The accumulation of zinc in oat grown in soils treated by incubated sewage sludge with peat and straw

J. Balík, P. Tlustoš, J. Száková, D. Pavlíková, J. Černý

Czech University of Agriculture in Prague, Czech Republic

ABSTRACT

The effect of addition of treated sewage sludge on the accumulation of Zn in plants was tested in pot experiment. The additions of eight months preincubated sewage sludge at temperature of 20°C under aerobic and anaerobic conditions with addition of peat and straw were tested. Two different combinations were designed: first consisted of 50% sludge + 35% peat and 15% straw, and second was made of 50% sludge + 5% peat and 45% straw (expressed as dry matter). Three different soils Chernozems, Luvisols, and Fluvisols and three sludges were tested in the experiment. Oat (cv. Pan) was planted as experimental crop. All treatments were fertilized by NPK. Green biomass of oat was harvested and analyzed. At treatments with addition of both composted sludges pH dropped down causing higher mobility of Zn in sewage sludge. Oat grown in these treatments contained higher amount of Zn compared to untreated soils. The application of anaerobically treated sludge led to increased Zn content in biomass compared to aerobically incubated one. Predominant effect on Zn accumulation in plants was determined by tested soil. The highest content was determined in plants grown on Fluvisols. The biomass yield was more affected by source of sewage sludge than by the soil type used. Treatments amended by anaerobically incubated sludge showed tendency to higher biomass production due to their higher content of nitrogen and carbon.

Keywords: sewage sludge; straw; peat; composting; zinc; oat

Modern strategy of environmental protection is mainly based on maximum recycling of waste materials with significant decrease of landfilling in developed countries. There is possibility to use agricultural land for sewage sludge recycling. Since the beginning of this year, Czech legislation also allows to apply sewage sludge of specific parameters on agricultural land. To minimize negative effects of sludge application, different treatments were tested. The most common is the application of lime materials (Balík et al. 1999), different compounds of high sorption capacity for example bentonites (Růžek et al. 1998, Kusá 2001) or their composting (Aldag et al. 1996, Planquart et al. 1999, Shuman 1999).

The main objective of presented experiment was focused on the investigation of organic materials addition (peat + straw) into sewage sludge and the effect of different techniques of their preincubation on the zinc mobility in the soil and zinc utilization by plants.

MATERIAL AND METHODS

Pot experiments were made with three different soils: Chernozems, Luvisols, Fluvisols (Table 1). Described experiments were started with half-year difference from published incubation experiments (Balík et al. 1999, 2000a, b). There are slight differences in total soil Zn content, even when soil was taken from the identical location. Preincubated sewage sludge for eight months at temperature 20°C under aerobic and anaerobic conditions amended by peat and straw was tested in the pot experiment. Tested crop was oats (cv. Pan). Treatment marked as compost I was made of 50% sludge + 35% peat + 15% straw (expressed as dry matter) and treatment marked as compost II was made of 50% sludge + 5% peat + 45% straw. Detailed description of preincubation experiments was published in Balík et al. (2000a, b). Treated sewage sludge was added into 5 kg of air dry soil as fresh one in the amount of 33.3 g dry matter per pot. The NPK fertilization was used in the rates 1 g N, 0.16 g P, and 0.4 g K per pot in all treatments. Nutrients were applied as NH_4NO_3 and K_2HPO_4. Pots were watered with deionised water and soil moisture was kept at 60% of MWHC. There were 20 plants grown in each pot. Oat harvest was done at milk-wax maturity. Each treatment consisted of three replications.

Content of Zn was determined by atomic absorption spectrometry (AAS) in the trace laboratory of Chemistry and Agrochemistry and Plant Nutrition Departments of CUA in Prague on Varian SpectrAA 400 and Varian SpectrAA 300 equipments.

Plant biomass was decomposed using dry ash procedure (Mader et al. 1989). Total content of zinc in soils was determined from solution after two step decomposition using dry ashing technique in the first step and mixture of HF + HNO_3 for dissolution of solid particles in the second step (Mader et al. 1998). Methods used for soil extraction were described by (Tlustoš 1999, Száková et al. 2001a), therefore we present only brief description of methods used in our experiments. 1) extraction by deionized H_2O 1:5 (w/v), 2) extraction by 0.01 mol.l^{-1} $CaCl_2$ solution 1:10 (w/v), 3) extraction by 1 mol.l^{-1} NH_4NO_3 solution 1:5 (w/v), 4) extraction by 0.43 mol.l^{-1} CH_3COOH

Table 1. Main parameters of experimental soils

Soil	C_{ox} (%)	pH/KCl	CEC (mval.kg^{-1})	$Zn_{NH_4NO_3}$ (mg.kg^{-1})	Zn_{tot} (mg.kg^{-1})
Chernozem (CHZ)	2.30	7.2	185	< 0.01	74.5 ± 6.2
Luvisol (LS)	1.55	7.0	146	< 0.01	41.5 ± 1.4
Fluvisol (FS)	0.95	5.5	73	3.8	26.0 ± 0.8

solution 1:40 (w/v), 5) extraction by 0.025 mol.l^{-1} NH_4EDTA (pH 4.6) 1:5 (w/v).

Sample of sewage sludge was decomposed by dry ash procedure and solid particles were subsequently dissolved by diluted aqua regia (Mader et al. 1998).

Quality of analysis was checked by certified reference materials: RM Silty Clay Loam (soil), RM Light Sandy Soil (soil), RM 12-03-12 Sludge (sewage sludge), RM 12-02-03 Lucerne (plants).

RESULTS AND DISCUSSION

Agrochemical characteristic of tested soils are described in Table 1 showing the lowest total Zn content at Fluvisols (26.0 mg Zn.kg^{-1}) and the highest one at Chernozems (74.5 mg Zn.kg^{-1}). The highest amount of mobile Zn amount was determined in NH_4NO_3 extractant in Fluvisols.

Three different sewage sludges preincubated for eight months under aerobic and anaerobic conditions were tested in the experiment. Zn mobility was affected by addition of peat and straw before incubation. Treatments marked as compost I and compost II contained from 84.9 to 98.1% of total Zn from sewage sludge (Zn_{sludge}). Low Zn content in peat also led to low portion of Zn_{peat} (0.1–2.3%) even when the peat portion in the incubated mixture was up to 35% of dry matter of the mixture. Compared to the peat, portion of Zn_{straw} was few times higher (1.9–15.1%). This documented that the highest portion of Zn was derived from sludge and addition of other materials can only change agrochemical parameters of incubated mixtures. Total Zn contents in sludge treatments are displayed in Table 2. Rate of sludge applied was 33.3 g of dry matter, which corresponds to about 20 t of sludge dry matter per ha. Treatment A1 (the highest content of Zn) supplied 78.8 mg Zn per pot and treatment A3 + compost I (the lowest content of Zn) 16.4 mg Zn per pot. Portion of Zn_{sludge} amount compared to amount of Zn in soil fluctuated between 4.3–21.2% in Chernozems, 7.7–38.1% in Luvisols, and 12.3–60.8% in Fluvisols, therefore the sludge effect could be mainly seen on sandy soil.

Table 2. Design of incubation experiment with description of main parameters at individual treatments after 8th month of incubation

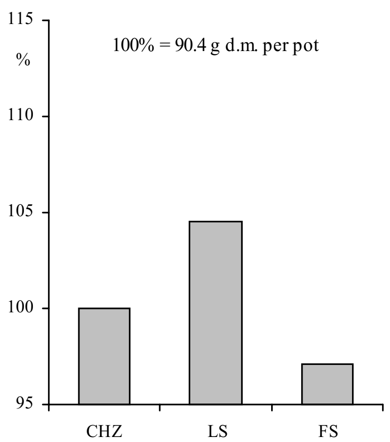
Sludge	Treatment	pH ($CaCl_2$)	C_{ox} (% in d.m.)	N_t (% in d.m.)	Zn_{tot} (mg .kg^{-1})	Zn_{H_2O}/Zn_{tot} (%)
Sludge 1	A1	5.2	13.0	2.3	2365	0.9
	A1 + compost I	4.6	25.9	2.2	1125	2.9
	A1 + compost II	4.7	24.7	2.5	1318	2.3
	AN1	6.7	16.0	2.8	1642	0.2
	AN1 + compost I	4.9	25.3	2.2	1065	3.2
	AN1 + compost II	5.1	22.1	2.2	1268	1.1
Sludge 2	A2	5.2	10.0	2.0	1890	2.7
	A2 + compost I	3.9	18.8	1.7	1145	18.6
	A2 + compost II	3.9	19.9	2.0	1296	18.3
	AN2	7.8	22.0	4.5	1399	1.6
	AN2 + compost I	4.2	28.9	2.5	905	12.2
	AN2 + compost II	5.2	25.0	2.0	1182	3.6
Sludge 3	A3	5.2	14.0	3.3	692	0.9
	A3 + compost I	3.1	26.4	2.6	491	36.3
	A3 + compost II	3.0	22.7	2.7	553	35.2
	AN3	7.3	17.0	6.1	838	0.9
	AN3 + compost I	6.0	30.5	3.5	554	0.8
	AN3 + compost II	6.7	31.6	3.4	586	1.3

A – preincubation with aerobic conditions
AN – preincubation with anaerobic conditions

Table 3. Yield of oat dry matter biomass (g/pot)

Sludge	Treatment	Soil	Yield	Soil	Yield	Soil	Yield
Sludge 1	A1	CHZ	85.4	LS	91.1	FS	79.7
	A1 + compost I		85.9		83.1		80.2
	A1 + compost II		80.0		85.4		78.3
	AN1		90.0		93.6		82.2
	AN1 + compost I		87.7		91.8		80.0
	AN1 + compost II		88.3		90.7		81.7
F-test			3.50		2.34		0.91
D_{min}			7.17				
Sludge 2	A2	CHZ	94.4	LS	95.1	FS	95.7
	A2 + compost I		98.3		90.2		96.9
	A2 + compost II		98.7		88.5		91.4
	AN2		93.5		96.1		81.4
	AN2 + compost I		91.2		105.9		91.3
	AN2 + compost II		87.4		103.7		93.0
F-test			2.25		10.48		8.64
D_{min}					8.39		7.22
Sludge 3	A3	CHZ	90.8	LS	92.1	FS	96.2
	A3 + compost I		92.0		97.9		86.6
	A3 + compost II		86.9		98.2		91.5
	AN3		87.7		97.9		85.2
	AN3 + compost I		96.1		99.5		88.0
	AN3 + compost II		93.6		99.6		100.8
F-test			2.32		1.01		8.16
D_{min}							8.27

The results displayed in Table 3 and in Figure 1 showed similar yields of oat dry matter on all three soils. The mean yield 90.4 g per pot was determined on Chernozems, higher by 4.5% (94.5 g) on Luvisols and lower by 2.9% (87.8 g) on Fluvisols. Substantially higher effect was achieved with sludge. Treatments with addition of sludge 2 and sludge 3 reached higher yields by 10.2% and 9.4% respectively compared to sludge 1 which corresponds with amount of nutrients in these materials. Mean N content in sludges 1, 2 and 3 was 2.37%, 2.45% and 3.60%. Slightly higher yields were determined in treatments with addition of anaerobic treatments (91.8 g) compared to aerobic treatments (90.0 g). Main reasons for yield differences are nitrogen losses as well as losses of easily mineralized organic compounds which are sources of energy and nutrients. Mean nitrogen content was



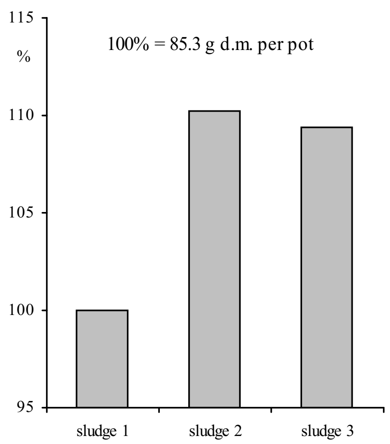


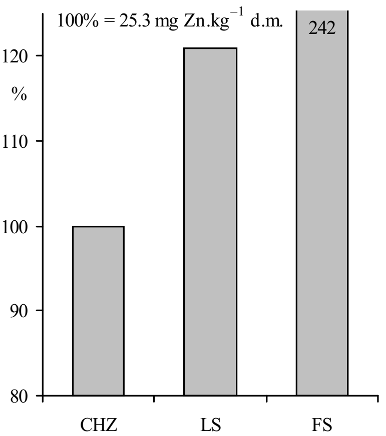
Figure 1. The effect of tested soil and sludge on the yield of oat dry matter

Table 4. Zn content in oat dry matter (mg.kg^{-1} d.m.)

Sludge	Treatment	Soil	Zn	Soil	Zn	Soil	Zn
Sludge 1	A1	CHZ	30.33	LS	19.80	FS	83.97
	A1 + compost I		21.90		36.90		56.80
	A1 + compost II		21.00		35.43		72.53
	AN1		20.13		19.90		69.57
	AN1 + compost I		24.77		40.17		61.40
	AN1 + compost II		41.87		35.80		51.10
F-test			1.42		16.69		4.98
D_{min}					8.59		20.66
Sludge 2	A2	CHZ	24.37	LS	23.17	FS	63.13
	A2 + compost I		25.13		33.47		58.37
	A2 + compost II		26.57		33.03		47.77
	AN2		29.47		31.07		83.50
	AN2 + compost I		33.80		37.17		68.90
	AN2 + compost II		19.37		45.70		41.13
F-test			8.67		13.08		3.20
D_{min}			6.44				32.85
Sludge 3	A3	CHZ	20.40	LS	23.57	FS	47.63
	A3 + compost I		21.70		24.50		52.30
	A3 + compost II		22.43		25.87		50.57
	AN3		29.23		32.03		80.37
	AN3 + compost I		21.70		27.10		65.87
	AN3 + compost II		21.47		27.50		44.93
F-test			2.68		2.31		11.96
D_{min}							15.23

2.36% in aerobically and 3.24% in anaerobically treated sludges. Content of C_{ox} was 19.5% in aerobic treatments and 24.3% in anaerobic ones. The lowest C:N ratio was always determined in plain sludge treatments and the widest in treatments with addition of 35% of peat (compost I).

Zinc content in plants is described in Table 4. The evaluation of presented results is quite difficult because of multi factor experiment. Different content of nutrients in sludge (effect on biomass yield) and differences in the amount of applied Zn with different portion of mobile Zn fraction causes these difficulties. Naturally, high heterogeneity of sludge even increases it. General evaluation presented in Figures 2 and 3 showed the highest effect of soil type on Zn plant content. On Fluvisols Zn content in plants was 142% higher than in biomass grown on



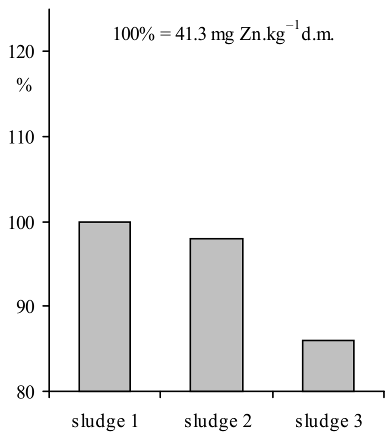


Figure 2. The effect of tested soil and sludge on the Zn content in plants

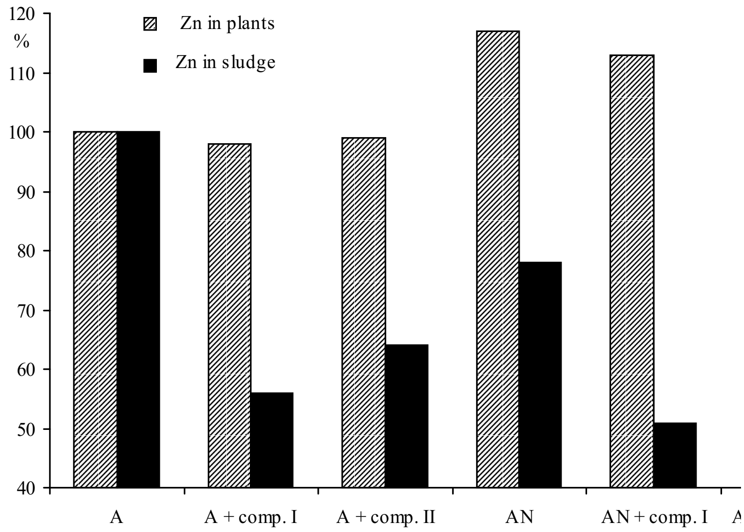


Figure 3. Relative Zn content in sludge and relative Zn content in plants (%)

Zn content in plants (100% = 37.4 mg Zn.kg^{-1} d. m.)
Zn content in sludge (100% = 1649 mg Zn.kg^{-1} d.m.)

Chernozems. At Luvisols Zn content in biomass was higher by 21% than in Chernozems. Biomass Zn contents well corresponded with mobile Zn content in tested soils as well as with their different pH and sorption properties. It is evident, that not only soil Zn affected its accumulation but also higher utilization of Zn from applied sludge played the role. Steadily released Zn from sludge was less sorbed by Fluvisols than by other soils during the experiment. In agreement with our results, Planquart et al. (1999) presented higher influence of soil than of compost made of sewage sludge on Zn content in plants. The highest Zn content in plants was determined in treatments with sludge 1 and the lowest with sludge 3 (86% of level at sludge 1). These differences only approximate-

Table 5. Zn uptake by oat plants (µg/pot)

Sludge	Treatment	Soil	Zn uptake	Soil	Zn uptake	Soil	Zn uptake
Sludge 1	A1	CHZ	2570	LS	1804	FS	6690
	A1 + compost I		1870		3061		4561
	A1 + compost II		1677		3010		5680
	AN1		1809		1860		5730
	AN1 + compost I		2165		3672		4911
	AN1 + compost II		3708		3251		4162
F-test			1.59		21.83		4.36
D_{min}					637.75		1715.09
Sludge 2	A2	CHZ	2295	LS	2204	FS	6020
	A2 + compost I		2470		3013		5664
	A2 + compost II		2620		2920		4344
	AN2		2765		2981		6829
	AN2 + compost I		3089		3939		6282
	AN2 + compost II		1687		4734		3797
F-test			6.80		21.82		2.17
D_{min}			709.34		742.54		
Sludge 3	A3	CHZ	1852	LS	2183	FS	4582
	A3 + compost I		1994		2407		4528
	A3 + compost II		1938		2539		4611
	AN3		2560		3138		6844
	AN3 + compost I		2075		2698		5771
	AN3 + compost II		2011		2736		4528
F-test			2.48		2.20		9.13
D_{min}							1237.33

Table 6. Amount of Zn extracted by different solutions from the soil after oat harvest

Treatment	Soil	Zn ($mg.kg^{-1}$)				
		H_2O	NH_4NO_3	$CaCl_2$	CH_3COOH	EDTA
A2	CHZ	0.009	0.030	0.098	3.49	13.35
A2 + compost II		0.008	0.018	0.074	4.46	12.92
AN2	CHZ	0.025	0.030	0.047	4.50	16.53
AN2 + compost II		0.044	0.027	0.018	5.30	16.52
A2	LS	0.056	0.059	0.063	3.56	7.53
A2 + compost II		0.039	0.130	0.147	3.29	6.01
AN2	LS	0.056	0.160	0.200	4.12	9.48
AN2 + compost II		0.089	0.127	0.174	3.21	3.95
A2	FS	0.233	2.039	3.264	8.60	10.55
A2 + compost II		0.297	1.581	2.996	8.52	10.62
AN2	FS	0.342	2.157	2.825	11.73	12.28
AN2 + compost II		0.292	2.222	2.933	9.10	10.64

ly corresponded with total Zn content in sludge because sludge 2 supplied 89% and sludge 3 only 42% of Zn supplied by sludge 1. It is essential to consider not only the total Zn content but also the mobile portion of Zn for recommendation of Zn utilization by plants.

The influence of different sewage sludge modification is presented in Figure 3. Mean Zn plant contents showed only very small relative differences among individual treatments A (100%), A + compost I (98%), A + compost II (99%) even when high differences in Zn inputs were found. Lower inputs at both composted treatments supplied only 56% in A + compost I and 64% in A + compost II of Zn derived from untreated sludge. Aerobic sludge incubation with addition of straw and peat led to higher Zn utilization by plants. Treatments with composted sludge decreased pH values and increased portion of mobile Zn forms in sludge (Száková et al. 2001b). Similar results showing higher metal mobility in relation with low pH published also Planquart et al. (1999). They also presented higher Zn uptake by *Brassica napus* plants in mentioned treatments. Results of spinach experiment run by our department also showed higher Zn content in plants grown in treatments with addition of composted sewage sludge (Kaewrahun 1999).

The comparison of A and AN treatments shows significant increase of plant Zn content, by 17%, in treatments with anaerobically incubated sludge even when Zn input was only 78% compared to A treatments. Results presented by Tlustoš et al. (2001) showed that aerobic incubation led to increase portion of exchangeable and oxide fractions and decrease of organic and residual fractions. The application of anaerobically incubated sludge probably led to mineralization of organic fraction and released zinc was taken up by plants and not bound on surface of oxides. This statement was indirectly confirmed by amount of organic compounds supplied to the soil by sludge. Mean C_{ox} content of all A treatments was 12.3% and AN 18.3%. Kaewrahun (1999) used sequential extraction of eight months incubated sewage sludge and found 24.6% of Zn bound in organic compounds in A treatments and 35.4% in AN ones from total Zn sewage sludge content. On other site, she found higher Zn content in A treatments (1649 mg $Zn.kg^{-1}$) than in AN treatments (1263 mg $Zn.kg^{-1}$). Results of mentioned two opposite factors showed that AN treatments supplied by 10% more of Zn bound in organic matter than A treatments. Due to high sludge rates portion of carbon supplied by sludge compared to soil carbon was relatively high. Portion of C_{sludge} presented 5.3% of C_{CHZ}, 7.9% of C_{LS} and 12.8% of C_{FS} in AN treatments. High C sludge portion allowed us to make assumption of substantial effect of sludge organic matter and organically bound Zn on Zn plant accumulation.

Results described in Table 3 and Figure 3 confirmed our previous investigation with soil + sludge incubation (Balík et al. 2000b). Treatments compost I showed higher Zn mobility than treatments compost II and higher Zn mobility caused by lower pH was not compensated by higher sorption capacity of added peat. Our results also confirmed statements of Alloway (1990) and Ross (1994) that reported lower zinc affinity to peat. Differences in Zn utilization between compost I and compost II could be also affected by portion of Zn_{straw} from $Zn_{compost}$. In compost I was Zn_{straw} portion 3.2% and in compost II 8.8%. Values presented in Figure 3 also show low differences between treatments with compost II treated by aerobic and anaerobic treatments. Explanation of low differences could be based on increased aeration of sludge incubated under anaerobic conditions with addition of 45% of straw.

Zn amounts accumulated in oat biomass are described in Table 5. This parameter describes both Zn content in oat and biomass yield. Highest Zn uptake was not determined in treatments with sludge 1, but in treatments with sludge 2 having high Zn biomass content and the highest yield of dry biomass. Mean Zn uptake by above ground biomass was 3455 μg in sludge 1 treatments, 3758 μg in sludge 2 and 3277 μg in sludge 3 treatments. Portion of Zn taken up by plants compared to addition of Zn by sludge was 7.6% in sludge 1, 10.2% in sludge 2 and 15.9% in sludge 3 treatments. These values were quite high and documented high ability of plants to accumulate zinc from sludge without any subsequent toxic effects.

Soil analyses after oat harvest are described in Table 6. Due to severity of extraction procedures, only treatments with addition of sludge 2 were analysed. Results again showed substantial effect of soil on extractable Zn portion. Few fold higher content of mobile Zn forms was determined by H_2O, NH_4NO_3, $CaCl_2$ a CH_3COOH solutions in Fluvisols compared to other soils. Presented results are in good correlation with plant Zn content from individual soils, but only insignificant differences in Zn mobility were found in treatments with composts, probably due to lower input of total Zn by these treatments.

The research was supported by GA CR project N° 526/97/0845.

REFERENCES

Aldag R., Bischoff H., Jobst E., Koch E., Zürcher C. (1996): Anorganische und organische Nähr- und Schadstoffe in Bio-, Pflanzen- und Klärschlammkomposten der Jahre 1994 und 1995 aus Rheinland-Pfalz. VDLUFA Schr.-R., *44*, K.-Bd.: 353–356.

Alloway B.J. (1990): Heavy metals in soils. John Wiley and Sons, New York.

Balík J., Tlustoš P., Száková J., Blahník R., Kaewrahun S. (1999): Sorption of cadmium in soil treated by limed sewage sludge. Rostl. Výr., *45*: 511–518.

Balík J., Tlustoš P., Száková J., Kaewrahun S., Hanč A. (2000a): The effect of bentonite addition into sewage sludge and conditions of its incubation on the cadmium sorption in soils. Rostl. Výr., *46*: 1–7.

Balík J., Tlustoš P., Száková J., Kaewrahun S., Hanč A. (2000b): The effect of addition of different ameliorative compounds into sewage sludge on zinc sorption in soils. Rostl. Výr., *46*: 93–102.

Kaewrahun S. (1999): Uptake of heavy metals by plants from soil treated by sewage sludge. [PhD Thesis.] ČZU, Praha.

Kusá H. (2001): Physical and chemical properties of zeolites in natural systems. [PhD Thesis.] VŠCHT, Praha. (In Czech)

Mader P., Kučera J., Cibulka J., Miholová D. (1989): Evaluation of mineralization procedure of liver for cadmium and lead determination by differential pulsing anodic voltametry using interlaboratory test. Chem. Listy, *83*: 765–773. (In Czech)

Mader P., Száková J., Miholová D. (1998): Classical dry ashing of biological and agricultural materials. II. Losses of analytes due to their retention in an insoluble residue. Analusis, *26*: 121–129.

Planquart P., Bonin G., Prone A., Massiani C. (1999): Distribution, movement and plant availability of trace metals in soils amended with sewage sludge composts: application to low metal loadings. Sci. Tot. Envir., *24*: 161–179.

Ross S.M. (1994): Toxic metals in soil–plant systems. John Wiley and Sons, Chichester.

Růžek P., Kusá H., Hrazdíra J. (1998): The utilization of differently treated sewage sludges in agriculture. In: Proc. 8th Int. Conf. RAMIRAN, Rennes, II: 159–166.

Shuman L.M. (1999): Organic waste amendments effect on zinc fractions of two soils. J. Envir. Qual., *28*: 1442–1447.

Száková J., Tlustoš P., Balík, J., Pavlíková D., Balíková M. (2001a): Comparison of suitability of mild extraction procedures for determination of available portion of As, Cd, and Zn in soil. Chem. Listy, *95*: 179–183. (In Czech)

Száková J., Tlustoš P., Balík, J., Pavlíková D., Balíková M. (2001b): The application of sequential extraction procedure to evaluation of influence of sewage sludge amendment on Cd and Zn mobility in soil. Chem. Listy, *95*: 645–648. (In Czech)

Tlustoš P. (1999): Mobility of arsenic, cadmium and zinc in soil and possibilities of their decreased uptake by plants. [Assoc. Prof. Thesis.] ČZU, Praha. (In Czech)

Tlustoš P., Balík J., Kaewrahun S., Pavlíková D., Száková, J., Hanč A. (2001): The effect of composting of sewage sludge under aerobic and anaerobic conditions on the zinc availability. In: Proc. 6th Int. Conf. Biogeochemistry of trace elements, Univ. Guelph, Ontario, Canada.

Received on June 27, 2002

ABSTRAKT

Příjem zinku rostlinami ovsa po aplikaci čistírenských kalů preinkubovaných s rašelinou a slámou

V nádobových vegetačních pokusech byl zjišťován vliv aplikace různě ošetřených čistírenských kalů na obsah zinku v rostlinách. Byly sledovány kaly předem preinkubované po dobu osmi měsíců při teplotě 20 °C za aerobních a anaerobních podmínek s přídavkem rašeliny a slámy. Byly vytvořeny dvě různé kombinace: I. 50 % kalu + 35 % rašeliny + 15 % slámy, II. 50 % kalu + 5 % rašeliny + 45 % slámy (v sušině). Experimenty proběhly se třemi různými zeminami (černozem, hnědozem, fluvizem) a se třemi kaly. Pokusnou plodinou byl oves (odrůda Pan). U všech variant bylo kromě ošetřeného kalu použito NPK hnojení. Rostliny byly sklízeny v mléčně-voskové zralosti a byla analyzována nadzemní biomasa. U kompostovaných kalů bylo stanoveno snížení hodnoty pH, což vedlo k nárůstu podílu mobilních forem zinku v kalu. U takto ošetřených variant byl zaznamenán nárůst obsahu zinku v rostlinách. U variant anaerobně preinkubovaných ve srovnání s aerobně preinkubovanými byl zjištěn nárůst příjmu zinku rostlinami. Dominantní vliv na koncentraci zinku v ovsu měla použitá zemina. Nejvyšší hodnoty byly stanoveny na fluvizemi. Výnos sušiny rostlin byl více ovlivněn testovaným kalem než použitou zeminou. U anaerobně preinkubovaných variant byla tendence k nárůstu výnosu biomasy v důsledku vyššího obsahu dusíku a uhlíku.

Klíčová slova: čistírenské kaly; sláma; rašelina; kompostování; zinek; oves

Corresponding author:

Prof. Ing. Jiří Balík, CSc., Česká zemědělská univerzita v Praze, 165 21 Praha 6-Suchdol, Česká republika,
tel.: + 420 224 382 732, fax: + 420 220 921 645, e-mail: balik@af.czu.cz