The Element Distribution into Main Fractions of Soil Amended by As, Cd, Cu, Pb, and Zn in Different Forms*

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The modified sequential extraction procedure standardized by Standards, Measurements and Testing program (SM&T EUR 14763 EN) was applied for evaluation of toxic element distribution into plant-available, exchangeable, bound on Fe/Mn oxides, organically bound, and residual fractions of soil amended by an addition of sewage sludge or treated with soluble compounds of toxic elements. The results suggested the ability of experimental soil to redistribute the contaminants from soil solution into the less mobile but labile soil fractions.

The application of sewage sludge into the agricultural soil can improve nutrient status of the soils as well as the physicochemical parameters of these soils. However, the sewage sludge usually brings to the soil elevated amount of potentially toxic elements, such as As, Cd, Cu, Pb, and Zn. The plant-availability of these elements can be affected by the source of sludge, pH, redox conditions, humidity, and preincubation of sludge [1—3]. In addition, the sludge treatment can alter the element distribution into main soil fractions according to individual soil. In this experiment, the distribution of potentially toxic elements, contained either in sewage sludge or in solution of soluble inorganic compounds, into individual soil fractions was investigated.

EXPERIMENTAL

Chernozem characterized by pH 7.2; 2.3 % of oxidizable carbon, and Me^+-cation exchange capacity 25.5×10^{-2} mol g^{-1} was treated by sewage sludge or by soluble inorganic compounds of toxic elements in pot experiment. The response of individual soil fractions on soil treatments was investigated at the end of vegetation period of radish and spinach. The sewage sludge was added in the rate of 50 g of dry sludge per pot containing 5 kg of experimental soil. This amount of sludge represented 0.355 mg As, 0.188 mg Cd, 16.3 mg Cu, 2.74 mg Pb, and 55.2 mg Zn, respectively. The solutions of inorganic compounds of investigated elements were added in two rates: either corresponding to their amount in sludge, or ten-fold increased value of elements as compared to sludge treatment.

The soil samples were extracted by the modified sequential analytical SM&T EUR 14763 EN procedure [4]. The extraction scheme was as follows: i) plant-available fraction extracted by 0.01 mol dm^{-3} $CaCl_2$; ii) exchangeable fraction by 0.11 mol dm^{-3} CH_3COOH; iii) fraction bound on Mn/Fe oxides by 0.1 mol dm^{-3} $HONH_3Cl$, pH = 2; iv) organically bound fraction by 8.8 mol dm^{-3} H_2O_2 evaporated to dryness followed by 1 mol dm^{-3} CH_3COONH_4, pH = 5; v) residual fraction calculated as the difference between total element content in the soil and a sum of all previous fractions. Atomic absorption spectrometry (Varian SpectrAA-400) was applied for determination of elements in the solutions.

RESULTS AND DISCUSSION

The differences in contents of individual elements in the sludge led to different changes of total contents of these elements in treated soil. The total element contents in treated soils as well as the element distribution into individual soil fractions are summarized in Table 1. Arsenic content in soil was diluted by an addition of sewage sludge reflecting relatively low contents of this element in sewage sludge. The arsenic solution applied into the soil was adsorbed mostly within the exchangeable fraction suggesting relatively high mobility of this portion of arsenic. Cadmium, the most mobile element, was distributed mostly into plant-available and exchangeable fractions. The fraction bound on Fe/Mn oxides representing the domi-

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Table 1. Total Element Contents in Soil and Element Distribution into the Main Soil Fractions; Medians, $n = 6$

Treatment[a]	w(total)	w(plant-avail.)	w(exchang.)	w(Fe/Mn oxid.)	w(org. bound)	w(residual)
	ppm	%	%	%	%	%
			Arsenic			
1	18.0	0.930	8.02	9.62	6.00	75.5
2	18.1	0.816	9.67	9.29	5.59	74.9
3	18.7	1.03	10.6	8.73	7.42	72.0
4	17.9	0.764	9.88	8.67	6.81	74.1
			Cadmium			
1	0.489	0.955	2.30	44.5	10.8	40.4
2	0.527	0.536	5.42	49.1	10.7	33.2
3	0.869	1.30	12.4	65.3	12.5	8.43
4	0.522	0.871	3.79	50.3	9.0	34.1
			Copper			
1	24.5	0.819	0	1.35	21.3	76.9
2	27.8	0.482	0.118	1.59	19.7	77.3
3	57.1	0.354	1.65	4.72	29.2	65.2
4	27.5	0.493	0.016	1.60	17.8	80.3
			Lead			
1	31.3	0.215	0	7.20	48.4	43.1
2	31.8	0.196	0.059	8.90	45.0	45.7
3	36.8	0.346	0	9.04	56.2	34.3
4	31.5	0.255	0	7.18	40.6	49.8
			Zinc			
1	87.1	0.510	2.67	15.3	6.81	73.5
2	98.1	0.776	4.93	22.5	8.21	63.1
3	198	0.729	25.9	35.8	16.0	22.4
4	97.2	0.527	3.44	16.5	6.47	71.9

a) 1 – control, 2 – elements added in salt solution equal to their content in the sludge, 3 – ten-fold increased salt solution of eleme 4 – sludge.

nant one for this element, was affected by an addition of element solutions while organically bound cadmium fraction decreased in sludge treatment because of decomposition of sludge organic matter during vegetation period. Copper, the relatively stable soil element associated predominantly with soil organic matter was distributed within plant-available, Fe/Mn oxides, and organically bound copper fractions while lead was significantly adsorbed by soil organic matter. The behaviour of zinc was similar to cadmium differing only in higher percentage of residual fraction.

The results suggested the ability of experimental soil to redistribute the contaminants from soil solution into the less mobile but labile soil fractions. The addition of sewage sludge showed lower mobility of toxic elements as compared to an application of solutions of inorganic element salts. However, long-term observation will be necessary for an evaluation of the fluctuation of potentially toxic elements among soil fractions.

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REFERENCES

1. Mullins, G. L. and Sommers, L. E., *J. Environ. Q* *15*, 382 (1986).
2. Canet, R., Pomares, F., and Tarazona, F., *Soil Use Management 13*, 117 (1997).
3. Balík, J., Tlustoš, P., Száková, J., Blahník, R., Kaewrahun, S., *Rostl. Vyroba 45*, 511 (1999).
4. Ure, A., Quevauviller, P., Muntau, H., and Griep B., *BCR Information EUR 14763 EN*, Community reau of Science, 1993.