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Phytoremediation study: Factors influencing heavy metal uptake of plants

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ABSTRACT Factors influencing heavy metal uptake of plants were studied by pot and field experiments. All results concern soils and dump samples originated from the surrounding of Pb/Zn mine at Gyöngyösoroszi characterised with high complex heavy metal content. This summarising work demonstrated effects on the heavy metal content of 20 cultivated and wild plant species, being determined with a view to phytoremediation. Influences of the most important plant species (developmental stage, plant parts, and ecological factors, such as pH-value, temperature, soil treatment with lime and lignite) were examined. Interaction between ecological factors and plant characters was demonstrated, as well as results of pot and field studies were compared. Tested plant species were grouped on the basis of their accumulation capability and susceptibility of heavy metals. **Acta Biol Szeged 49(1-2):69-70 (2005)**

KEY WORDS

pot and field study
heavy metal
plant species
ecological factors
interaction

Heavy metal pollution causes potential ecological risk. The base of phytoremediation, a promising method for cleaning of soil and water, is pollutant uptake or bounding by plants. Initially much more interest was focused on hyper-accumulator plants than those taken in non-accumulator plants (Baker et al. 1994; Brooks 1998), but later, as an alternative to substitution of the endemic, hardly cultivable plants accumulator plants have been used; possibly coupled with treatment of soil (Deram et al. 2000); either considering factors (Németh et al. 1993) to increase the metal availability and plant uptake. Other possibility to decrease available concentration of pollutants is stabilisation. Phytostabilisation can gain results from either physical or chemical effects of plants and of chemicals, such beringit, lime or clay minerals (Gworek 1997; Lehoczky et al. 2000; Simon 2001).

This summarising work demonstrated effects influencing the heavy metal content of 20 cultivated and wild plant species with a view to phytoremediation. Interaction between ecological factors and plant characters was determined, as well as results of pot and field studies were compared. The tested plant species were grouped on the basis their accumulation capability and susceptibility of heavy metals. Results assist to elaborate a possible combination of phytoextraction and phytostabilisation technology under the present ecological conditions.

Materials and Methods

Pot and field experiment

Polluted soils collected for pot studies originated (0 to 20 cm depth) from surrounding area of the Gyöngyösoroszi mine. Chemical properties of the polluted soil for pot studies: $CaCO_3$ 13.8%, pH $_{KCl}$ 7.05, org C 2.9%, characterised by high content of Pb, Zn, Cd, Cu (2890, 1760, 28, 1200 mg/kg, respectively). The in the pot studies tested 14 species (radish, erysimum, wallflower, maize, orache, trigonella, sorrel, leek, chieve, calendula, antirrhinum, willow, maple, black elder) were sown in plastic pots; shoot and root were harvested on the 30th day and /or 60th day after emergence.

Site of field study is located in Gyöngyösoroszi, lower flooded area of Toka valley. Cd, Cu, Pb and Zn content of polluted soil of field plots were high (≥18.0, 276, ≥955, ≥3082 mg/kg, respectively). The tested 9 plant species (rape, horseradish, willow, maize, orache, golden-rod, amarant, robinia, rye-grass) are frequent plants of natural or cultivable sites of this region.

Sample preparation and chemical analysis

Plant samples (shoots and roots) were separated and washed with deionized water after mechanical cleaning, and then dried at 70°C until the stabilisation of weight. The metal concentrations of soils (“total”: extracted by HCl/HNO_3, “available”: extracted by NH_4-acetate-EDTA) and plants (digested by HNO_3) were determined after standard preparation by ICP spectrometry.

Statistical analysis

Mean values were calculated, and analysis of variance (ANOVA) and Student’s t-test were performed. Bioaccumulation factors (BAF-s) were calculated for heavy metal content of plant parts (mg/kg) / heavy metal content of soil (mg/kg), for each metal.

Results and Discussion

The tested plant species were grouped by their capability of

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Table 1. BAF-s of shoot and root of four plants in field study.

plants	plant parts	BAF-s of shoot and root			
		Cd	Cu	Pb	Zn
rape	root	1.43	0.61	0.43	0.74
	shoot	0.47	0.07	0	0.36
willow	root	3.12	0.76	0.2	1.03
	shoot	3.4	0.06	0	1.23
maize	root	2.94	1.01	0.06	0.37
	shoot	0.39	0.07	0.01	0.45
horseradish	root	0.17	0.03	0	0.14
	shoot	0.18	0.02	0	0.06

heavy metal uptake and sensitivity to high metal pollution, which characters were determined in the present and a previous work (Anton and Mathe-Gaspar 2005):

1. Accumulator and tolerant species: e.g. maize (Zn) or willow (Cd, Zn); accumulator and moderately sensitive species: e.g. rape (Cd, Zn) or sorrel (Cd, Cu, Zn) leek (Cd, Pb, Zn); accumulator and sensitive species: e.g. black elder (Pb) or calendula (Zn);

2. Moderately accumulator and tolerant species: e.g. orache and golden-rod; moderately accumulator and moderately sensitive species: e.g. amaranth, sensitive species: e.g. trigonella;

3. Non-accumulator and tolerant species: e.g. horseradish or ryegrass and sensitive species: e.g. robinia or maple.

The BAF-s of shoot and root differed significantly by plant and plant parts (Table 1). Element content of stem and leaves differed by species too, but metal content of leaves was generally higher than those of stem. This result is notably override by use of trees (e.g. for zinc 4.1 by willow).

Previous work has shown, that higher temperature and lowering soil pH resulted a significant increase of cadmium and zinc contents of sorrel and maize shoot and indicated different characters of species for element uptake. Present work demonstrated: liming and lignite added to the polluted soil decreased plant metal uptake: especially Cd and Zn to the highest degree (24-36%). Effects are complex: LE-soluble soil metal concentrations decreased after liming (except Cu and Pb solubility), due to chemical and physical bounding of lime and lignite and increase of pH by liming (pH $_{H2O}$ of soil from 6.21 increased to 7.91), as well as competition between Ca^{2+} and heavy metal cations (Cd^{2+}, Zn^{2+}, Pb^{2+}, Cu^{2+}) in the uptake and translocation by plants. Results assist to elaborate a possible combination of phytoextraction and phytostabilisation technology under the present ecological conditions.

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