ACCUMULATION OF HEAVY METALS IN RYE (SECALE CEREALE L.) FROM MUNICIPAL SEWAGE SLUDGES

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Abstract: *Accumulation of heavy metals in rye from variously treated municipal sewage sludges from 3 big cities from Eastern Hungary was studied in pot experiment. The studied sewage sludges proved to be relatively uncontaminated with Cd, Cr, Cu, Ni, Pb and Zn, their heavy metal concentrations were considerably lower than the values of Hungarian regulatory limits. Heavy metals were accumulated prevalently in the roots of rye test plants, and rate of metal translocation to shoots was low.*
Key words*: heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), municipal sewage sludge, rye (Secale cereale L.)*

1. INTRODUCTION

Sewage sludges are unavoidable by-products of sewage treatment. Continuously growing quantity of municipal sewage sludges and rigorous environmental regulations makes safe disposing of this material more and more difficult (Vermes, 1998).

In Hungary – in accordance with EU directions – agricultural utilization of municipal sewage sludges has the priority in their disposing (Barótfi, 2000). Since municipal sewage sludges are rich in plant nutrients (i.e. nitrogen, phosphorus, trace elements), in humus-forming, soil ameliorative and soil fertility enhancing materials their utilization in agriculture is advisable. Beside beneficial substances various toxic materials are present in municipal sewage sludges, among which heavy metals and organic micro-pollutants are the most dangerous. Depending on their origin and previous treatment municipal sewage sludges contain more or less heavy metals. Uncontrolled amendment of arable soils with sewage sludges may result in excessive accumulation of Cd, Hg, Pb, Zn etc. in soil, and through soil-plant system these dangerous materials can get into the food chain (Tamás and Filep, 1995). Therefore the heavy metal concentration of municipal sewage sludges is one of the most important limiting factors in case of their agricultural utilization (Vermes 1998).

2. MATERIALS AND METHODS

Sewage sludge and soil examinations

Municipal sewage sludges (abbreviated thereafter as SS) generated in sewage treatment plants of 3 cities from Eastern Hungary were studied. In Nyíregyháza SS is aerobically composted with wheat straw. In Debrecen SS is dewatered with centrifuging, and is anaerobically digested. In Miskolc SS is mixed with ground rhyolite tuff, the mixture is then composted and incubated. In the first section of our research work heavy metal composition and concentration of the above municipal sewage sludges, and also of basic untreated soil (utilized in pot experiment) was investigated. SS and soil samples were collected, dried, ground, sieved and sampled as described in Simon et al. (2000). Elemental composition of samples was determined with inductively coupled plasma optical emission spectroscopy (ICP – OES) after cc. HNO_3 – cc. H_2O_2 digestion (Simon et al., 2000). Concentration of the environmentally most problematic heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) was evaluated.

Pot experiment with rye test plant

Growth chamber pot experiment was conducted with rye (*Secale cereale* L., cv. Kisvárdai legelő) test plant during winter of 2001 in the light chamber of College of Nyíregyháza, Technical and Agricultural Faculty, Hungary. „Kisvárdai legelő" is a double-utilized rye cultivar. In case of early sowing it could be grazed by sheeps during winter and / or spring period. Test plants were cultivated in loamy sand (pH_{KCl} 6.6) untreated brown forest soil (for characteristics of this soil see Simon et al. 2000), or in soil–SS mixture. Total weight of mixture was around 6 kg, ratio of SS from Nyíregyháza, Debrecen or Miskolc was 2.5 or 10 % (m/m%), respectively. Treatments were set up with 4 replications. After 4 months of mixture incubation (mixture was saturated weekly with distilled water) rye seeds were sown into growth media. Growth parameters (illumination 13000 lux for 10 hours daily, day temperature 21°C±2°C, night temperature 16°C±2°C, humidity 35~50 %) were controlled, plants were watered 2-3 times weekly until constant weight with distilled water. To investigate heavy metal accumulation of rye plant organs, shoots were sampled 40 days after sowing (1^{st} cut). At the termination of experiment, 65 days after sowing shoot (2^{nd} cut) and root samples were taken for ICP-OES analysis.

3. RESULTS AND DISCUSSION

Heavy metal concentrations in untreated soil and in municipal sewage sludges

Table 1 shows heavy metal concentrations in untreated experimental soil and in municipal sewage sludges at the beginning of the experiment.

Table 1. Heavy metal concentrations (mg kg^{-1} dry matter) in untreated experimental soil and in municipal sewage sludges (Nyíregyháza, 2001)

Elements	Experimental soil	SS from Nyíregyháza	SS from Debrecen	SS from Miskolc	Regulatory limit*
Cd	1.00	2.54	2.42	1.29	15
Cr	15.6	29.3	166	14.7	1000
Cu	15.1	92.2	319	41.1	1000
Ni	8.77	11.8	22.3	3.38	200
Pb	43.6	93.1	84.4	25.5	1000
Zn	71.3	792	1091	222	3000

* Heavy metals concentration regulatory limits in sewage sludges in case of agricultural utilization and deposition (MI-08-1735: 1990 Hungarian Technical Standard)

Heavy metal concentrations in untreated soil are in normal range charasteristic for uncontaminated soils. In municipal sewage sludges concentration of heavy metals does not exceeded the Hungarian regulatory limits, which could be advantageous in case of agricultural utilization. Heavy metal concentrations of SS from Miskolc are definitively lower than in SS-s from Nyíregyháza or Debrecen. In comparison with untreated soil in SS from Miskolc lower Ni and Pb concentrations were found. The highest Cr, Cu, Ni and Zn concentrations were measured in SS from Debrecen, while the highest Cd and Pb concentration was found in SS from Nyíregyháza.

Effect of municipal sewage sludges on the heavy metal accumulation of rye

Table 2 shows heavy metal accumulation in plant organs of 40 days or 65 days old (harvested) rye. From our results is evident that heavy metals were accumulated prevalently in roots of rye. Translocation of Cr, Ni and Pb from roots to shoots was low, therefore we can suppose that in case of agricultural utilization of the studied sewage sludges heavy metals will not be transported to above grown parts of rye, utilized as a fodder. Heavy metal concentrations measured in the shoots of rye are low. Concentrations of Cu and Zn, which are in the same time essential trace elements are normal. A slight increase of Cu and Zn concentration was observed in roots or cultures receiving 10 % SS from Nyíregyháza or 10 % SS from Debrecen. It is obvious that in cultures treated with SS from Miskolc less Cr, Ni and Zn was accumulated both in roots and shoots of plants than in case of other two treatments. This could be attributed to good metal adsorbing capacity of rhyolite tuff, which was mixed to SS.

Table 2. Effect of variously treated municipal sewage sludges on the heavy metal accumulation of rye (pot experiment, Nyíregyháza, 2002)

	Elements ($\mu g\ g^{-1}$)					
Treatments	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
	40 days-old shoots					
Control	0.13 ^{a}	0.31 ^{a}	13.5 ^{ab}	0.45 ^{a}	0.30 ^{a}	80.7 ^{b}
SS from Nyíregyháza 2.5%	0.14 ^{a}	0.26 ^{a}	13.2 ^{a}	0.36 ^{a}	1.04 ^{a}	88.6 ^{b}
SS from Nyíregyháza 10%	0.16 ^{a}	0.84 ^{a}	13.3 ^{a}	0.29 ^{a}	0.79 ^{a}	88.3 ^{b}
SS from Debrecen 2.5%	0.15 ^{a}	0.37 ^{a}	13.3 ^{a}	0.15 ^{a}	0.95 ^{a}	85.0 ^{b}
SS from Debrecen 10%	0.19 ^{a}	0.40 ^{a}	15.3 ^{b}	0.29 ^{a}	0.50 ^{a}	85.9 ^{b}
SS from Miskolc 2.5%	0.13 ^{a}	0.33 ^{a}	14.2 ^{ab}	0.20 ^{a}	1.36 ^{a}	62.1 ^{ab}
SS from Miskolc 10%	0.17 ^{a}	0.30 ^{a}	14.2 ^{ab}	0.20 ^{a}	0.87 ^{a}	53.6 ^{a}
	65 days-old roots					
Control	0.32 ^{a}	4.84 ^{b}	20.0 ^{a}	5.74 ^{a}	2.26 ^{a}	400 ^{a}
SS from Nyíregyháza 2.5%	0.40 ^{a}	2.47 ^{a}	25.2 ^{abc}	6.35 ^{a}	2.65 ^{a}	620 ^{a}
SS from Nyíregyháza 10%	0.49 ^{a}	1.32 ^{a}	30.5 ^{bc}	5.58 ^{a}	2.77 ^{a}	540 ^{a}
SS from Debrecen 2.5%	0.37 ^{a}	1.53 ^{a}	33.2 ^{cd}	5.76 ^{a}	1.38 ^{a}	550 ^{a}
SS from Debrecen 10%	0.37 ^{a}	1.11 ^{a}	47.2 ^{e}	4.46 ^{a}	2.53 ^{a}	451 ^{a}
SS from Miskolc 2.5%	0.43 ^{a}	2.46 ^{a}	22.5 ^{ab}	4.66 ^{a}	3.25 ^{a}	303 ^{a}
SS from Miskolc 10%	0.47 ^{a}	1.18 ^{a}	41.2 ^{de}	4.88 ^{a}	4.41 ^{a}	477 ^{a}
	65 days-old shoots					
Control	0.16 ^{ab}	1.05 ^{b}	11.2 ^{a}	0.44 ^{a}	0.99 ^{a}	107 ^{bc}
SS from Nyíregyháza 2.5%	0.11 ^{a}	0.47 ^{a}	12.6 ^{ab}	0.35 ^{a}	1.43 ^{a}	87.8 ^{abc}
SS from Nyíregyháza 10%	0.16 ^{ab}	0.74 ^{ab}	13.6 ^{ab}	0.41 ^{a}	0.45 ^{a}	123 ^{c}
SS from Debrecen 2.5%	0.15 ^{ab}	0.35 ^{a}	12.4 ^{a}	0.25 ^{a}	0.81 ^{a}	72.1 ^{ab}
SS from Debrecen 10%	0.22 ^{b}	0.49 ^{a}	14.9 ^{bc}	0.52 ^{a}	0.43 ^{a}	87.0 ^{abc}
SS from Miskolc 2.5%	0.12 ^{a}	0.50 ^{a}	11.4 ^{a}	0.24 ^{a}	0.90 ^{a}	58.3 ^{a}
SS from Miskolc 10%	0.22 ^{b}	0.38 ^{a}	15.9 ^{c}	0.35 ^{a}	1.57 ^{a}	80.2 ^{ab}

Statistical analysis was done by Tukey's test. Data are means of 4 replications. Means within the columns followed by the same letter are not statistically significant at P=0.05.

4. CONCLUSIONS

Studied municipal sewage sludges are relatively uncontaminated with heavy metals, this could be advantageous in case of agricultural utilization. When rye was grown in soil mixed with sewage sludges most of the metals were accumulated in roots. Low rate of metal translocation to shoots indicate low risk of heavy metal contamination of rye grown as a fodder in municipal sewage sludge amended arable soils.

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