or regeneration of organic substances that are not used as solvents (including composting and other biological transformation processes), R12 – replacement of waste for submission to any of the processes listed in item R1–R11 (Act on waste, 2013c, Annex 1, Indicative list of recovery processes).

One should consider the method of collecting statistical data, because in the present situation more than half of sewage sludge escapes public statistics on the ways of their management, and even if sewage sludge is transferred to another entity for development, it should be known how to deal with it and recorded statistical data. In the current situation, official statistics from Poland show a rather disturbing picture, especially against the background of EU-15 countries where the category "other". It practically disappears. It grows only in Romania from just under 10% to over 26%.

In Bulgaria, the use of farms from almost nil to almost 65% has significantly increased as a process replacing the storage dominating in 2005. The most diversified path of sewage sludge management, according to data, was adopted by the Czech Republic. In the years 2004-2014, agricultural use increased from about 16 to 48%, composting decreased from 50% to 35%, storage decreased from 14 to about 10% and combustion occurred – almost 7%. The category "other decreases from 20 to less than 8%. This is all with the growing total amount of sewage sludge (this means that despite the decrease in the composting share, the nominal decrease from 87.5 t.d.s. to 72.9 t.d.s., ie less than 17%).

In Hungary, with a significant increase in the volume of sewage sludge produced, the percentage of composting increased from almost 13% to over 75% and the decrease in storage from nearly 30% to less than 5% and decrease in agricultural use from nearly 50% to 8.5%

Conclusions and data for Central and Eastern European countries

Some conclusions can be drawn from the data presented. In the EU-15 countries, the amount of sewage sludge is decreasing due to the decreasing number of inhabitants, savings, limitation of inflow of rainwater to the network, but probably also due to technological changes in the treatment pro-

cess and their initial treatment. Depending on the country, the main strategy for their management is incineration (Austria, Germany) or composting and agricultural use (France). It goes away from the storage of sludge, which was enforced by regulations.

The storage constraint is also visible in the surveyed EU-12 countries. Moreover, as trends dominating in the decade under review, the following should be calculated: increase in the share of population with access to sewage system, increase in the amount of treated wastewater and improvement of the quality of the treatment process, which results in an increase in the amount of generated sewage sludge.

Is it possible to form unambiguous recommendations for the management of sewage sludge: Yes and No. Yes, as some generalizations can be drawn from the observed trends in other countries. No, because each decision should be made on the basis of a detailed analysis of costs and benefits. It is necessary to coordinate activities at the national level, support facilitating the transition in the desired direction, taking into account the legal and economic environment, in particular:

- quality and quantity of generated sewage sludge,
- restrictive legal requirements for agricultural use (which generates costs) and limitation of the possibility of storing sewage sludge,
- organizational and legal form of the conducted activity (whether at the sewage treatment plant or by specialized regional entities),
- existing infrastructure,
- a growing number of treatment plants with increased biogen removal, which contributes to the increase of sewage sludge,
- increasing saturation of the sewer trash (except for Bulgaria), which in a certain perspective will contribute to the stabilization of the amount of generated sewage sludge,
- limiting or stabilizing water consumption by households due to rising water prices and limiting the inflow of rainwater to the sewage system, which will contribute in the long run should lead to stabilization or even reduction of the amount of generated sewage sludge,
- increasing technological progress enabling the recovery of nitrogen phosphorus from deposits or ashes after their combustion,
- possibility of energy recovery from sewage sludge,
- restrictions on the possibility of transporting sewage sludge,
- mechanisms supporting RES and cogeneration,
- emerging markets for recovered raw materials.

On a national scale, it seems that the strategy that develops the main directions of development, that is composting with the recovery of energy and raw materials through their introduction into the soil and burning with

the recovery of energy and raw materials from ashes, seems to be the most flexible. Of course, the costs are also critical. Taking into account the costs (Milieu Ltd, WRc and RPA for the European Commission, DG Environment, 2010) and the fact that after reaching the maximum level of sewage sludge production, their number may stabilize or start to decline as in western countries, as well as the fact of dynamic technology progress Co-firing should be considered.

However, taking into account the impact on the environment and health of the population, the research conducted indicates that controlled composting (organic recycling) with recovery of energy and agricultural use of compost is a better destination (Wójtowicz et al., 2013, p. 427). In addition, research related to technologies related to the management of sewage sludge as well as the study of their impact on the environment should be supported. Thermal directions are usually recommended for large wastewater treatment plants whose catchments are threatened by excessive pollution of potentially toxic elements (e.g. heavy metals).

However, a number of local factors affect the decision on a particular solution. The direction of sewage sludge management depends, first of all, on the quality and quantity of sewage sludge and existing possibilities, e.g. the existing possibility of utilization in the vicinity of a mono-refinery or a restriction of the possibility of using certain criteria. In mountainous areas or near protected areas such possibilities will be limited, so one should consider another solution. Each time it translates into the costs of wastewater treatment.

Conclusions

Changes in legal regulations are one of the important elements affecting the management of sewage sludge (and general waste). Among the important factors affecting the selection of these trends should be distinguished:

- legal requirements (national and EU),
- the level of available technology (innovative technologies, improving existing ones),
- knowledge about the environmental effects of each method,
- possibilities of control and monitoring (quality of sludge, products from processes, soils and waters),
- financial abilities.

It should be noted that these factors influence each other. The extended knowledge about environmental and social effects as well as technological progress affects changes in the law and mobilization of financing sources, and changes in law in turn stimulate technological progress.

In EU-15 countries, the quantity of sewage sludge produced decreased, with a very high percentage of people connected to municipal sewage treatment plants. Production of sewage sludge from municipal wastewater treatment plants per capita is falling. Depending on the country, the dominant method of management is either agricultural utilization and composting (France) or combustion is prevalent (Austria and Germany). Storage virtually disappears.

In the countries adopted since 2004, the amount of produced sewage sludge is growing, but it is far less than in the surveyed EU-15 countries. The share of people connected to the sewage system and municipal sewage treatment plants is increasing (Poland, the Czech Republic, Hungary) and there is a large potential for growth of this indicator in Bulgaria and Romania. The number and capacity of sewage treatment plants with increased nutrient removal increase and the amount of produced sewage sludge per capita is increasing.

In the studied EU-12 countries, sewage sludge storage significantly decreases (too slow decline in Romania) for agricultural use (Bulgaria, the Czech Republic), composting (Hungary, the Czech Republic), the incidence of combustion per level is just over 10-15% (Poland, Hungary). In Poland, the category "Other" is a disturbingly large share, which includes the transfer of sludge to another use, which is an argument for the establishment of a national strategy for the management of sewage sludge.

Thus, in the surveyed EU-12 countries, the road of organic recycling is more often chosen, which should be a recommendation to focus efforts on developing the monitoring system and assessing environmental effects and supporting research and transfer of their results to the economy in these areas.

Looking at data from EU-15 countries, it should be pointed out that EU-12 countries should take into account – when building their sewage sludge management strategies – that currently the amount of sewage sludge is increasing, but in the future (rather further) it may stabilize or fall, and this will be favored by modern technologies used in wastewater treatment and primary treatment of sewage sludge. The possibility of their development should be taken into account, especially in the context of agricultural development and clauses limiting the transport of sludge. The provisions regarding the recognition of sewage sludge as a zero-emission energy source and provisions related to instruments supporting renewable energy sources and energy production in cogeneration may be of significant importance. Future priorities in financing investments in environmental protection from funds coming from the EU budget will also be important, especially if the possibilities of spending them on incinerators are limited. Probably the path chosen by Aus-

tria and Germany towards almost complete combustion of sludge for EU-12 countries is no longer available. Therefore one should create or verify quality standards, monitoring and certification programs.

Literature

EU (1986), Council Directive of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture (86/278/EEC), Official Journal L 181, 04/07/1986 P. 0006 – 0012

EU (2001), 2001/118/EC: Commission Decision of 16 January 2001 amending Decision 2000/532/EC as regards the list of wastes (notified under document number C(2001) 108), OJ L 47, 16.2.2001, p. 1-31

Milieu Ltd, WRc and RPA for the European Commission, DG Environment (2010), Final Report, Part II: Report on Options and Impacts-Environmental, economic and social impacts of the use of sewage sludge on land, http://ec.europa.eu/environment/archives/waste/sludge/pdf/part_ii_report.pdf [09-11-2018]

Baltic Marine Environment Protection Commission (2017), HELCOM Recommendation 38/1

Eurostat (2018a), *Eurostat – Population change – Demographic balance and crude rates at national level [demo_gind]*, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=demo_gind&lang=en [09-11-2018]

Eurostat (2018b), *Eurostat – Population connected to wastewater treatment plants [env_ww_con]*, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_con&lang=en [09-11-2018]

Eurostat (2018c), *Eurostat – Treatment capacity of wastewater treatment plants, in terms of BOD5 [env_ww_cap]*, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_cap&lang=en [09-11-2018]

Eurostat (2018d), *Eurostat – Wastewater treatment plants by treatment level [env_ww_plt]*, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=env_ww_plt&lang=en [09-11-2018]

Eurostat (2018e), *Eurostat – Sewage sludge production and disposal from urban wastewater [env_ww_spd]*, http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00030&language=en [03-01-2018]

Eurostat (2018f), *Water statistics on national level*, https://ec.europa.eu/eurostat/cache/metadata/en/env_nwat_esms.html [09-11-2018]

EU (1974), *Decyzja 94/156/WE w sprawie przystąpienia Wspólnoty do Konwencji o ochronie Środowiska Morskiego obszaru Morza Bałtyckiego* (Konwencja Helsińska z 1974 r.)

EU (1998b), Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, Dz.U. L 312 z 22.11.2008, p. 3-30

Ustawa z dnia 14 grudnia 2012 r. o odpadach, Dz.U. 2013 poz. 21

Bień J. et al. (2014), *Ekspertyza, która będzie stanowić materiał bazowy do opracowania strategii postępowania z komunalnymi osadami ściekowymi na lata 2014-2020*

Fijałkowski K. et al. (2017), *The Presence of Contaminations in Sewage Sludge – The Current Situation*, "Journal of Environmental Management" No. 203, p. 1126-36, DOI: 10.1016/j.jenvman.2017.05.068

Górski M. (2018), *Prawo ochrony środowiska*. 3, Wolters Kluwer, Warszawa

Grace M.A. et al. (2016), *The Potential for the Use of Waste Products from a Variety of Sectors in Water Treatment Processes*, "Journal of Cleaner Production" No. 137, p. 788-802, DOI: 10.1016/j.jclepro.2016.07.113

Kelessidis A., Athanasios S.S. (2012), *Comparative Study of the Methods Used for Treatment and Final Disposal of Sewage Sludge in European Countries*, "Waste Management" No. 32(6), p. 1186-95, DOI: 10.1016/j.wasman.2012.01.012

Makisha N. (2016), *Waste Water and Biogas – Ecology and Economy*, "Procedia Engineering" No. 165, p. 1092-97, DOI: 10.1016/j.proeng.2016.11.824

Pająk T. (2013), *Thermal Treatment as Sustainable Sewage Sludge Management*, "Environment Protection Engineering" No. 2 Vol. 39, DOI: 10.5277/EPE130205

Podewils W. (2016), *Aktualne dane statystyczne dotyczące utylizacji osadów ściekowych w Niemczech*, "Wodociągi i Kanalizacja"

Radecki W. (2016), *Ustawa o odpadach – Komentarz*. 4, Wolters Kluwer, Warszawa

Raghuvanshi S. (2017), *Waste Water Treatment Plant Life Cycle Assessment: Treatment Process to Reuse of Water*, "Procedia CIRP" No. 61, p. 761-66, DOI: 10.1016/j.procir.2016.11.170

Raheem A. (2018), *Opportunities and Challenges in Sustainable Treatment and Resource Reuse of Sewage Sludge: A Review*, "Chemical Engineering Journal" No. 337, p. 616-41, DOI: 10.1016/j.cej.2017.12.149

Wójtowicz A. (2013), *Modelowe rozwiązania w gospodarce osadowej*, Izba Gospodarcza "Wodociągi Polskie" oraz Stowarzyszenie Eksploatatorów Obiektów Gospdoarki Wodno-Ściekowej, Bydgoszcz