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After-effect of heavy metal pollution in a brown forest soil

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ABSTRACT Heavy metal pollution (of Cd-, Cr-, Zn-load: 270 kg/ha and $CdSO_4$, K_2CrO_4, $ZnSO_4$) has been shown affecting the soil actual element content, plant and soil microbial function. Pot and laboratory experiments were set up to examine the extent of pollution in the soils collected from the upper 20 cm ploughed layer in the 8th year of a long-term field trial. Actual heavy metal concentration of the polluted soils was low, although Cr and Cd values were significantly higher, exceeding the Hungarian „B" soil pollution threshold limit. Compared to control, Cd content of each plant root and shoot increased significantly, Zn and Cr content increased in few cases, Cd-Zn, Cd-Mn, and Cd-Ni interactions reflected in some instances the soil pollution, too. Microbial basal respiration rate was stimulated by Zn and Cd treatment and it inhibited by Cr. Based on these results we can demonstrate different after-effects of tested heavy metals determined by the changes of microbial C-metabolism. The after-effect of the observed heavy metal pollution influenced in all cases the metabolism of soil microbes, reactions of plants were less general, while Cd-load exhibited the most significant effect.
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KEY WORDS
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Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Ernst 1996; Zayed et al.1998; Gimmler et al. 2002). In general, an increase of metal concentration influences soil microbial properties (e.g. respiration rate, enzyme activity), which appear very useful as indicators of soil pollutions (Brookes 1995; Szili-Kovács et al. 1999). Short-term and long-term effects of pollution differ depending on metal and soil characters (Kádár 1995; Németh and Kádár 2005). In the after-effect of heavy metal pollutions, the role of pollutant bounding or leaching increases, which determine their bioavailability and toxicity.

In the present study the after-effect of three heavy metals (Cd, Cr, Zn) was examined in pot experiment on six plant species and soil microorganisms.

Materials and Methods

Soil samples and pot experiment

Studies were made on the soil samples, which were collected from the Cd, Cr, Zn-loaded (270 kg/ha metal salts: $CdSO_4$, K_2CrO_4, $ZnSO_4$) plots in autumn 2001, in the 8th year of a long-term field trial one by one from 0 to 20 cm depth in Experimental Station at Tas-puszta of College Gyöngyös. Chemical properties of the unpolluted brown forest clay soil: pH_{KCl} 6.3, humus content 3.2%, content of Pb, Zn, Cd, Cr, Co, Cu, Ni, and Ba (25.5, 92.0, 0.61.0, 53.7, 16, 26.4, 34.0 mg/kg, respectively). After being air-dried and sieved to <2 mm, homogenized soils were watered to 70% of saturation water holding capacity. The tested six plant species (radish (*Raphanus sativus* L.), wallflower (*Cheiranthus cheiri* L), erysimum (*Erysimum cheiranthoides* L), orache (*Atriplex hortensis* L.), sorrel (*Rumex acetosa* L.), and antirrhinum (*Antirrhinum majus* L.) were sown and grown in a greenhouse. Plants were harvested on the 60th day after emergence, whereas growth rate and element content was determined.

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Microbial measurements and chemical analysis

Respiration rate was determined with Oxitop controller pressure meter after absorption of CO_2 (8 weeks incubation at room temperature with 70% moisture capacity), fraction of labile humus content was determined by extinction through spectrophotometer at 400-700 nm. Shoot and root samples were washed (d water), and dried at 70°C. The metal concentrations of soils were determined after standard preparation ("total": extracted by HCl/HNO_3, "available": extracted by NH_4-acetate-EDTA) and plants (digested by HNO_3) by ICP spectrometry.

Statistical analysis

Mean values and SD of the element contents were calculated, and analysis of variance (ANOVA) and Student's t-test were performed.

Results and discussion

The actual concentration of observed heavy metals in the polluted soils was low: total Zn (123 mg/kg) concentration was similar to unpolluted soil samples, although Cr (83.6

Table 1. Zn, Cr and Cd concentrations (mgkg^{-1} dry weight) in plant shoots .

Plant species	Zn, Cr and Cd concentrations of shoots, mgkg^{-1} DW)					
	Zn		Cr		Cd	
	control	+Zn	control	+Cr	control	+Cd
radish	84	127*	1.01	1.18	0.46	3.81***
erysimum	30	31	0.81	0.93	0.23	2.88**
wallflower	61	69	0.39	1.24*	0.22	1.55***
orache	139	163*	0.50	0.74	0.46	1.41***
sorrel	71	74	0.69	1.14	0.34	2.53***
antirrhinum	48	53	0.32	0.67	0.19	0.56*

Significance at the *0.05, ** 0.01, *** 0.001 probability level.

Table 2. Relative values of the microbial respiration rate and the labile humus fraction (control = 1).

Soil treatment	Microbial respiration rate	Fraction of labile humus
+Cr	0.73***	1.38*
+Zn	1.08**	1.34*
+Cd	1.09**	1.28*

Significance at the *0.05, ** 0.01, *** 0.001 probability level.

mg/kg) and Cd (2.3 mg/kg) values were significantly higher, exceeding the Hungarian „B" soil pollution threshold limit. LE-soluble element content of polluted soils was higher than the control. These results show a discrepancy between proportions of the "available" metal forms: the lowest value was characteristic to Cr and the highest value to Cd, respectively.

Long-term heavy metal pollution in the 8th year has not induced significant differences in plant seedling emergence and growth. Compared to the control, Cd content of each plant root and shoot increased significantly. Zn and Cr contents of plants grown in polluted soils in few cases were higher than those of control plants (Table 1). Cd-Zn, Cd-Mn, and Cd-Ni interactions, in some instances reflecting the soil pollution too, indicated slight differences in metal uptake varying by plant species.

The actual concentrations and influence of metals is a consequence of the mobility, bioavailability and toxicity as direct effect, as well as of plant biomass and different humus fraction ranges as indirect effect. Basal respiration rate was stimulated by Zn and Cd, and it was inhibited by Cr. Based on these results we can demonstrate different after-effects of tested heavy metals determined by the changes of microbial C-metabolism (Table 2).

The after-effect of the observed heavy metal pollution influenced the metabolism of soil microbes in all cases, whereas reactions of plants were less general. Under the present ecological conditions the Cd-load expressed the most significant effect on plants.

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