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SEWAGE SLUDGE UTILIZATION FOR THE MUNICIPALITY OF GDANSK

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ABSTRACT

In the municipal wastewater treatment plant in Gdansk a biological treatment technology allowing removing of nutrients was launched recently. This will result in increasing of the volume of sludge from 27.3 t d.m./d now to about 45 t d.m./d in the near future. The analysis of various possibilities of sludge utilization was made. It was concluded that incineration of the sludge seems to be the most promising method, while the possibilities of application of sludge in agriculture, forestry or to land reclamation are limited. Therefore it is suggested that 90% of sludge should be incinerated and the remaining 10% - stabilized with lime and applicated to land reclamation. The ahses generated during the incineration of sludge should be deposited at the municipal waste dump, with possible phosphorus extraction in the future.

KEYWORDS

sewage sludge, utilization, sustainable development, incineration, application to land.

INTRODUCTION

In the Gdansk municipal wastewater treatment plant "Wschod" a biological treatment technology allowing removing of nutrient is being introduced. Up till now only mechanical and chemical treatment of sewage was performed. Introduction of biological treatment will result in increasing of the amount of generated sewage sludge to approximately 45 t d.m./d. Therefore it is indispensable to work out a conception of sludge utilization that will both cause minimal impact to the environment and will be possible to launch in the specific local conditions.

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The sludge management should be submitted to the rule of sustainable development which assumes recirculation of resources: the mass or the energy. The recirculation of mass means reuse of organic matter and nutrients, especially phosphorus, contained in the sludge. This could be accomplished by application of the sludge in agriculture, forestry or to land reclamation. The incineration of sludge allows for recirculation of energy. Due to Mossakowska (1998) the proper sludge management ought to fulfill several conditions: the sludge cannot be stored at the waste dumps, the organic substances toxic to the environment should be neutralized and the heavy metals should be withdrawn from the circulation in the environment. The sludge management ought to be energy-saving. These conditions are fulfilled when the sludge is applied in agriculture, forestry or to land reclamation or if it is incinerated.

CHARACTERISTIC OF THE "WSCHOD" WWTP AND THE PROCESSING OF THE SLUDGE

The "Wschod" WWTP is located in the eastern, low-lying part of Gdansk. At present the inflow of sewage to the WWTP is about 120 000 m^3/d, but in future it is expected to increase to 180 000 m^3/d. The treated sewage is discharged to Wisla-Przekop, which inflows to the Bay of Gdansk.
The mechanical treatment of sewage is performed at the screens, aerated grit chamber with grease-removal traps and in the primary settling tanks. Then the sewage is directed to the biological reactors (3 of them are already working and the remaining 3 will be put to operation this year), where carbon, nitrogen and phosphorus are removed simultaneously. In the secondary settling tanks the sedimentation of the excess activated sludge occurs. Chemical precipitation of phosphorus could be also performed there.
The sludge processing will consist of anaerobic digestion and mechanical dewatering in centrifuges and chamber presses. Prior to this, the excess activated sludge will be thickened. It is expected that the final content of water in the digested and dewatered sludge will be approximately 67%.
Until the City Council of Gdansk decides how to utilize the sludge, the dewatered sludge will be stored at the sludge drying lagoons at the WWTP.

THE QUANTITATIVE AND QUALITATIVE DESCRIPTION OF THE SLUDGE

It is estimated that if the 3 remaining biological reactors are put to operation, 27.3 t d.m. of sludge will be generated daily in the "Wschod" WWTP in 1999. In future, when the inflow of sewage increases to 180 000 m^3/d, the quantity of sludge may rise to 45 t d.m./d, which is 138 t of sludge of the moisture of 67% daily.
The sludge will contain 50% of organic matter. The calorific value of the sludge containing 10% of water will be equal to 10 MJ/kg and for the sludge containing 67% of water – 3.5 MJ/kg.
In the development project of the biological treatment technology in the "Wschod" WWTP, the probable content of heavy metals and pathogenes in sludge undergoing various stages of processing (mechanical dewatering, heat drying, composting, incineration) was estimated (BIPROWOD, 1998). The comparison of these values with the proposal of obligatory regulations for the sludge applied in agriculture or land reclamation given by the Department

of Environmental Protection, Natural Resources and Forestry (DEPNRF) indicates that the sludge from the "Wschod" WWTP does not meet the proposed requirements (tables 1,2). The concentration of cadmium exceeds the proposed values at each stage of the processing of the sludge. Also the content of pathogenes in the dewatered sludge will not meet the requirements, unless it is subjected to heat processing.

Table 1
The comparison of the content of heavy metals in the sludge from the "Wschod" WWTP after various stages of processing with the admissible values proposed by the DEPNRF (BIPROWOD, 1998).

	the sludge after mechanical dewatering	the sludge after heat drying	the ashes from incineration of the sludge	the composted sludge	the sludge stabilized with lime	proposed admissible values
	[mg/kg d.m.]	[mg/kg d.m.]	[mg/kg d.m.]	[mg/kg d.m.]	[mg/kg d.m.]	[mg/kg d.m.]
Pb	14-76	14-76	46-250	19-104	10.6-59.3	500
Cd	3.7-14	3.7-14	12-46	5-19	2.66-10.6	10
Cr	12.8-115	12.8-115	42-376	18-157	10-89.2	500
Cu	87-179	87-179	286-588	119-245	68-140	800
Ni	6.7-19	6.7-19	22-62	9-26	5.33-14.6	100
Hg	0.2-0.8	0.2-0.8	0.6-2.6	0.25-1.0	0.13-0.6	5
Zn	457-878	457-878	1500-2880	625-1200	535-1028	2500

Table 2.

Comparison of the content of pathogens per 1 kg of dry matter of the sludge from the "Wschod" WWTP with the admissible values proposed by the DEPNRF (BIPROWOD, 1998).

	the sludge after mechanical dewatering	the sludge after heat drying	the ashes from incineration of the sludge	the composted sludge	the sludge stabilized with lime	proposed admissible values
Salmonella	1×10^{-5}-1×10^{-3}	>0,01	-	1×10^{-3}-1×10^{-2}	>0,01	0
eggs of Ascaris	0 - 300	<10	-	<10	< 10	10

The sewage sludge may also contain other toxic chemical compounds such as PCFBs, PCDDs, pesticides, as well as pathogenic fungi. The content of these substances is not limited in Poland and there is no data concerning this issue for the Gdansk WWTP "Wschod".

THE LEGISLATION CONCERNING SLUDGE MANAGEMENT IN POLAND

According to the obligatory Polish regulations, the institution generating the wastes is obliged to eliminate generation and, if it is not possible, reduce the amount of wastes. In the case of wastewater treatment plants elimination of generation of wastes cannot be accomplished since the more effective treatment of sewage is performed, the greater volume of sludge is created. In such cases utilization of the sludge in one of the three ways given below ought to be performed:
1. Disposal of the sludge
a) application of the sludge to the soil (in agriculture, forestry or to land reclamation),
b) incineration of the sludge.
2. Deposition of the sludge at the waste dumps.

POSSIBLE WAYS OF SLUDGE UTILIZATION IN GDANSK

Application of Sludge to the Soil

The sewage sludge could be applied to fertilization of soils (in agriculture and forestry), land reclamation, regeneration of soils exposed to water and wind erosion and for production of compost from the vegetation growing on the sludge.
The sludge utilized in the listed above ways ought to fulfill the standards given in the proposal of the regulations of the DEPNRF, concerning the quality of the sludge applied in agriculture and to land reclamation, that were given in tables 1,2.
As it was mentioned above, the sludge from the "Wschod" WWTP contains excessive concentrations of cadmium at each stage of processing, which bounds it from direct application in agriculture. The content of cadmium in the sludge could only be decreased if the loads of cadmium inflowing to the WWTP are lower. This could be accomplished by regular monitoring of sewage discharged by the industry located in the catchment area of the WWTP. Also the concentrations of zinc in the sludge are periodically too high and the content of pathogenes permanently exceeds the admissible level. Stabilization of the sludge with lime or heat drying to the moisture of 10% would allow for elimination of the pathogenes from the sludge.
Even if the quality of the sludge improves and satisfies the requirements for application in agriculture, the problem of finding the agricultural area of necessary size will remain. The admissible dose of sludge per 1 ha proposed in Poland is 10 t d.m. every 4 years (2.5 t d.m. yearly). The size of demanded area is:

- assuming production of sludge equal to 27.3 t d.m./da 27.3·365/2.5 = **3990 ha**,
- assuming production of sludge equal to 45 t d.m./d : 45·365/2.5 = **6570 ha.**

There is not enough available area in agricultural use around Gdansk. Moreover the sludge cannot be applied in the forests since the Regional Board of the National Forests does not allow

for it. It is worth mentioning here, that the dose of sludge per hectar proposed in Poland is quite high if compared for instance to Norway (2 $t \cdot ha^{-1} \cdot year^{-1}$) or Sweden and Holland ($1t \cdot ha^{-1} \cdot year^{-1}$). In Denmark the admissible dose of sludge depends on the concentration of cadmium - the dose of cadmium has to be lower than 0.15 $t \cdot ha^{-1} \cdot year^{-1}$. For the concentration of cadmium in the sludge equal to 10 kg/t d.m., the admissible dose of sludge due to Danish standards would be 0.66 $t \cdot ha^{-1} \cdot year^{-1}$, which is much less than 2,5 $t \cdot ha^{-1} \cdot year^{-1}$, proposed in Poland.
The application of sludge to land reclamation was also considered. In Poland the admissible doses of sludge for land reclamation are from 40 to 220 t d.m./ha. If the highest dose of sludge, equal to 220 t d.m./ha, is applied, the area of 75 ha yearly would be necessary. According to Rek and Gielert (1996) the total area of land demanding reclamation in Gdansk is about 300 ha. If all of the sludge generated in the "Wschod" WWTP was used to reclamation of these lands, the task would be completed within 4 years, and another way of utilization of sludge would have to be worked out. Moreover most of the institutions that own these lands are not intrested in any land reclamation with application of the sludge due to its odour, too high moisture and the presence of pathogenes. Therefore utilization of all of the generated sludge by applying it to land reclamation seems to be impossible. Still some part of sludge (about 10%, which is 4,6 t d.m./d) may be utilized in this way, under the condition that its quality improves. Stabilization of the sludge with lime is recommended since high costs connected with the heat-drying make it reasonable only if the sludge is incinerated after drying. The proposed dose of lime for stabilization is 0.4 kg CaO/1 kg d.m. of the sludge. The amount of sludge after mixing with lime would increase to 6440 kg d.m./d. Assuming the dose of sludge for land reclamation of 200 t d.m./ha, the yearly demand of land for reclamation is 11.9 ha, which is a realistic value in the local circumstances.
Another possibility of utilization of the sludge from the "Wschod" WWTP is the offert of the firm EKOLOG, which is willing to take the sludge if the WWTP pays for it. The price for taking 1 m^3 of sludge varies from about 70 to 110 zl, depending on the content of water and pathogenes. The sludge is taken under the condition that it meets the obligatory standards for the sludge applied to the soil, since EKOLOG plans to transform it into market products that could be used in agriculture, forestry, land reclamation, for production of the lawns or seedlings of trees and bushes. This way of utilization of the sludge would be covinient for the city and for the WWTP. The disadvantages are quite high costs and difficulty in locating a plant for transforming the sludge close to Gdansk.

Incineration of the Sludge

In the recent years incineration of the sludge becomes more popular method of sludge utilization in the European countries. This results from the strict requirements for the quality of sludge applied in agriculture and withdrawing from depositing of the sludge at the waste dumps. At the same time the modern installations for the flue gases treatment allow to keep the emission of toxic substances at the admissible level. At present 30% of the sewage sludge produced in Austria and England is incinerated. Also in Germany the amount of incinerated sludge increased a few times in the recent years. Incineration of the sludge is thought to be a reasonable method of sludge disposal especially in case of big municipal wastewater treatment plants.
During incineration the mass and volume of the sludge decreases several times, however the ashes usually contain high amounts of heavy metals. The essential problem connected with the incineration of the sludge is the emission of toxic gases and dust, which is limited by obligatory regulations (Piecuch, 1998). Since there are no adequate regulations in Poland, the

corresponding ones from Germany (BlmSchV17 from 1993) and the European Union (the project of the European Union Directive from 1997) should be obeyed (tab. 3). All of the incinerating plants built nowadays allow to keep the emission levels under the obligatory limits.

Table 3.
The admissible emission of toxic substances to the atmosphere in the sludge incineration process due to the German regulations (BlmSchV17 from 1993) and due to the project of of the European Union Directive from 1997.

CO	50 mg/Nm^3
TOC	10 mg/Nm^3
dust	10 mg/Nm^3
HCl	10 mg/Nm^3
HF	1 mg/Nm^3
NO_x (as NO_2)	200 mg/Nm^3
SO_2	50 mg/Nm^3
VOC	10 mg/Nm^3
Pb+Cr+Cu+Mn+Ni+As+Sb+Co+V+Sn	0.5 mg/Nm^3
Cd+Ti	0.05 mg/Nm^3
Hg	0.05 mg/Nm^3
PCDDs and PCFDs	0.1 ng w Nm^3

The calorific value of the sludge depends on the content of combustible componetnts, their chemical composition, and on the moisture of the sludge. For the heat-dried sludge, of the content of water equal to 10% and the content of organic substance equal to 50%, the calorific value is approximately 10 MJ/kg, which is nearly two times less than the calorific value of the coal. The greater moisture of the sludge, the more energy generated in the incineration process is used for vaporization of water. Then the calorific value decreases, sometimes to 0. In such cases the additional source of energy, such as straw, coal, oil, biogas or wood, has to be added in the incineration procepp. The autothermic incineration of the sludge is possible only when the moisture of the sludge is 67% or lepp. It is advantageous to incinerate the heat-dried sludge which contains less than 10% of water. There are several technologies of sludge incineration: incineration with the additional source of, incineration in the fluidized-bed furnace and incineration preceded by pyrolysis and gasification of the sludge. The last method allows for considerable decreasing of the emission of toxic substances to the atmosphere. At the same time it is much cheaper than conventional incineration and the treatment of flue gases.
In Gdansk a plant generating heat and power from the gasificated sewage sludge could be built. If 90% of the produced sludge is utilized in the plant, the power production will be about 1 MW(e). The incineration technology would be based on a similar plant working in Hamburg. The sludge dewatered on the centrifuges and chamber presses would be heat-dried

until the content of dry mass reaches 90%, then the sludge would be milled and pelletised into minibriquets of the diameter 0.5-0.8 cm and the length 2-3 cm. After such processing the sludge would undergo pyrolysis and gasification and, finally, would be incinerated in the heat and power generating plant. The parameters of such a fuel would be 14/40/0.8 (14 MJ/kg, 40% of ash, 0.8% of sulphur), while the corresponding parameters of the coal usually are 25/22/0.8. The incineration preceded by pyrolysis would allow to solve the problem of utilization of the sludge from the "Wschod" WWTP for the following 30 years. The disadvantage of the proposed solution are high costs (about 20 million USD).The energy generated in the incineration process would be used for heat-drying of the sludge and for production of heat and electricity.
The ashes generated during incineration of the sewage sludge would be stored at the municipal waste dump. In future the phosphorus could be recycled from the ashes. The ashes generated during incineration of the sewage sludge contain from 12 to 27% of phosphorus (as P_2O_5) (Levlin, 1998). The technology of recycling of phosphorus from the ashes is not completed yet, but it may become interesting for the industry of phosphorus fertilizers in future.

Deposition of the **S**ewage **S**ludge at the **W**aste **D**umps

The third possible way od utilizing the sludge generated in the "Wschod" WWTP in Gdansk is deposition at the waste dump. According to Polish obligatory regulations deposition of the sludge is considered to be a method of neutralization of the sludge. Lesz and Szpadt (1998) point out that this is a basic difference between Polish and European Union legislation, since in the countries of the European Union the deposition of the sludge is gradually eliminated, for instance by limiting of the content of organic substance in the deposited wastes below 5%. Due to the tendency of adapting Polish regulations to those obligatory in the European Union, it is probable that the regulations in Poland will become more strict in the near future. Not only the limitation of the content of organic matter in the deposited wastes could be introduced, but also the costs of deposition of the wastes, that are low at the present time, could be rised.
The sludge could not be deposited at the municipal waste dump of Gdansk, since it is almost completely filled. Only the ashes in the amount of 20 t/d could be deposited there.
Near the WWTP there is an area of 35 ha where the dewatered sludge could be deposited, but this is a short-term solution. Assuming the final amount of the sludge of 45 t d.m./d, the dump will be filled within 10-12 years. Besides the comparison of the costs of construction and operation of the dump with the corresponding costs of incinerating plant with the necessary installations for sludge proccessing and treatment of flue gases indicates that the costs of utilization of 1 m^3 of sludge will be similar in both cases. When the dump is filled, the problem of utilization of the sludge would have to be considered once more and the city would have to carry the investment costs again. Therefore deposition of the sewage sludge is unjustified both from the economical and the environmental point of view.

CONCLUSIONS

In Poland the issue of utilization of the sewage sludge is quite new and controversial. According to the present regulations there are three ways of sludge utilization: incineration of the sludge, application of the sludge to the soil and deposition at the waste dumps. Countries of the European Union withdraw from depositing of the sludge at the waste dumps since this solution is considered to be contrary to the rule of sustainable development. Also Polish regulations concerning deposition of the sludge are expected to become more strict If the sludge is used in agriculture, forestry and land reclamation, it has to satisfy the requirements concerning the content of heavy metals and pathogenes. Besides in the cases of large municipal WWTPs it is difficult to find the area of demanded size for application of the sludge. For instance if all of the sludge generated in the "Wschod" WWTP was to be applied in agriculture, the demand for area in agricultural use would be about 4-6,5 thousand of hectars, that are not available around Gdansk. The demand for sludge in Gdansk refers to 10% of produced sludge, that could be used to land reclamation and fertilization of the municipal parks after stabilization with lime.

In this case the major part of sludge (90%) should be incinerated (after pyrolysis and gasification). The incineration of the sludge would solve the problem of utilization of the sludge in Gdansk for the next 30 years. The ashes after incineration, in the amount of 20 t/d, would be deposited at the municipal waste dump. Petrification of the ashes in order to eliminate the leakage of heavy metals could be considered. In future recycling of the phosphorus from the ashes may be performed.

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