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Possibilities of Sewage Sludge Application in the Conditions of Slovak Republic

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***Abstract*—**The direct sewage sludge application is a relative cheap method for their liquidation. In the past heavy metal contents increase in soils treated with sewage sludge was observed. In 2003 there was acceptance on act n.188/2003 about sewage sludge application on soils. The basic philosophy of act is a safety of the environmental proof of sludge application on soils. The samples of soils from wastewater treatment plant (WTP) Poprad (35) and WTP Michalovce (33 samples) were analyzed which were chosen for sludge application on soils. According to the results only 14 areas for Poprad and 25 areas for Michalovce are suitable for sludge application according to act No. 188/2003. The application dose of sludge was calculated 50 $t.ha^{-1}$ or 75 t. ha^{-1} once in 5 years to ensure that heavy metal contents in treated soils will be kept.

***Keywords*—**Environmental safety, heavy metals in soils, sewage sludge application.

I. INTRODUCTION

IN 2004 production of sewage sludge represented 53,085 tons of dry residues. 42,504 tons from this was utilized in agriculture (80%), 5,858 tons was temporarily stored (11.1%), 4,723 tons was stocked piled (8,9%) and 12,000 tons of dry residue were applied directly in the agricultural soil, in other way 1,417 tons of sludge was utilized (soil recultivation).

In EU countries about 45 % of sludge from wastewater treatment plant is utilized in agriculture, 30-35 % is still stocked piled, 15-20 % is burned and the rest of production of sludge is utilized in other way [2]. Authors [2] declare, regarding agricultural utilization of sludge in Czech Republic their contamination by heavy metals is not the biggest problem. Microbial contamination of applied sludge is causing a bigger problem.

A possibility of sludge utilization in agriculture for soil fertilization is direct application of stabilized sludge or utilization of compost forms. Direct application into the soil is the most common and a cheap way to eliminate sludge. Only stabilized sludge that meets the maximum allowed contents of monitored risk elements can be used. Inappropriate increase of sludge dose was applied very often. That increased accumulation of heavy metals in soils even though the contents of heavy metals in sludge were normal. Szabová at al. [6] after sewage sludge application determined statistical significant increase of lead, zinc, chrome, cadmium except nickel in soil. At the same time higher contents of lead, zinc, cuprum, cadmium, nickel, and chrome were determined in root crop, kohlrabi, beet and potatoes which were growing on these soils. The heavy metal contents highly exceeded the limit concentrations. Morena et al. [5] monitored the bioavailability of copper, nickel, lead and zinc after sludge application in greenhouse conditions on three various soil types. Increasing the dose of sludge the concentrations of metals in plant increased. The influence of soil type on accumulation of metals in plant was higher than the influence of dose of sludge.

Until 2003 the applied dose of sludge was counted by zinc equivalent (Zn_{eq}) in Slovakia (3). The content of heavy metals in soil was not considered in this method. Insufficient information about the content of heavy metals in soils caused, that the calculated dose of sludge considering Zn_{eq} were causing soil contamination by heavy metals.

Nowadays the act No. 188/2003 is valid [8]. It modifies conditions of application sewage sludge – 15 tons of sludge dry residues can be applied into the soil once in 5 years. The aim of this act is to modify conditions of sewage sludge application into the soil. It is essential to cut out the negative influence on the soil characteristics and plants. The basic philosophy of the act is the safety of environmental proof of sludge application on soils.

The goal of this study was a calculation of application dose of sludge for wastewater treatment plants in the cities Poprad and Michalovce to topsoil according to act No. 188/2003.

II. MATERIALS AND METHODS

In 2003 – 2004 soil samples were collected in the area of districts Poprad, Gelnica, Spišská Nová Ves where application of the sewage sludge is supposed. Thirty-five soil samples were collected together. In 2003-2004 thirty-three soil samples were collected in the area of district Michalovce.

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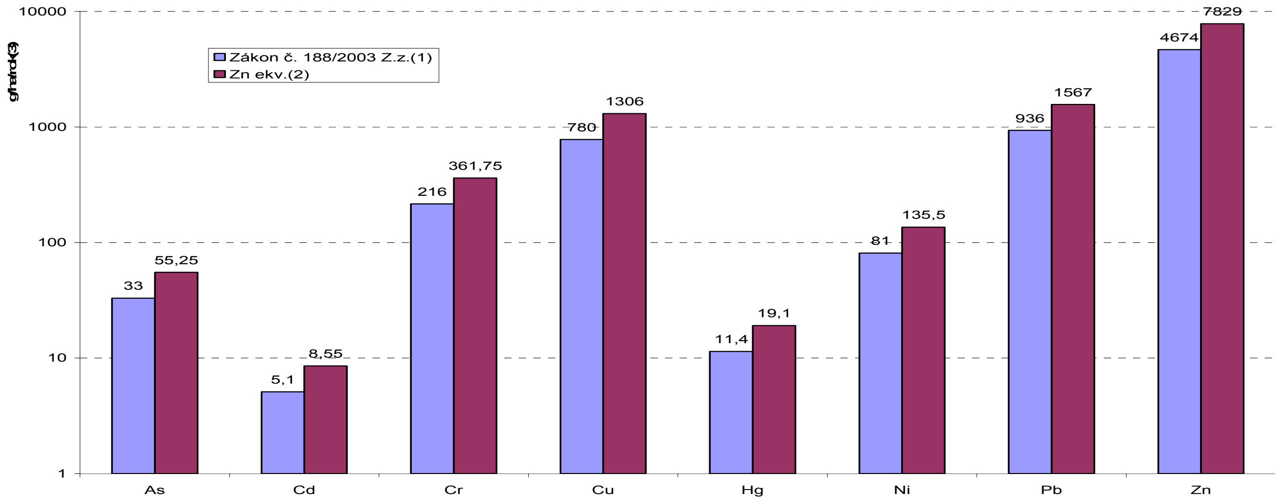

Fig. 1 A comparison if the influence of sewage sludge doses calculated according to act No. 188/2003 and Zn_{eq} from WTP Poprad on heavy metal contents in the soils. (1) Act No. 188/2003; (2) Zn_{eq}; (3)g/ha/year

Soil samples were collected in compliance with the relevant methods, dried at ambient temperature and sieved through a sieve with aperture size 2 mm. This prepared fine-grained soil was used for determination of pH/KCl. Heavy metal contents were determined in compliance with the relevant methods. The contents of copper, nickel, chrome, lead and zinc (mg. kg^{-1}) in filtrate were analyzed using AAS. According to the results of sewage analysis, which were realized in an accredited testing laboratory, heavy metal contents in sludge do not exceed the limit values of risk elements concentrations in sludge according to act No. 188/2003 and it is possible to use them for direct application in the soil.

III. Results

A. Wastewater treatment plant Poprad

Figured soils are situated in a submontane area. The soil pH is acid (4.6) to weakly alkaline (7.4) with lower, middle to very high sorption capacity.

Following the Appendix 4 of act No. 188/2003 in which the limit values of risk elements concentration in agricultural and woodland soil are interpreted, 21 areas from all the soil samples (35) were selected where it is not possible to apply sewage sludge according to act No. 188/2003.

Two soil samples are acid – pH/KC is 4.60 and 4.87 - they do not achieve required pH for application (pH=5). In eight soil samples overlimit concentration of copper, in eight samples overlimit concentration of zinc, in one sample overlimit concentration of copper and zinc, in one sample overlimit concentration of copper and lead, in one sample overlimit concentration of copper, lead and zinc were determined. It is not possible to apply sewage sludge in this area.

According to the soil samples analysis [14] the sludge can be applied in this area. Calculation of doses of sludge for this wastewater treatment plant, according to act n. 188/2003, is presented in Table I.

According to the sludge composition calculated, it is recommended to apply the sludge once in five years in the amount of fifty tons of sludge per one hectare of soil that also fulfill the essential criteria for sludge application of act No. 188/2003, Appendix No. 5 about maximum amounts of risk elements that were added in sewage sludge into agricultural soil per year. This application dose will ensure that the content

TABLE I
Calculation of Sewage Sludge Dosage from WTP Poprad according to act No. 188/2003

Maximum quantity of risk elements added in sewage sludge to the soil according to act No. 188/2003		Poprad		
		Sewage sludge composition	15 t of dry matter	
Indicator	g/ha/year	mg/kg	g/ha/5years	g/ha/year
Arsenic	60	11	165	33
Cadmium	30	1.7	25.5	5.1
Chromium	3000	72	1080	216
Copper	3000	260	3900	780
Mercury	30	3.8	57	11.4
Nickel	900	27	405	81
Lead	2250	312	4680	936
Zinc	7500	1558	23370	4674
			50 t/ha of sewage sludge	

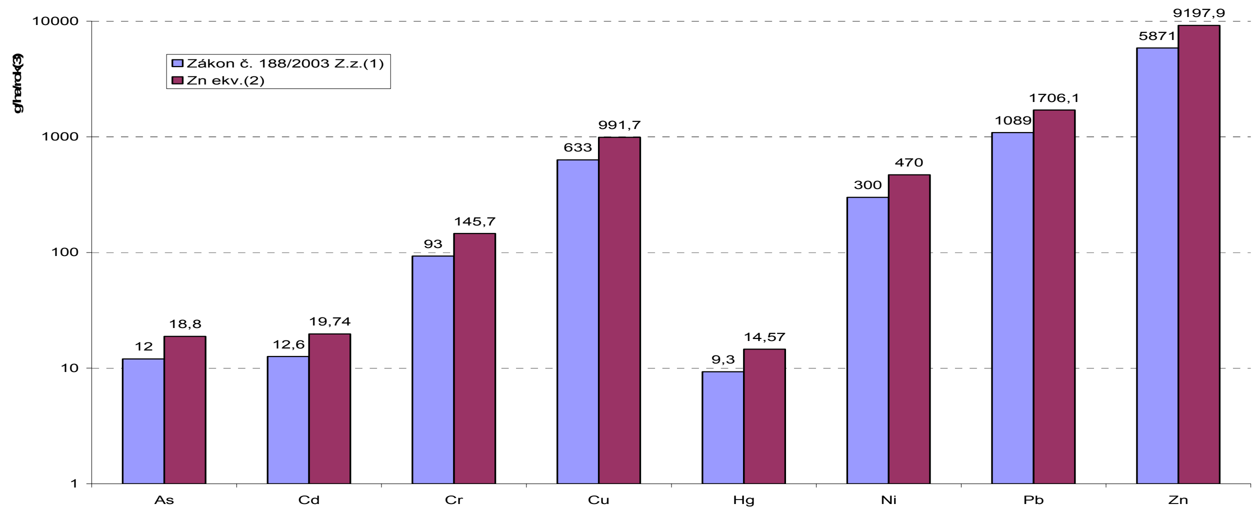

Fig. 2 A comparison of the influence of sewage sludge doses calculated according to act No. 188/2003 and Zn_{eq} from WTP Michalovce on heavy metal contents in the soils. (1) Act No. 188/2003; (2) Zn_{eq}; (3)g/ha/year

of heavy metals in soils will not be exceeded. It is necessary to make new calculations of application amounts in case of change of sludge content.

To compare the environmental safety of sludge application according to act No. 188/2003 a calculation of applied amount of sludge based on zinc equivalent (Zn_{eq}) that was valid till 2003 is presented.

Simple amount of sludge 67 t.ha-1 that is 20.1 t.ha^{-1} (Fig. 1) of dry mass of sludge was calculated for the region situated in the submontane and potato-growing region. As presented in Fig. 1, applying the calculated amount of sludge on the base of Zn_{eq} in comparison with the amount of sludge according to act no. 188/2003, the contents of all heavy metals in sludge will increase.

The value of pH is within the range from 5.3 to 6.4. According to act it is possible to apply the sludge in these samples but concerning the mobility of heavy metals in soils most metals will be acceptable for plants in this range of pH. Even though the law allows applying the sludge in soil, that the mobility of heavy metals may increase and plants cultivated in these areas may be contaminated.

B. Wastewater Treatment Plant Michalovce

The sampled soils are situating in lowlands. These soils are fertile with a good content of nutrients. According Appendix No. 4 of act No. 188/2003 8 areas were selected from 33 samples where it is not possible to apply sludge, because these areas have high contents of nickel, copper, zinc and lead.

According to the composition of sludge in WTP Michalovce it was calculated, that in the areas where it is possible to apply sludge according to act No. 188/2003 it is recommended to apply 75 t.ha^{-1} of sludge i.e. 15 tons of dry residue of sludge once in 5 years (Table II). The calculated dose of sludge according to Zn_{eq} 94 t.ha^{-1}, i.e. 18.8 tons of dry residue of sludge will cause an increase of heavy metal contents in soil by 56.7 % (Fig. 2).

IV. Discussion

A serious problem, which arises from the analysis of soils in the surrounding of WTP Poprad is, that the values of pH of 51.8 % soils are in the range from 5.3 to 6.4, whereas in soils in the area around WTP Michalovce there are only 3 samples with pH from 5.1 to 5.4. In spite of that the act allows to apply sludge into these soils, it is suggested to apply lime into the

TABLE II
Calculation of Sewage Sludge Dosage from WTP Michalovce according to act No. 188/2003.

Maximum quantity of risk elements added in sewage sludge to the soil according to act No. 188/2003		Michalovce		
		Sewage sludge composition	15 t of dry matter	
Indicator	g/ha/year	mg/kg	g/ha/5years	g/ha/year
Arsenic	60	4	60	12
Cadmium	30	4.2	63	12.6
Chromium	3000	31	465	93
Copper	3000	211	3165	633
Mercury	30	3.1	46,5	9.3
Nickel	900	100	1500	300
Lead	2250	363	5445	1089
Zinc	7500	1957	29355	5871
			75 t/ha of sewage sludge	

soil first and apply the sludge only a few years later as the mobility and share of bioavailable heavy metals increases in acid environment. Domažlická [1] specifies that increase of pH from 5.1 to 7.2 significantly reduces the content of cadmium, lead, aluminum and mercury in agricultural plants. Mitchell [4] considers the sludge to be a good source of nutrients in the soils, but he recommends not applying the sludge to soils without complete analyses of the sludge and the soils. According to [4] the sludge can be applied only in the soils with pH above 6.5, because lower pH will increase the availability of heavy metals in the plants.

The act No. 188/2003 eliminates the risks of non-controlled applications in the soil and enables to make necessary structure for sludge management and to take necessary steps to eliminate the productions in the areas of WTPs.

An essential condition to fulfill the conceptual intentions of the sludge treatment is sustaining the necessary quality and not exceeding the limits of harmful substances which limit the process of sludge application into the soil. At the same time it is reasonable to decrease the limit values and spread the area of monitored values to control the increase of sludge qualities [7].

V. Conclusion

According to the results of calculated doses of sludge into agricultural soils with respect of act No. 188/2003 and comparing the calculated values according Zn_{eq} valid until 2003 it can be concluded:

1) The calculated dose of sludge according to act No. 188/2003 for WTP Poprad is 50 $t.ha^{-1}$ (15 $t.ha^{-1}$ of dry residue of sludge) and according to $Zn_{eq\ it}$ is 67 $t.ha^{-1}$ of sludge (20 $t.ha^{-1}$ of dry residue of sludge), and for WTP Michalovce it is 75 $t.ha^{-1}$ and according to Zn_{eq} it is 94 $t.ha^{-1}$ of sludge (18.8 $t.ha^{-1}$ of dry residue of sludge).

2) The limiting element for sludge dose calculation is zinc. If heavy metals content in sludge changes it is necessary to calculate again.

3) From 35 analyzed soil samples in the area around WTP Poprad it is only possible to apply sludge in14 areas. In two soil samples pH was below 5 and in 19 samples overlimit concentration of heavy metals in soils were determined according to act No. 188/2003. Sludge can be applied in 25 areas around Michalovce.

4) We recommend adjusting the value of pH using lime for the soils with pH in range 5.3 – 6.0, because pH affects the element mobility causing heavy metal contamination of grown crops.

5) Meeting the application doses of sludge calculated according to act No. 188/2003 in accordance with Appendixes No. 4 and No. 5 the environment safety of sludge application in soils will be fulfilled – soil contamination with heavy metals will be prevented.

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