

EFFECT OF COMMUNAL SEWAGE SLUDGE LOADS ON Zn AND Cu CONTENT OF SOILS AND PLANT UPTAKE

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Introduction

The benefits of sewage sludge application to agricultural soils as a source of nutrients and soil ameliorant have been widely acknowledged. However, sewage sludges may contain high concentrations of potentially toxic elements such as Cd, Cu, Ni, Pb and Zn. The contamination of soils with these elements continues to be a matter of great concern because of their persistence in soils and increased uptake by crop plants even many years after sludge applications (Kádár, 1999; Csathó, 1994; Simon, 2000).

The bulk of communal sewage sludge in Hungary is 700 thousand t/yr (25-30% D.M.), 23% of this amount is used on field. At the same time the toxic element content of sludge must be considered. These toxic and other elements may be fixed different ways, according to soil properties (Kádár, 2005; Tamás and Filep, 1995).

In this work, the effect of communal sewage sludge on different soil's element fractions and plant uptake was investigated in pot experiment.

Methods

A pot experiment was set up in 1999 for examining the effect of sewage sludge loads on soils and plants. Applied sludge had high Cu and Zn content, 1885 and 6157 mg/kg, respectively. Imre Kádár and Balázs Morvai designed the experiment using four different soils (Table 1). Applied sewage sludge loads were the followings: 0, 2,5, 5, 10, 20 g sludge D.M. / kg air-dry soil. Number of treatments were: 4 soil x 5 load level = 20, with 4 replications.

Table 1. Several properties of soil samples

	Örbottyán	Nagyhörcsök	Gyöngyös	Nyírlugos
pH H ₂ O	8.3	8.1	6.8	5.4
KCl	7.3	7.6	5.8	3.9
Plasticity index ¹	22	40	44	25
CaCO ₃ %	15	10	0	0
Clay+silt %	6	36	57	5
OM %	0.69	2.55	3.05	0.71

1: Upper limit of plasticity (water holding capacity)

Air-dry soil (<5 mm particle size) and homogenized fresh sludge was mixed and filled into 10-liter pots. After 1-month incubation, spring barley (April) and after its harvest (July) peas were sown. The barley had 3 months growing period. Soil sampling took place after pea harvest in October. Composite soil samples consisted of 10 cores/pot and all plant material (above-ground total plant mass/shoot) was used for analysis and yield assessment. Pots were irrigated with deionized water during the experiment, according to the water demand of

plants. Determination of plant element concentrations was carried out with ICP-AES method after cc. $\text{HNO}_3 + \text{H}_2\text{O}_2$ digestion.

From the soil samples the pseudo total (cc. $\text{HNO}_3 + \text{H}_2\text{O}_2$ digestion), the 0.5 M ammonium-acetate + 0.02 M EDTA extractable (Lakanen - Erviö, 1971) and 1 M NH_4NO_3 extractable (DIN 1973) element concentrations were measured. Determination of plant element concentrations was carried out with ICP-AES method.

Results and discussion

The Cu and Zn concentration exceeded 1.9 and 2.5 times responsibly the permitted limit concentrations of sewage sludge, concerning the utilisation on agricultural field. The loads also exceeded the yearly-approved limit (50/2001. Government Order). Apart from this fact the pseudo total concentrations in soils remained under the highest permitted 75 mg/kg Cu and 200 mg/kg Zn concentrations (Table 3 and 4), even in case of the greatest load.

Table 3. Effect of sewage sludge load on Cu content of soil and barley grain (mg/kg)

<i>Measured characteristics</i>	Load (g sludge D.M. / kg soil)						
	0	2.5	5	10	20	LSD_{5%}	Average
calcareous chernozem							
grain (total)	6.2	6.2	6.6	7.1	7.7	0.6	6.8
soil pseudo total	19	23	25	27	41	5	27
soil mobilisable¹	2.7	4.4	5.1	8.5	15	2.3	7.3
soil mobile²	0.18	-	0.24	0.21	0.32	0.05	0.24
calcareous sandy soil							
grain (total)	7.7	8.7	8.9	8.7	9.4	1	8.7
soil pseudo total	9	12	13	19	34	12	17
soil mobilisable¹	2.8	4.4	4.1	9.2	15	3.7	7.2
soil mobile²	0.21	-	0.37	0.47	0.93	0.07	0.49
brown forest soil							
grain (total)	5.5	5.8	6.3	6.7	7.7	0.5	6.4
soil pseudo total	31	30	37	42	56	5	39
soil mobilisable¹	6.4	8.7	12.5	15.2	15.8	3.2	11.7
soil mobile²	0.133	-	0.182	0.163	0.234	0.076	0.178
acid sandy soil							
grain (total)	6.3	8.4	9.4	9.3	10.9	1.2	8.8
soil pseudo total	5.0	7.1	8.9	12.2	20.5	4.3	10.7
soil mobilisable¹	0.9	3.1	2.6	7.6	10.5	3.8	4.9
soil mobile²	0.14	-	0.25	0.49	0.61	0.22	0.37

1: Lakanen-Erviö soluble; 2: NH_4NO_3 soluble; -: Not measured

The concentrations of Cu and Zn were the lowest on acid sandy soil in each fraction. The two soils with higher clay+silt and organic matter content (Nagyhőrcsök, Órbottyán) showed the smallest relative increment in pseudo total concentrations because these soils had originally high concentrations. The control Cu and Zn concentrations were the highest on these soils. The NH_4 -acetate + EDTA soluble concentrations increased in the highest rate in case of each soil sample. This increment was more than 10 fold on acid sandy soil. The soil mobile Cu and Zn concentrations were usually 3 orders of magnitude smaller than LE or pseudo total.

Table 4. Effect of sewage sludge load on Zn content of soil and barley grain (mg/kg)

Measured characteristics	Load (g sludge D.M. / kg soil)					LSD _{5%}	Average
	0	2.5	5	10	20		
calcareous chernozem							
grain (total)	24	29	33	38	45	2.7	34
soil pseudo total	60	81	93	92	131	18	91
soil mobilisable ¹	8	12	14	26	50	9	22
soil mobile ²	0.05	-	0.06	0.08	0.1	0.1	0.07
calcareous sandy soil							
grain (total)	27	36	36	42	53	4	39
soil pseudo total	22	28	30	57	95	34	46
soil mobilisable ¹	6	11	9	29	54	13	22
soil mobile ²	0.14	-	0.07	0.11	0.27	0.34	0.15
brown forest soil							
grain (total)	37	38	41	45	54	2	43
soil pseudo total	96	105	137	150	198	15	137
soil mobilisable ¹	14	22	33	44	44	11	31
soil mobile ²	0.07	-	0.12	0.48	0.35	0.33	0.25
acid sandy soil							
grain (total)	37	62	70	76	87	10	66
soil pseudo total	17	27	34	82	73	50	47
soil mobilisable ¹	4	7	11	26	38	12	17
soil mobile ²	0.07	-	3.6	2.0	1.6	4.1	1.8

1: Lakanen-Erviö soluble; 2: NH_4NO_3 soluble; -: Not measured

In present work the barley grain element concentrations are discussed because this may have risk from the view of human health. In spite of the grain is genetically protected, both element showed significant increment in it. As a result of sewage sludge treatment the Cu concentration of all soil fractions and barley grain increased significantly. Whereas the soil mobile Zn fraction – which should be in the closest correlation with plant uptake (Keresztény et al., 1977) – did not grow in the treatments, the Zn accumulation increased significantly in grain.

On acid sandy soil both Cu and Zn reached the highest concentration in grain compared to control treatment (1.7 and 2.3 times higher, respectively). Zn accumulated better than Cu in grain on each soil: the average (all treatments, all soils) transfer coefficient (T.c. = plant concentration (mg/kg) / soil pseudo total concentration (mg/kg)) was 0.5 for Cu and 0.9 for Zn.

Conclusions

Sewage sludge with higher Cu and Zn (1.8 and 2.5, respectively) content in loads higher than legally permitted did not cause any standard limit excess on investigated soils under the conditions of the experiment.

On the acid sandy soil both Cu and Zn reached the highest concentration in grain compared to control treatment (1.7 and 2.3 times higher, respectively). These soils have less colloid that is why their buffer capacity against heavy metal loads is smaller.

The Lakanen-Erviö soluble concentrations increased relatively in the highest rate in case of each soil sample. This increment was 2 times as much as that of other fractions.

Zn accumulated better than Cu in grain on each soil: the average transfer coefficient was 0.5 for Cu and 0.9 for Zn.

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