Characteristics and nature usability of municipal sewage sludges in Dolnośląskie Voivodeship

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Introduction

Natural utilization of sewage sludges is an economically justified method of their disposal. However, the sludges destined for utilization in the natural environment must fulfil relevant requirements concerning chemical composition and the sanitary-hygienic features defined by the stipulations of law [2 – 5]. Many years lasting studies of sewage sludges conducted at the IOŚ-PIB (Institute of Environmental Protection – National Research Institute) allowed for determining the possibilities and tendencies of the nature utilization of these sludges on the example of small and medium size towns of Dolnośląskie Voivodeship.

The program od nature utilization of sludges for the particular sewage treatment plant should be elaborated on the basis of investigating possibility of their utilization in the close area. Expenses born for processing and utilization of sewage sludges are considerable but unavoidable due to the requirements of ecology related to production of wastes in the sewage treatment process. In case of small and medium size sewage treatment plants, undoubtedly less expensive and simpler solution will be the nature utilization of sewage sludges preceded by their relevant processing.

Methodology of data analysis

Analyses of physio-chemical, microbiological and parasitological parameters of sewage sludges from the particular sewage treatment plants in years 1998 – 2012 at the ZTŚiOW IOŚ-PIB laboratory (Sewage and Water Protection Technology Department of Institute of Environmental Protection – National Research Institute), Wroclaw Branch. The studies were conducted according to the reference methods defined in ordinances [2 – 5]. Each time the object of a study was a representative sample of sludge collected at a municipal sewage treatment plant. The study objective was to assess possibility of sludge utilization for the nature purposes.

The surveyed material obtained from 21 sewage treatment plants was analysed in respect of content of heavy metals, fertilizing substances content and biological contaminations, taking into consideration:

a) the size (RLM) of examined sewage treatment plants:
   I – to 10.000 RLM,
   II – above 10.000 to 50.000 RLM,
   III – above 50.000 RLM.
b) ordinances in force – until August 2002, from August 2002 till July 2010 and since July 2010
c) used sludge stabilization process (aerobic stabilization / digesting)

Comparative analysis of the sewage sludge study results
Content of heavy metals

The basic element deciding about the possibility of the nature utilization of the sewage sludges is their content of heavy metals. Fluctuations of the contents of heavy metals between the particular treatment plants and even within the same object are substantial. Alongside with the sludges featuring small content of heavy metals, there are the sludges with increased or even large content of one or some of them.

After the analysis of the study material gathered by the IOŚ-PIB in Wroclaw, the content of the particular heavy metals in sewage sludges can be ordered in the following sequence: Cu> Cr> Ni> Zn> Hg> Cd. In no case exceeding of lead content level was noticed.

The analysis of the metals contents acc. to RLM demonstrates the regularity – the larger treatment plant the smaller factor of heavy metal exceeding in the sludges. It could be explained with the lower level of the sewage treatment process or sludge processing at smaller objects. For the treatment plants to 10.000 RLM it was ascertained that almost in a half of examined sludges (48%) there was exceeding heavy metals. For the objects above 10.000 RLM, 33% of sludges did not comply with these requirements, while for the treatment plants above 50.000 RLM only 7% did not comply with the requirements for the heavy metals.

The accumulation of heavy metals drops in sludges at larger treatment plants (Zn, Cu, Pb, Cd). Between the first (to 10.000 RLM) and the second (above 10.000 – 50.000 RLM) group of treatment plants the difference is especially large, in further comparisons, drops of heavy metal contents are smaller or even disappear – e.g. Cd, Ni. No tendency can be observed in the case of mercury and chromium whose contents vary.

Table 1

The values of concentrations of the particular metals in sludges depending on RLM

Parameter	Unit	to 10.000	above 10.000 to 50.000	above 50.000
Zinc	mg Zn/kg s.m.	1567	1204	1055
Copper	mg Cu/kg s.m.	372	226	224
Lead	mg Pb/kg s.m.	44	40	35
Nickel	mg Ni/kg s.m.	66	53	54
Chromium	mg Cr/kg s.m.	146	240	150
Cadmium	mg Cd/kg s.m.	9.4	5.2	5.0
Mercury	mg Hg/kg s.m.	0.84	1.7	1.05

Analysing the content of heavy metals in years 1998 – 2012 decrease of Zn, Ni, and Hg content can be noticed during the last years, which is a positive phenomenon. The cause of it may be both decreasing of industrial production due to liquidation of numerous manufacturing plants with outdated processes as well as tightening the regulations concerning industrial sewages, which among others was the condition of entering the EU by Poland [1]. The progress in manufacturing and sewage treatment processes also has the crucial meaning here. Concentration of copper increases, which may be influenced by installation of copper water mains and development of electrochemical, chemical and metallurgical industry.

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Table 2
The values of concentrations of the particular metals in sludges acc. to the ordinances in force

Parameter	Unit	Until August 2002			From August 2002 till July 2010			Since July 2010		
		Minimum	Arithmetic mean	Maximum	Minimum	Arithmetic mean	Maximum	Minimum	Arithmetic mean	Maximum
Zinc	mg Zn/kg s.m.	652	1524	5879	184	1239	4868	238	888	1586
Copper	mg Cu/kg s.m.	43	159	375	9	282	1167	56	219	302
Lead	mg Pb/kg s.m.	24	52	137	2	36	151	17	58	97
Nickel	mg Ni/kg s.m.	24	53	102	11	58	312	9	34	66
Chromium	mg Cr/kg s.m.	17	324	1735	13	196	1876	7	50	187
Cadmium	mg Cd/kg s.m.	2	5.0	11	0.9	6.9	37.8	0.0	2.5	6
Mercury	mg Hg/kg s.m.	0.30	2.00	12	0.04	2.11	20	0.10	0.95	3.10

The contents of heavy metals in sludges after change of the limits for less tight in the ordinance dated 22nd July 2010. (Journal of Law No. 137, pos.924) were not exceeded. These sludges comply in 100% with the requirements set forth in the legal act currently in force. The average concentrations of pollutions fit within the permissible standard for nature utilization according to all the up to this date ordinances.

Comparing the arithmetic means of concentration values of the particular metals in the sludges from aerobic and anaerobic stabilization, it was ascertained that the sludges after aerobic stabilization feature slightly higher share of heavy metals in respect to the sludges after anaerobic stabilization.

Table 3
The values of concentrations of the particular metals in sludges taking into consideration either the aerobic or anaerobic stabilization

Indicator	Unit	Aerobic stabilization	Anaerobic stabilization
Zinc	mg Zn/kg s.m.	1675	1139
Copper	mg Cu/kg s.m.	344	229
Lead	mg Pb/kg s.m.	56	35
Nickel	mg Ni/kg s.m.	68	53
Chromium	mg Cr/kg s.m.	268	181
Cadmium	mg Cd/kg s.m.	8.4	5.5
Mercury	mg Hg/kg s.m.	1.50	1.31

Content of fertilizing substances

It is usually accepted that the more microelements are contained in sludges, the larger is their fertilizing value. The optimal content of organic substances in the dry mass of a sludge amounts 55 45% (the average from the studies of IOŚ-PIB – 53.27%) and nitrogen 3.0 2.0% (the average from studied sludges 3.63%). The sludge containing less than 35% of organic substance is considered little effective in nature use, especially in fertilizing.

The chemical composition of the sewage sludges is subject to considerable variations, depending on quality of the sewage flowing into the treatment plant. Therefore in Table 4, apart from the mean values, also their extreme concentrations are given. P-50% value should be close to the arithmetic mean. The results confirm the necessity of treating the sludges individually for each the treatment plant while deciding the dose.

Table 4
Chemical composition of sewage sludges from 21 municipal sewages treatment plants in Lower Silesia[1)]

Indicator	Unit	Minimum	Arithmetic mean	Maximum	P – 50%	P – 90%
Reaction	pH	5.70	8.12	13.10	7.10	12.40
Dry sludge mass - total amount	%	10.02	30.57	95.50	22.31	61.82
Dry sludge mass - organic particles	% s.m.	9.61	53.27	81.43	55.20	71.80
Total nitrogen	% s.m.	0.30	3.63	8.85	3.59	5.33
Ammonium nitrogen	% s.m.	0.03	0.70	5.87	0.33	1.57
Total phosphorus	% s.m.	0.11	1.90	10.60	1.61	3.18
Calcium	% s.m.	0.27	5.88	26.60	3.78	14.40
Magnesium	% s.m.	0.01	0.47	2.88	0.40	0.72

[1)] Arithmetic mean, extreme (min./ max.) and growing values are presented occurring with probability 50% (P-50%) and 90% (P-90%), obtained on the basis of population of 106 results, ammonium nitrogen on the basis of 99 results

The analysis of fertilizing substance content acc. to RLM values demonstrated similar tendency as in the case of metals – the bigger RLM value the smaller content of nutrients for soil and plants, which causes diminishing of the fertilizing value of the sludge – especially in the case of N and P. Meanwhile clear concentration increase is noticeable for calcium in the sludge at larger treatment plants, where more frequently and in larger doses lime is used to disinfect the sludges.

The analysis of fertilizing substances in years 1998–2012 demonstrates the chronological increase of the principal fertilizing components – nitrogen and phosphorus, dry mass decrease with simultaneous increase of organic substances, which from the perspective of nature utilization of sludges is a positive phenomenon.

Table 5
The fertilizing values in sludges after taking into consideration of the aerobic or anaerobic stabilization process

Indicator	Unit	Aerobic stabilization	Anaerobic stabilization
Reaction	pH	5.85 – 12.70	5.70 – 13.10
Dry sludge mass - total amount	%	24.84	32.32
Dry sludge mass - organic particles	% s.m.	57.73	52.14
Total nitrogen	% s.m.	4.11	3.45
Ammonium nitrogen	% s.m.	0.75	0.69
Total phosphorus	% s.m.	1.94	1.88
Calcium	% s.m.	6.83	5.59
Magnesium	% s.m.	0.52	0.45

Comparing the arithmetic means of fertilizing component values it was found, as expected, that after an anaerobic stabilization process the sludge featured smaller hydration, its mean dry mass amounted 32.32% in comparison to s.m. of the aerobic stabilization 24.84% (Tab. 5). Dehydration and calcification effect after anaerobic stabilization was not so effective in reduction of the organic mass. Despite known regularities, during the aerobic stabilization increased total phosphorus content was not noticed; these values were comparable.

Sanitary condition of sludges

The fertilizing usefulness is also decided by their sanitary condition. The results of biological – sanitary analysis of examined sludges (Tab. 6) demonstrate, that the sanitary condition of the examined sludges is not satisfactory. The factor, which most frequently eliminates agricultural utilization and application of sludges in land reclaiming is presence of the bacteria of*Salmonella*kind (52% of examined sludges). Exceeding of alive intestinal parasite eggs (ATT) were less frequent instances; only 12% of the sludges were excluded from agricultural application due to this reason and less than 10% – completely from the nature utilization.

In order to improve the properties of the studied sludges, liming of sludges may be ordered; the fertilizer using such sludges may be used for all soils, which require liming. The disadvantage of such solution are high lime costs; therefore in such instances it is necessary to procure recipients of sludges for nature utilization of the waste or defining of other utilization strategy.

Table 6 presents percentage of sludge share, in which exceeding of the sanitary state depending on the RLM value occurred. The tendency similar to the one for metals and fertilizing components is noticeable – the larger treatment plant the smaller amount of sludges, in which sanitary pollution limits are exceeded. At the larger treatment plants (above 50,000 RLM), where lime is used for sludge disinfection, the problem of biological pollution does not appear.

Table 6

Percentage share of sludges, in which exceeding of sanitary condition occurred depending on RLM values

Parameter	Purpose	to 10.000	above 10.000 to 50.000	above 50.000
Salmonella bacteria	excluded from RW	69.6%	57%	0%
Total number of alive intestine parasite eggs Ascaris sp., Trichuris sp., Toxocara sp.	excluded from RW	4.3%	4.4%	0%
	excluded from PW	21.7%	7.4%	0%

On the basis of the studied treatment plants the tendencies of changes in sewage sludge utilization are being noticed. Acc. to information from users in 2003 for 21 object – the predominant way of sludge utilization was storage – 71% of objects; 29% of treatment plants used nature utilization, including: 9% for stockpile reclaiming and 4% for agricultural utilization. This tendency changed for the studied objects already in 2006. The number of sewage treatment plants storing sludges diminished (to 53%); still a stockpile was the principal way of sludge utilization. Meanwhile there was substantial increase of sludge utilization for agricultural purpose (farming, land reclaiming for farming): 47% of the treatment plants declared this solution [9]. This tendency in the results of the IOŚ-PIB studies is in accord with the Voivodeship waste management plan [7].

Summary and conclusions

Dolnośląskie Voivodeship is of agricultural-industrial character, but there is only a little animal production, which is the reason of the natural fertilizer deficit. Agricultural areas have definitely acidified soils [8]. Thus the agricultural utilization of sewage sludges seems to be justified. It results out of the GUS (Central Statistical Office) data that Dolnośląskie Voivodeship leads in utilization of sludges for agricultural purposes but also it has the largest share in sewage sludge storage [6].

The article sums up real results of studies on sewage sludges from over 20 sewage treatment plants in South-West Poland, which provides an outlook on the real situation in this economy sector.

On the basis of the conducted result analysis it was found that:

- large differences occur in standardized sewage sludge parameters from the particular treatment plants and even noticeably between sludges from the same object,
- sludges from bio-treatment of sewage are rich in soil forming organic substance and plant nutrients; they contain optimal value of the organic substance in sludge dry mass, in average 53.27%, nitrogen 3.63% and phosphorus 1.89%,
- falling tendency is noticeable for heavy metals content, fertilizer components content, Salmonella bacteria and alive ATT eggs presence, depending on the size of the treatment plant; the larger RLM value, the smaller content of fertilizing components, heavy metals and biological pollutions,
- study results demonstrate that in the recent years there was decrease of heavy metals content (Zn, Ni, Cr, Hg) and increase of the principal nutrient components – nitrogen and phosphorus in sewage sludges and also decrease of dry mass with simultaneous increase of the organic substance; therefore the progress of technology generates better and better possibilities of nature utilization of the municipal sewage sludges,
- on the basis of obtained results by the IOŚ-PIB, it was ascertained that after aerobic sludge stabilization the sediments feature increased concentration of heavy metals in comparison with the sludges after anaerobic stabilization,
- only 33% of examined sludges could be used as fertilizer in agriculture and for land reclaiming for farming purposes. Almost 80% of sludges could be used for non-agricultural land reclaiming. As much as 90% of sludge could be used for ground application for defined purposes resulting from the local plans (waste management, land development, constructing and land utilization), for planting of composting plants or plants not destined for food or fodder; only 10% of sludges was excluded from the possibility of utilizing them for non-industrial purposes,
- factors limiting various possibilities of nature utilization of sewage sludges are mostly excessive amount of heavy metals and presence of pathogenic micro organisms,
- contents of heavy metals in sludges after change of the limits for less tight in the ordinance dated 22nd July 2010. (Journal of Law No. 137, item 924) are not exceeded,
- limed sewage sludges can make good material improving the quality of degraded and acidic soils; they are good substitutive fertilizer at diminishing volume of natural fertilizers,
- in case of procurement of recipients of the sludges it is possible to utilize completely produces sediments and complete elimination of their storage. In the conditions in Dolnośląskie Voivodeship there are real possibilities of nature utilization of sewage sludges, including agriculture.

Literature

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