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CHAPTER X

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TREATMENT AND FINAL UTILIZATION OF SEWAGE SLUDGE FROM DAIRY WASTE WATER TREATMENT PLANTS LOCATED IN PODLASKIE PROVINCE

Introduction

From the beginning of the 90-s of the latest century, there is observed the development of dairy processing plant on the north east part of Poland. The accession of Poland to European Union has had the impact on this process. On the one hand, it causes economic growth of the region, but on the other, it increases the danger for natural environment caused by industrial plants. According to researches conducted in the period of 1998-2000, the amount of treated sewage in Podlaskie province reached about 138 000 $m^3 \cdot d^{-1}$ among others - 9070 $m^3 \cdot d^{-1}$ was treated by individual dairy systems. The amount of sewage sludge generated during the whole year in Podlaskie province, reached 19600 tons d.m., among others 1200 tons d.m. were produced by dairy plants (Boruszko and others, 2000). While analysing problems connected with the amount of sewage and sewage sludge in Podlaskie province in 2008, there was observed the increase of dairy sewages, which are treated in individual dairy waste water treatment plants in the province. According to the data of the author, this amount reached 12 000 $m^3 \cdot d^{-1}$. While assessing the quantity of dairy sewage, it is necessary to take into account the fact that during last years the rate of the used water and generated sewage decreased in relation to the amount of processed milk. The changes, which were observed in individual dairy waste water treatment plants, are proved by such parameters like personal equivalent (P.E.) or the amount of sludge produced during sewage treatment. The quantity of sludge in dairy waste water treatment plants rose from 1140 tons d.m. in 1998 to almost 3700 tons d.m. in 2008. In the biggest plant located in the town of Wysokie Mazowickie (Mlekovita Diary Cooperative) there was noticed the increase of generated sludge from 600 to almost 2200 tons d.m. in analogous period of 10 years. Sewage sludge is the by- product in the process of sewage treatment, the way of its finale utilization depends on many factors among others physico-chemical composition of sewage which is put through the treatment process and the method of its processing. On the account of the law, sewage is the waste, however while meeting the criteria (ROZPORZĄDZENIE, 2002) it can be the essential product, which will come back to the environment in safe form. The quantity of sewage sludge among others dairy sludge, will rise together with the load of sewage.

Figure 1 shows the increase of the stream of sewage sludge predicted in National Sewage Treatment Programme.

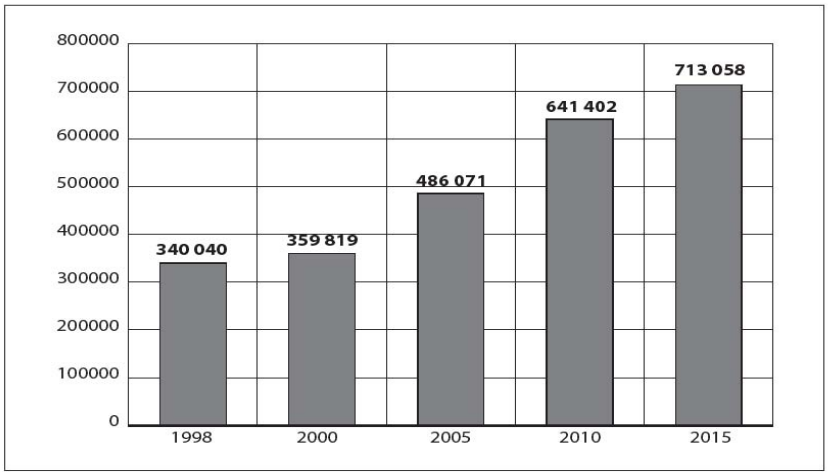

Fig. 1 The forecast of sewage sludge quantity [Mg d.m. y^{-1}] in Poland up to 2015 according to National Sewage Treatment Programme

The quantity of sludge in Poland in a period of 2000-2010 will rise almost twice that is why its treatment and final utilization will be the main current problem within the next years. It considers also the sludge produced in dairy wastewater treatment plants. It is differentiated by physico-chemical composition in relation to the sludge formed in municipal waste water treatment plants.

Dairy waste water treatment plants, characteristics of research base

In Podlaskie province there exist nowadays nine plants using individual waste water treatment systems. On the one hand, the quantity of treated sewage is not high in relation to the quantity of municipal sewages but on the other hand, taking into account pollution load, there is easily seen the impact of them on the state of surface waters which are receiving waters of treated sewage. Sewage sludge produced during the process of dairy sewage treatment is used to fertilize soils.

Table 1 shows the basic parameters of chosen systems of dairy sewage treatment plants in Podlaskie province according to the data from 2008. The analysis covered the largest dairy objects, which use individual wastewater treatment plants. The size of these plants is proved by the fact that 7 from 9 analysed objects work on the basis of integrated pollution prevention permission (IPPC).

Apart from the quantity of sewage and sewage sludge there was given personal equivalent (P.E.) characteristic for each object describing the level of load, which is treated by dairy waste water treatment plants. The average BOD_5 in dairy sewage is

about 6 to 10 times higher than in case of municipal sewage. It is proved by the own research and also by literature (B.A.T., 2005, RUFFER 1998).

Table 1

Characteristics of chosen dairy W.W.T.P-s in Podlaskie province

Plant	Sewage quantity $m^3 \cdot d^{-1}$	P.E.	Sludge amount Mg d.m. y^{-1}	Waste water and excess sewage sludge treatment
Wysokie Mazowieckie	5500	277000	2200	Intensive biological and chemical removal of C,N,P. Aerobic sewage sludge stabilization in separate chamber, filter press dewatering
Bielsk Podlaski	700	9800	230	Aerobic activated sludge system, aeration ditches, chemical phosphorus removal. Simultaneously aerobic stabilization, gravitational thickening
Grajewo	1800	41300	420	Sludge activated system (Promlecz) , chemical phosphorus removal. Simultaneously aerobic stabilization, sewage sludge dewatering with mobile centrifuge
Kolno	730	31800	220	Aerobic activated sludge system, aeration ditches. Simultaneously aerobic stabilization, sewage sludge dewatering with mobile centrifuge
Zambrów	697	17000	90	Aerobic activated sludge system. Separated aerobic stabilization, sewage sludge dewatering with mobile centrifuge
Sejny	800	7100	130	Activated sludge in aerobic system, aeration ditches, chemical phosphorus removal. Simultaneously aerobic stabilization, sewage sludge dewatering with mobile centrifuge
Mońki	600	15000	80	Intensive biological and chemical removal of C,N,P. Aerobic sewage sludge stabilization in separate chamber, filter press dewatering
Piątnica	1300	35100	250	Intensive biological and chemical removal of C,N,P. Aerobic sewage sludge stabilization in separate chamber, filter bed dewatering
Suwałki	700	8000	25	Activated sludge system (Promlecz), chemical phosphorus removal. Simultaneously aerobic stabilization, sewage sludge dewatering with filter bed

Source: own researches

Dairy waste water treatment plants, which worked to the middle of 90-s of the last century, used the method of activated sludge mainly in the form of two stage chambers of activated sludge (the chamber of high and low loaded activated sludge). These systems were not initially adapted to intensive nitrogen and phosphorus removal, because there was not required by current law restrictions. In the process of treatment there were not used intensive biological and also chemical methods. The original Polish solution is an activated sludge chamber of "Promlecz" type and "Potap" aerations – the project of the Office of Studies and Investments Realisation in Dairy Industry (patented in Poland and abroad) (Piotrowski, 1982). Sludge stabilization process was done simultaneously thanks to long periods of aeration and low load of activated sludge chambers. Dairy plants working in 70s and 80s of the last century were characterised by high production changeability during the whole year. On account of heavy decrease of production in a period from fall to spring, dairy waste water treatment plants used only a part of appliances to treat sewage and sewage sludge. In the 90s of the XX-th century the situation changed, the plants did not register the sharp fall of production except of summer time. To the end of the XX-th century, sludge dewatering was conducted only with the use of filter bed, which effectiveness depended; to the large extend, on atmospheric conditions. Taking into account high increase of sludge, filter beds are used nowadays to gather treated sludge before its final use. The utilization of natural methods of sludge dewatering needs very large surface, while dairy waste water treatment plants are usually located near localities. Offensive smell connected with sewage sludge dewatering has negative impact on the level of habitants' life, the use of mechanical systems gives the possibility of the utilization of more commonly seen deodorising devices of sludge draft. Dairy waste water treatment plants which used Polish solutions from the 70s of the last century, still work beside of new systems created for intensive removal of carbon, nitrogen and phosphorus compounds from sewage. The potential of dairy waste water treatment plants working on Podlaskie province are much differentiated. The oldest dairy waste water treatment plant located in Bielsk Podlaski has been working over 30 years, within the modernization there has been introduced only chemical phosphorus removal from sewage. It is essential to underline that this object complies with binding regulations, but also very significant is the experience of users who are able to conduct effective sewage treatment and sewage sludge utilization. The dairy waste water treatment plants which are analysed in Table 1, use many different ways of sewage and sewage sludge treatment. The shared feature is the utilization of activated sludge method to sewage treatment and aerobic stabilization of excess sludge. Among nine analysed waste water treatment plants, only one object can be an example of modern system of sludge treatment worthy the XXI century. Dairy waste water treatment plant in Wysokie Mazowieckie is the biggest one of this object type in Poland but also in Europe. In summer period this plant processes over two millions of litres of milk per day. To 2000, this waste water treatment plant worked according to typical system of Promlecz with simultaneously stabilization and dewatering sludge with filter beds, which were commonly used in the beginning of the 90-s of the last century. After modernization and introduction of intensive biological and chemical sewage treatment, the amount of sewage sludge rose over

twice. The increase of sludge reached 5200 kg of sludge dry matter per day on average reaching the increase rate on the level of 0,46 kg d.m.·kg^{-1} BOD_5 (Kajurek 2005). There were used separate chambers in aerobic stabilization, which processed mechanically thickened sludge. Stabilization time ranged between 5 to 8 days, the process is exothermic and the stabilization temperature reached 30-36 ºC. In order to limit the temperature increase in chambers and to provide suitable air change, under the cover of each chamber there is pressed air in amount of 2.5 thousands $m^3 \cdot h^{-1}$. After stabilization process, sludge is dewatered with filter press. There is possibility of additional lime stabilization. At the moment, on account of production increase in this plant, it is necessary to modernize both sewage treatment line, but also sewage sludge treatment. In Podlaskie province there has not been used anaerobic stabilization of dairy sludge. These solutions were used in the largest municipal waste water treatment plants in the region, which is connected with the energy harvesting from produced biogas. The course of sludge stabilization process is influenced by the content of organic matter and the composition of reject water (DĄBROWSKI, 2006, 2008). In case of dairy waste water treatment plant in Wysokie Mazowieckie it is possible to use anaerobic sewage reactor, as the first stage of treatment, and later typical aerobic system. It is also connected with the possibility of energy recovery and total change of the way of sewage sludge treatment. The use of sewage treatment processes and sludge treatment with energy recovery must be stimulated by appropriate regulations and must be economically explained. However, it will not change the final sludge use – nowadays sludge from dairy waste water treatment plants owned by Mlekovita and Mlekpol (the two biggest producers in Poland) is used to fertilize soil. Farmers who are the members of cooperative society or those who have contracts on milk delivery use stabilized sludge as a fertilizer. This kind of sludge utilization gives the guarantee that it is safely used. Sludge producer is obliged to make not only periodical sludge examinations but also soils tests before and after fertilization by sludge in accordance with the order on municipal sewage sludge.

Research conditioning

Sewage sludge composition and its sanitary state are two basic elements, which decide about agricultural utilization of municipal and industrial sludge in accordance with current order on municipal sewage sludge. Equally essential is the composition of soils on which sludge from dairy waste water treatment plant can be used as beneficial fertilizer. In analysed sludge samples, there was determined the content of lead, copper, cadmium, nickel, zinc and chromium but also nitrogen, phosphorus, magnesium and calcium. Organic matter content was also determined in order to assess the level of diary sludge stabilization. The range of metals research shown in table 2, 3, and 5 is connected with the order on municipal sewage sludge mentioned above, which describes research range on account of stabilized sludge management, as raw material, not as waste (ROZPORZĄDZENIE 2002). Sludge was mineralised with the use of microwave system Mars 5 in accordance with EPA 3015 and EPA 3051 procedures. Metals determination, except of mercury, was done with the use of emission spectrometry with inductively stimulated plasma, mercury was determined

by atomic absorption spectrometry on AMA-254 analyser. Macro elements determination in sludge was done in accredited laboratory in accordance with PN-EN ISO 11885 standard, with the use of optical emission spectrometer with inductively stimulated plasma – spectrometer of Varian Vista MPX Company. The results shown in Table 2 were compared with the permissible limits. In case when sewage sludge is used naturally and also agriculturally, the strictest criteria apply to chosen heavy metals. There was shown also the composition of chosen fertilizers used in agriculture (tab. 4). The examinations were conducted during working out of environmental impact statement on sludge management from dairy waste water treatment plant in Wysokie Mazowieckie in 2001 (DĄBROWSKI, 2003). In a period of 1998 – 2000 within the project "Water, sewage and sewage sludge in waste water treatment plants in Podlaskie province", there were carried out the researches of municipal sewage sludge. Regional Environmental Protection Fund in Białystok financed this project. It covered all waste water treatment plants in Podlaskie province. The research results of municipal sludge were compared with the examinations of sludge quality from two biggest meat-processing plants in a period of 1999-2001, which had individual waste water treatment systems and from dairy waste water treatment plants in a period of 1998-2002. The comparison of sludge research results from dairy, municipal sewage plants and chosen natural fertilizers prove the usefulness of dairy sludge utilization to fertilize or make reclamation of soils on the area of Podlaskie province.

Characteristics of sewage sludge

In dairy plants of Podlaskie province, the production but also sewage load and sewage sludge increases. In the largest analysed plant in Wysokie Mazowieckie, there was observed the rise of sewage load determined by BOD_5 by 30% in a period of 2004-2008. The increase of load influences mainly the rise of following parameters: BOD_5 and COD_5 and the quantity of produced sewage in small extend. It is typical for sewage plants in Podlaskie province, taking into account the decrease of individual water use per product unit. According to authors' examinations water use rate was within the range of 1.3 to 4.2 $m^3 \cdot m^{-3}$ of processed milk in a period of 2004-2005. The amount of sewage fluctuated between 1.8 to 4.3 $m^3 \cdot m^{-3}$ of milk. These rates did not change sharply in 2008. On the basis of the analysis of dairy waste water treatment plants in Podlaskie province, the quantity of generated sludge amounted from 0.13 to 0.45 kg d.m. per 1 m^3 of treated sewage. According to the data from 2005, in case of municipal waste water treatment plants, this indicator reached 0.247 kg d.m. per 1 m^3 of sewage.

The results of the analysis presented in Table 2 show that heavy metals content in sludge produced in diary waste water treatment plant is low, sharply below the limit values, which allows to use sludge as fertilizer in some crops. Lead content in all analysed sludge ranged between 3.2 to 19.9 mg $Pb \cdot kg^{-1}$ d.m. alongside the limit quantity of 500 mg.kg d.m. if sludge is used as fertilizer. In comparison, the average lead content in Polish soils used agriculturally amounts 13.6 $mg \cdot kg^{-1}$ d.m. (Mocek 2002) alongside the range of 3.6 to 42 $mg \cdot kg^{-1}$ d.m. (Łukowski, 2009). In case of zinc, higher level of this element was observed in sludge from milk plant in

Suwałki. This situation can be caused by the fact that rain watere comes to dairy waste water treatment plant from the area around the plant. Moreover, the higher zinc content in dairy and municipal sludge is caused by industrial installations made of zinc-plated steel. The content of the rest of metals like copper, chromium, cadmium, nickel and mercury, was similar in all sludge from analysed plants. The low heavy metals content was in dairy sludge, which was analysed in Lugo province in Spain. The average heavy metals content in sludge ($mg \cdot kg^{-1}$ d.m.) amounted: in case of chromium 15.99, nickel 11.04, copper 58.55, zinc 289.74, cadmium 0.11, mercury 0.08 and lead 10.05 (MOSQUERA LOPEZ M.E., 2000). In table 5 there were shown the research results of municipal sludge together with the previous sludge examinations from industrial sewage plants of Podlaskie province. It was stated that heavy metals content of sludge in municipal waste water sewage plants was sharply higher than the values characteristic for dairy sludge shown in table 2. In case of meat plants, which have their own waste water treatment plants, there was stated similar metals content in sewage sludge, only zinc content was on lower level. Tanning plants, which use chromium technology of hide tanning, caused high chromium content in sludge from municipal waste water treatment plants. Moreover, in case of municipal sewage plants, there was observed high zinc content in sludge. It is typical for sludge from large municipal waste water treatment plants in Podlaskie province (Białystok, Łomża, Suwałki). Substantial impact on high contamination of municipal sludge by zinc has the fact that municipal sewage plants take rain water in case of combined sewerage system.

Low metal content is one of criteria, which conditions the possibility of recycling of dairy sludge to environment. The legislator determined also the characteristics of soils on which can be used sludge divided into light, medium and heavy. Permissible dose must be determined on the basis of examinations and counting, the limit value is the utilisation of 5 tons d.m. of sludge in a period of 10 years. Except of determination of metals content in sludge and soils before its utilization, it is necessary to monitor soils also after its use. Dairy sewage sludge contained similar quantity of heavy metals in comparison with natural fertilizers (Table 4). In Table 3 there were shown research results of theses metals in sludge like nitrogen, phosphorus, magnesium or calcium. These are essential parameters, which prove the fact that sewage sludge can be used to fertilize or soils reclamation. Filipek and Fidecki presented similar examination results while analysing sludge from dairy waste water treatment plants. According to their researches, magnesium content fluctuated between 4.5 to 6.2 $g \cdot kg^{-1}$ d.m., while calcium from 3.0 to 46.9 $g \cdot kg^{-1}$ d.m. (FILIPEK 1999).

The separate element conditioning sewage sludge utilization is their sanitary state. The legislator determined the necessity of sludge examinations on pathogenic bacteria in a type of Salmonella and the quantity of alive eggs of following helminths: *Ascaris sp*., *Trichuris sp*., *Toxocara sp*. Precise examinations conducted in two dairy waste water treatment plants in Podlaskie province in 1998 showed that sludge from dairy waste water treatment plants can be safely used in agriculture in process of fertilisation and soils reclamation.

The installation of sanitary sewage sludge stabilization in Wysokie Mazowieckie was done but after 2000, there was no necessity to use it. In case of the majority of dairy waste water treatment plants these devices are not installed.

Table 2

Heavy metals content in sewage sludge, from dairy W.W.T.P-s

Plant	Quantity of heavy metals $mg \cdot kg^{-1}$ d.m.						
	Pb	Zn	Cu	Cd	Ni	Cr	Hg
Wysokie Mazowieckie	10.2	170	22.40	0.52	3.10	4.60	0.18
Bielsk Podlaski	5.8	163	20.00	0.40	3.30	4.30	0.19
Grajewo	19.9	207	22.50	0.45	17.70	13.30	0.32
Kolno	12.6	139	27.00	2.30	13.90	14.20	0.16
Zambrów	8.1	234	28.00	0.60	9.10	9.60	0.26
Sejny	10.0	240	26.00	0.80	1.90	2.10	0.06
Mońki	3.2	150	20.00	0.15	6.20	9.60	0.20
Piątnica	7.1	410	62.10	0.84	14.00	8.80	0.10
Suwałki	9.0	675	7.70	0.50	3.70	8.50	0.03
Maximum accepted for agriculture reuse	500	2500	800	10	100	500	5

Table 3

Biogenic compounds content and organic substances in sewage sludge from dairy W.W.T.P-s

Plant	Chosen characteristic parameters				
	N-total $g \cdot kg^{-1}$ d.m.	P-total $g \cdot kg^{-1}$ d.m	Mg $g \cdot kg^{-1}$ s.m	Ca $g \cdot kg^{-1}$ d.m	Organic substances %
Wysokie Mazowieckie	93.6	17.0	3.9	28.0	82.1
Bielsk Podlaski	26.9	1.9	6.8	61.9	74.2
Grajewo	31.0	10.4	1.2	24.8	67.0
Kolno	71.0	2.5	5.9	42.3	31.2
Zambrów	93.5	48.8	5.7	41.3	72.0
Sejny	69.0	2.0	4.2	18.0	61.0
Piątnica	62.7	36.0	24.7	73.3	82.8
Mońki	60.0	8.2	2.1	18.0	64.0
Suwałki	20.8	5.3	4.5	47.8	74.2

Dairy production is connected with many sanitary obligations, material (milk) and water is examined, treatment process is monitored on account of sanitation. It is translated into sanitary quality of sewage and later on sewage sludge quality. Different situation is observed in municipal dairy waste water treatment plants where sewage sludge goes through sanitary decontamination, more often there are used also the processes of thermal processing of sludge to limit its capacity and provide sludge stabilization.

Table 4

Contents of heavy metals in chosen organic fertilizers (mg·kg^{-1} d.m.)

Fertilizer	Pb	Cd	Cr	Cu	Ni	Hg	Zn
Cow liquid manure	11	0,46	5,4	45	3,8	0,05	222
Swine liquid manure	11	0,82	9,0	294	11,0	0,04	896
Manure	17	0,1	22,0	27	16,0	0,10	190

Table 5

Heavy metals contents in municipal and industrial sludge from W.W.T.Plants of Podlaskie province - max. value 1996-2002

Type of W.W.T.P, research period	Heavy metals content (mg·kg^{-1} d.m) – maximum value						
	Pb	Zn	Cu	Cd	Ni	Cr	Hg
Dairy waste water treatment plants,1998-2002	19,0	48	26	0,80	12,0	19,0	0,38
Meat industry waste water treatment plants, 1999-2001	7,0	80	136	1,4	19,0	21,0	0,2
Municipal waste water treatment plants-Podlaskie province, 1998-2000	94	1436	136	4,9	25	1000	5,15

Summary

Sewage sludge produced in analysed dairy waste water treatment plants are exposed to recycling. They come back to environment in a form of fertilizer, because they comply with the requirements of the order of 2002. According to European hierarchy waste management, the most preferable is prevention of their forming, reuse and recycling.

In case of dairy or municipal sewage sludge, the prevention consists in limit of produced sludge. On account of the fact that sludge quantity depends on the capacity of sewage load and technology of their treatment, it is difficult to limit their amount on the level of treatment process. According to recommendations shown as the Best Available Technology (B.A.T.) for food industry, in case of milk plant the most important is high quality and product safeness. Less important are activities, which limit water use and sewage production in comparison with processed material unit, which means milk.

The current order on water quality carried to receiving water, demands high requirements from treated sewage, which translates into intensive technology of removal of carbon, nitrogen and phosphorus compounds. Moreover the use of modern intensive treatment methods causes the increase of sludge quantity. On account of low metals content in dairy sludge, high content of nitrogen, phosphorus,

calcium and magnesium and the lack of sanitary danger, there is no alternative for sludge recycling to the environment in a form of for example fertilizer. In Podlaskie province 96,91 % of soils agriculturally used have natural heavy metals content, while only 0,03% of them can be classified to second degree of contamination, which also proves the necessity of sludge recycling coming not only from dairy waste water treatment plants (Terelak, 2001). There is no explanation for the utilization of expensive thermal processes in sludge treatment, which are more often used in Poland, in case of municipal waste water treatment plants. The situation can be changed after introducing methods of anaerobic treatment of dairy sewage, which can take place in case of the largest objects. Among analysed plants, this situation can consider the ones in Wysokie Mazowieckie, Grajewo and Piątnica. The experiences gathered from introducing of new technologies can be used by the whole dairy industry and similar food plants, which have individual waste water treatment plants.

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