CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

No. 2 2007

AN EVALUATION OF THE USABILITY OF SLUDGE FROM THE MECHANICAL-BIOLOGICAL SEWAGE TRATMENT PLANT OF THE TOWN OF ZIELONA GÓRA FOR SEWAGE FARMING

Michał DRAB
University of Zielona Góra

The paper contains an evaluation of the possibilities of using sludge from the town of Zielona Góra in agriculture. The sludge under research demonstrated positive fertilizing properties. It has been found that because of increasing sludge doses the crops of plants grown have increased. The amount of organic matter and most of soil components marked have also increased.

The evaluation of the usability of sludge from the town of Zielona Góra has been done in compliance with the current legal regulations. The chemical properties of the sludge under research indicate its usability for the purpose chosen. The sanitary properties make it necessary for the sludge to be processed for example by composting.

Keywords: sludge, sewage farming

1. INTRODUCTION

The development, modernization and construction of new sewage treatment plants in recent years have increased considerably the amount of sludge produced in Poland and in the world. The forecast of the Institute of Environmental Protection [Biernacka and Pawłowska 1996] assumes that the production of sludge in Poland will reach 413 – 450 thousand tonnes of dry mass yearly by 2010.

The utilization of sludge becomes a serious problem. Recent research into sludge indicates that the most advisable way of utilization is its ecological use. According to the abovementioned authors in Poland the amount of sludge utilized ecologically is 20 – 25%. According to Baran [2004] in Poland about 15% of sludge is used in agriculture, and in the countries of the European Union 38%.

The reason for the agricultural utilization of sludge is a large quantity of minerals nutrients in it [Baran 1997; Mazur and Ciećko 2000; Czekała 2000 and 2003; Krzywy et al. 2000]. This matter is particularly important in Poland, because in recent years the use of mineral fertilizers has decreased considerably as well as the number of animal farms animals. Sludge can also be used for the reclamation of land without soil [Baran and Turski 1997; Stępień et al. 2000] and for hydroseeding while reclaiming post-mining heaps [Głażewski 2000].

An uncontrollable use of sludge is not advisable because of the possibility of polluting the environment in terms of sanitary conditions and with heavy metals.

The purpose of this paper is to evaluate the use of sludge from the sewage treatment plant in the town of Zielona Góra in agriculture. The paper describes the use of sludge as fertilizer applied in different amounts, and presents an analysis of the possibilities of using it in light of the current legal regulations.

2. MATERIALS AND METHODOLOGY

The use of sludge as fertilizer was researched in the pot experiment carried out in 2002 in a completely random way in three batches. Two kinds of soil were used:

- light soil consisting of granular light clay sand with pH in H_2O 6.5 and 6.0 in 1 $mol \cdot dm^{-3}$ KCL; electrolytic conductivity was 0.12 $mS \cdot cm^{-1}$; quantity of available P and K was 0.06 $g \cdot kg^{-1}$; quantity of organic C 15.5 $g \cdot kg^{-1}$,
- medium soil consisting of granular light clay with pH 6.4 in H_2O and 5.9 in 1 $mol \cdot dm^{-3}$ KCL; electrolytic conductivity was 0.14 $mS \cdot cm^{-1}$; quantity of available P was 0.07 $g \cdot kg^{-1}$ and absorbable K 0.08 $g \cdot kg^{-1}$; quantity of organic C 14.4 $g \cdot kg^{-1}$.

Sludge conditioned with iron salts, polyelectrolyte and $CaCO_3$ from the mechanical-biological sewage treatment plant from the town of Zielona Góra was used in the research. The sludge had the following qualities: pH – 8.1, electrolytic conductivity – 3 $mS \cdot cm^{-1}$;moisture content 63%. Organic matter was detected in the dry mass of the sludge in the quantity of 656 $g \cdot kg^{-1}$, and total forms in the quantities of 4646 $gN \cdot kg^{-1}$, 9 $gP \cdot kg^{-1}$, 7 $gK \cdot kg^{-1}$, 113 $gCa \cdot kg^{-1}$, 3 $gMg \cdot kg^{-1}$, 3 $gFe \cdot kg^{-1}$, 188 $mgMn \cdot kg^{-1}$, 421 $mgZn \cdot kg^{-1}$, 124 $mgCu \cdot kg^{-1}$, 24 $mgNi \cdot kg^{-1}$, 93 $mgPb \cdot kg^{-1}$ 9 mg $Cd \cdot kg^{-1}$, i 36 $mgCr \cdot kg^{-1}$.

In the experiment two test plants were grown: asparagus and turnip. The pattern of the experiment was the same for both plants, it comprised two fertilizer variants:

1. O without (fertilizers)
2. K 0.66 g/pot i.e. 100 kg K2O·ha
3. Sludge 6.66 g s.m.+0.066gK/pot i.e. 10t of sludge+100 kg K2O·ha-1

4. Sludge 33.30 g s.m.+0.066gK/pot i.e. 50t of sludge+100 kg K2O·ha-1
5. Sludge 66.60 g s.m.+0.066gK/pot i.e. 100t of sludge+100 kg K2O·ha-1
6. Sludge 133.30 g s.m.+0.066gK/·pot i.e. 200t of sludge+100 kg K2O·ha-1

The pots were placed in the open, receiving an identical amount of sunlight. They were watered with water up to 60% of maximum water-holding capacity. The experiment lasted from 15.06 to 15.08. After that time the plants were taken away. The crops of fresh dry mass were specified. Samples of the plants and soil after the crops were gathered were analysed chemically.

Total forms of N, P and K were specified in the plants as well as Cu, Zn, Pb and Ni. The following were specified in the soil: pH in H_2O and 1 mol·dm^3 KCL, electrolytic conductivity, organic C by the Tiurin method, absorbable forms of P and K by the Enger Riehm method and total forms of N, P, K, Ca, Cu, Zn, Pb, and Ni.

An analysis of the possibilities of the use of sludge in agriculture was carried out on the basis of legal regulations [Directive 1986, Law 2001 and Regulation 2002].

3. RESULTS AND DISCUSSION

Sludge can be included among controversial wastes. On the one hand it contains a number of valuable ingredients for fertilizing soil, on the other it can contain considerable quantities of harmful components. It can also be polluted in terms of sanitary properties. Harmful substances found in sludge and sanitary pollution make it necessary to use sludge in agriculture carefully. In spite of the disadvantages presented, it seems that the use of sludge in agriculture should be the most advisable way of utilizing it.

The sludge used had a favourable influence on the crops from the plants grown in the experiment (table 1). The reaction of the plants to the fertilizer variants used were proved statistically. It turned out that the larger sludge doses were used the faster the plants grew, and the largest crops were gathered when the largest amount of sludge was used.

Changes in the quantities of the components under analysis in the plants and soil after the crops had been gathered have been presented in the paper [Drab et al. 2004]. It results from the paper that:

- the more sludge was used the larger quantities of general forms of nitrogen, phosphorus and micro-components were found in the plants. Changes in the quantities of calcium and potassium were small. That reaction could have resulted from large quantities of nitrogen, phosphorus and micro-components in the sludge. Kalembasa and Kuziemska [1993], Krzywy et al. [2000 and 2003] have shown a similar relation in their works,

- sludge doses caused considerable changes in the chemical properties of the soil tested after the crops had been harvested. The changes included: an increase in the quantity of organic C, general forms of nitrogen and phosphorus and absorbable forms of phosphorus and potassium,
- an increase in the quantities of micro-components caused by increasing sludge doses was found in the soil analysed.

The use of sludge in agriculture should include the nutritive needs of plants and it can not spoil the quality of soil or ground or underground water [Directive 1986 and Law 2001].

The condition that have to be met while using sludge in agriculture are formulated quite clearly, Regulation [2002]. These conditions refer to chemical and sanitary conditions.

As regards chemical properties:

- sludge can be used in agriculture if its reaction is not lower than 5.6 and the quantity of heavy metals in it does not exceed the quantities presented in table 2,
- particularly important is the quantity of heave metals which can be applicated into soil with sludge in one year, on average in 10 years (tab. 3),
- sludge can be used on land whose surface layers contain particular quantities of heavy metals (tab. 4 and 5),
- the amounts of sludge that can be used on land are presented in table 6.

The sanitary conditions which have to be met by sludge used on land the abovementioned Regulation specifies as follows:

- town sludge used in agriculture and for land reclamation for agricultural purposes should not have Salmonella bacteria in 100g,
- an overall number of live eggs of intestinal vermin : Ascaris, Trichuris, Toxocara in 1 kg s.m. of sludge used in agriculture is 0, and in sludge used for land reclamation not more than 300.

Sludge from the sewage treatment plant of the town of Zielona Góra taken for research in June 2002 was by all means useful for agricultural purposes in terms of chemical qualities. Its reaction was 8.1, which was much more than the reaction suggested by current regulations [Directive 1986 and Regulation 2002]. The quantities of all heavy metals detected in the sludge was much lower than the quantities regarded as acceptable [Directive 1986 and Regulation 2002].

A microbiological analysis proved the usefulness of that batch of sludge for agricultural purposes after composting. The results of the paper by Bich Loc Thi Ngujen [2002] did not show the presence of Salmonella bacteria but they revealed the presents of live vermin eggs. Composting eliminated the presence of vermin eggs.

The doses of sludge used in the experiment were much varied and amounted to 10 to 200 t s.m after recalculation on 1 ha. While specifying the amount of doses attention was given to the possibility of testing doses of fertilizers for fertilizing soil as well as land reclamation. It is necessary to emphasize that even the largest doses of sludge did not cause a decrease in the crops of plants, on the contrary they increased the crops.

Using sludge in large quantities may result in introducing into soil with them large quantities of heavy metals.

Table 7 presents the quantities introduced into soil with the doses of sludge used in the experiment. The above data shows that it was only in the case of cadmium that those quantities exceeded the values presented in table 3. In the case of the other metals the amount of components introduced into soil, even with the dose of 50t/ha did not exceed the quantities regarded as acceptable, on condition that the dose is used once in five years.

4. CONCLUSIONS

The sludge used in the experiment had a favourable effect as fertilizer. The crops of plants increased as the doses of sludge increased. Fertilization with sludge increased the quantity of organic matter in the soil and a majority of marked mineral nutrients.. The chemical qualities of the sludge tested proved its usability in agriculture. While using sludge attention should be given to the amount of heavy metals introduced into soil with it.

The microbiological analysis showed the presence of live eggs of intestinal vermin in raw sludge. The danger posed by them can be eliminated by composting sludge.

REFERENCES

1. Baran S, 1997. *Przyrodnicze wykorzystanie osadów ściekowych.* Ekoprofit 6(11): 13-16.
2. Baran S, 2004.*Osady ściekowe w gospodarce rolno-środowiskowej.* Zesz. Prob.. Post. Nauk Roln. 499:15-20.
3. Baran S., Turski R. 1997. *Degradacja, ochrona i rekultywacja gleb.* Wyd. AR Lublin.
4. BICH LOC THI NGUYEN 2002.*Charakterystyka mikrobiologiczna i możliwość wykorzystania osadów ściekowych do produkcji kompostu z oczyszczalni ścieków dla miasta Zielona Góra.* Zesz. Prob.. Post. Nauk Roln. 484:401-408.

5. Biernacka J.,Pawłowska L.:1996 *Przeróbka osadów z miejskich oczyszczalni ścieków w kraju. Stan obecny i kierunki modernizacji.* Mat. Konf. ."Osady ściekowe, przeróbka i wykorzystanie. Poznań:15-24.
6. Czekała J. 2000. *Wartość próchnicotwórcza i działanie nawozowe osadu ściekowego. Fol. Univ. Agric. Stetin.* 211, Agricultura 84: 75-80.
7. Czekała J. 2003. *Zmiany ilościowe węgla i azotu związków próchnicowych powstających podczas inkubacji osadu ściekowego i obornika.* Zesz. Probl. Post. Nauk Roln. 494: 61-68. Probl. Post. Nauk Roln. 494: 105-111.
8. Drab M., Węclewski S., Długosz A. 2004:*Działanie nawozowe osadu ściekowego z mechaniczno-biologicznej oczyszczalni miasta Zielona Góra.* Zesz. Prob.. Post. Nauk Roln.499:69-77.
9. Directive of the European Union Council 86/278/ EWG of 13 June 1986 on environmental protection, especially soil while using sludge in agriculture.
10. Głażewski M. 2000. *Przeciwerozyjne biologiczne zabezpieczenie skarp metodą hydroobsiewu.* Mat. Konf. „Tereny zdegradowane – możliwości ich rekultywacji". Akademia Rolnicza Szczecin: 75-90.
11. Kalembasa S., Kuziemska B. 1993. *Wpływ osadów ściekowych na plony wybranych roślin oraz zawartość w nich metali ciężkich.* Roczn. Glebozn. 42 (314).
12. Krzywy E., Wołoszyk Cz., Iżewska A. 2000. *Ocena przydatności do nawożenia kompostów z osadów ściekowych z oczyszczalni komunalnych. Cz. I. Plonowanie rekultywacyjnej mieszanki traw w uprawie polowej.* Fol. Univ. Agric. Stetin. 211, Agricultura 84: 199-204.
13. Krzywy E.,Iżewska A., Jeżowski St.2003. *Wpływ komunalnego osadu ściekowego na zmiany niektórych wskaźników żyzności gleby.* Zesz. Prob.. Post. Nauk Roln. 494:215-223.
14. Krzywy E., Iżewska A.2004. *Gospodarka ściekami i osadami ściekowymi.* AR Szczecin.
15. Mazur T., Ciećko Z. 2000. *Nawożenie organiczne w zintegrowanym rolnictwie.* Fol. Univ. Agric. Stetin. 211, Agricultura 87: 285-288.
16. Rozporządzenie MŚ 2002. *Z dnia 1 sierpnia 2002 r. w sprawie komunalnych osadów ściekowych.* Dz. U. nr 134, poz. 1140.
17. Stępień W., Szulc W., Mercik S. 2000. *Ocena wartości nawozowej surowego i uzdatnionego osadu ściekowego.* Fol. Univ. Agric. Stetin. 211, Agricultura 84: 456-470
18. Law of 27 April 2001 roku on wastes. Law Reg. 2001 No 62 item. 628.

Table 1. Crops of green mass of turnip and beans in grams/pot

Fertilizer variants	Turnip		Asparagus	
	Light soil	Heavy soil	Light soil	Heavy Soil
O (without fertilizers)	16,9	10,4	62,1	53,0
K 0,066 g·pot^{-1}	22,2	11,8	75,0	51,9
Sludge 6,66 g+ 0,066 gK·pot^{-1}	18,6	11,3	62,6	61,8
Sludge 33,30 g + 0,066 gK·pot^{-1}	19,4	15,1	83,4 .	54,2
Sludge 66,60 g + 0,066 gK·pot^{-1}	24,5	19,6	89,2	66,7
Sludge 133,30 g + 0,066 gK·pot^{-1}	26,4	20,1	110,2	73,6
NIR, LSD - for fertilizer variants; - for soil	3,7 g from a pot 2,8 g from a pot		5,6 g from a pot 6,2 g from a pot	

Table 2. The acceptable quantity of heavy metals in sludge used for non-industrial purposes [Regulation 2002].

Metals	Quantity of heavy metals [mg·kg^{-1} sludge dry mass] not larger than when:		
	Used in agriculture and land reclamation for agricultural purposes	used for land reclamation for non-agricultural purposes	preparing land for particular needs , which result from plans for waste management, site planning and land development, growing plants intended for compost production, growing plants not intended for consumption or feed production
1. Lead (Pb)	500	1000	1500
2. Cadmium (Cd)	10	25	50
3. Chromium (Cr)	500	1000	2500
4. Copper (Cu)	800	1200	2000
5. Nickel (Ni)	100	200	500
6. Mercury (Hg)	5	10	25
7. Zinc (Zn)	2500	3500	5000

Table 3. The acceptable quantities of heavy metals which can be emitted into soil yearly over the period of 10 years [Regulation 2002].

Heavy metals	Quantities of heavy metals [g·ha $^{-1}$· year $^{-1}$]
1. Lead (Pb)	1000
2. Cadmium (Cd)	20
3. Chromium (Cr)	1000
4. Copper (Cu)	1600
5. Nickel (Ni)	200
6. Mercury (Hg)	10
7. Zinc (Zn)	5000

Table 4. The quantity of heavy metals in the soilsurface layer (0-25cm) while using town sludge in agriculture and reclamation for agricultural purposes [Regulation 2002].

No.	Metals	Quantity of heavy metals in mg·kg-1of ground dry mass not larger than in the case of soil:		
		Light	Medium	Heavy
1	Lead (Pb)	40	60	80
2	Cadmium (Cd)	1	2	3
3	Mercury (Hg)	0,8	1,2	1,5
4	Nickel (Ni)	20	35	50
5	Zinc (Zn)	80	120	180
6	Copper (Cu)	25	50	75
7	Chromium (Cr)	50	75	100

Table 5. The quantity of heavy metals in the land surface layer (0-25cm) while using town sludge in agriculture and reclamation for non-agricultural purposes, growing plants intended for compost production, growing plants not intended for consumption of feed production and preparing land for particular purposes, which result from plans for waste management, site planning or a decision about the building conditions and land development [Regulation 2002].

No.	Metals	Quantity of heavy metals in $mg \cdot kg^{-1}$ of ground dry mass not larger than in the case of soil:		
		Light	Medium	Heavy
1	Lead (Pb)	50	75	100
2	Cadmium (Cd)	3	4	5
3	Mercury (Hg)	1	1,5	2
4	Nickel (Ni)	30	45	60
5	Zinc (Zn)	150	220	300
6	Copper (Cu)	50	75	100
7	Chromium (Cr)	100	150	200

Table 6. Quantities of town sludge [Regulation 2002].

No.	The purpose of using town sludge		Dose of town sludge in Mg s.m. ·ha -1	Notes
1	Agriculture		to 10 dose over the period of 5 years	To be applied once or twice
2	Recla-mation	of land for agricultural purposes	200 depending on the required organic substance in the soil (to 3%)	To be applied once with one introduction into soil or with a number of introductions
		of land for non-agricultural purposes	To 200	To be applied once with one introduction into soil or with a number of introductions
3	Adaptation to particular needs resulting from plans for waste management, site planning or decisions about building land development		To 200	To be applied once with one introduction into soil or with a number of introductions

No.	The purpose of using town sludge	Dose of town sludge in Mg s.m. ·ha -1	Notes
4	Growing plants for compost production	To 250 dose for the first 3 years	To be applied a number of times
		To 10 dose for the following years	
5	Growing plants not intended for consumption or feed production	To 250 dose for the first 3 years	To be applied a number of times
		To 10 dose for the following years	

Table 7. The amount of heavy metals introduced into soil with sludge

Components	Acceptable amounts [g·ha $^{-1}$· year $^{-1}$]	Amounts of metals introduced with sludge [g·ha $^{-1}$]			
		Sludge dose[t·ha $^{-1}$]			
		10	50	100	200
1. Lead (Pb)	1000	930	4650	9300	18600
2. Cadmium(Cd)	20	90	450	900	1800
3. Chrome (Cr)	1000	360	1800	3600	7200
4. Copper (Cu)	1600	1240	6200	12400	24800
5. Nickel (Ni)	200	240	1200	2400	4800
6. Zinc (Zn)	5000	4200	21000	42000	84000

OCENA PRZYDATNOŚCI OSADÓW ŚCIEKOWYCH Z MECHANICZNO-BIOLOGICZNEJ OCZYSZCZALNI MIASTA ZIELONA GÓRA DO ROLNICZEGO WYKORZYSTANIA

Streszczenie

Praca zawiera ocenę możliwości rolniczego zagospodarowania osadów ściekowych miasta Zielona Góra. Badane osady wykazały pozytywne działanie nawozowe. Pod wpływem wzrastających dawek osadów stwierdzono wzrost plonów uprawianych roślin. Nastąpił też wzrost zawartości substancji organicznej oraz większości oznaczanych składników w glebach.Ocenę przydatności osadów do rolniczego zagospodarowania dokonano w oparciu o obowiązujące przepisy prawne. Właściwości chemiczne badanego osadu wskazują na jego przydatność do wybranego kierunku zagospodarowania. Właściwości sanitarne wymuszają poddanie osadów procesowi przeróbki np. kompostowaniu.