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Phytoremediation of heavy metal pollution: A case study

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ABSTRACT In the framework of a phytoremediation project for decontamination of heavy metal-polluted environment, two experimental fields were monitored for the existing plant species and soil contaminants. At the site of the slurry deposition from the oxbow lake at Mártély, mainly Zn, Pb and Cr were determined as pollutants. *In situ,* a number of plant species were found, most importantly Salix species. At the other study site, at Almásfüzitő, „red sludge" deposition from aluminum earth factory was monitored. In laboratory investigations, Salix species were found as Zn-accumulator species, therefore their capabilities and diversity were further investigated in 6 clones of *Salix alba*, as well as in *S. caprea* and *S. viminalis* rooted, grown and loaded with heavy metals under controlled conditions.
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KEY WORDS

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phytoremediation
phytoextraction
phytostabilization
Salix species and clones
slurry deposition

Phytoremediation is a low cost, *in situ* applicable technique for the clean-up of sites contaminated with toxic metals or organic pollutants. Depending on the degree of contamination and the size and volume of the polluted area, different technologies can be used to achieve the desired goals (Salt et al. 1998). In the present study, we are to work out the technology proper to remediate a deposition of dredged sediment form the oxbow lake at Mártély (South Hungary), which used to be a bend in Tisza river. In this case, two technologies can be applied with different aims: phytoextraction, when the level of bioavailable contaminants is only moderately high and it can be decreased below the environmentally acceptable value within a reasonable time. If the volume of the contaminated material is too large, phytostabilization should be applied (Bert et al. 2003).

Materials and Methods

Description of the study site

The dredged slurry has been deposited in 6 cassettes on a 37x200 m area containing 16000 m^3 sediment. The cassettes are separated with dikes which at the time of the first monitoring in November 2004, were already occupied by vegetation. On the wet surface of the slurry the first pioneer species also appeared. Along with plant samples, slurry samples were collected from all the cassettes for analysis.

Plant and soil analysis

Aliquots of homogenized plant samples were wet digested. Cd, Cu, Cr and Zn contents were determined by atomic absorption spectrophotometry (Hitachi, Type Z-8000). Soil samples were extracted with aqua regia and ethylenediamine tetraacetic acid (EDTA) for the determination of the total and the bioavailable fractions of metals, respectively.

Laboratory experiments

In order to compare metal accumulation capabilities of willow species, cuttings were rooted and grown hydroponically in half strength Hoagland solution. Metal treatment was administered after 3 weeks of growth for one week with the addition of 100 μM Zn, Cu, Pb and Cr. Here data only for Zn treatments are shown. Six clones of *Salix alba* were obtained from ERTI Sárvár (Hungary): 'Bédai egyenes', 'Drávamenti', 'Sárvár-1', 'SI 2/61', 'I-1/59' and 'I-4/59'. In addition, cuttings of *S. caprea* and *S. viminalis* were also investigated.

Results and Discussion

Monitoring at the study site

At the first monitoring in November 2004 the following species were found on the dikes, shores and surface of the dredged sediment: *1-Lycopus europeaus* L.*; 2-Lycopus exaltatus* L.f.*; 3-Carex sp.; 4-Elymus sp.; 5-Gnaphalium uliginosum* L.*; 6-Daucus carota* L.*; 7-Lythrum sp.; 8-Asclepias syriaca* L.*; 9-Eleocharis sp.; 10-Equisetum palustre* L.*; 11-Rorippa palustris* (L.) Bess.*; 12-Vicia biennis* L.*; 13-Glycyrrhiza sp.; 14-Rorippa sylvestris* (L.) Bess.*; 15-Sinapis arvensis* L.*; 16-Typha latifolia* L*; 17-Salix alba* L.*; 18-Phragmites australis* (Cav.) Trin. ex Steudel.

Recent soil analysis revealed that three metals, Cr, Pb and Zn concentrations exceeded the allowed limit values. In this case the EDTA-extracted fraction is considered as bioavailable part of the total extracted with aqua regia (Table 1).

Plants, collected *in situ*, were analyzed for their Zn content. Figure 1 shows that most species retained Zn in their

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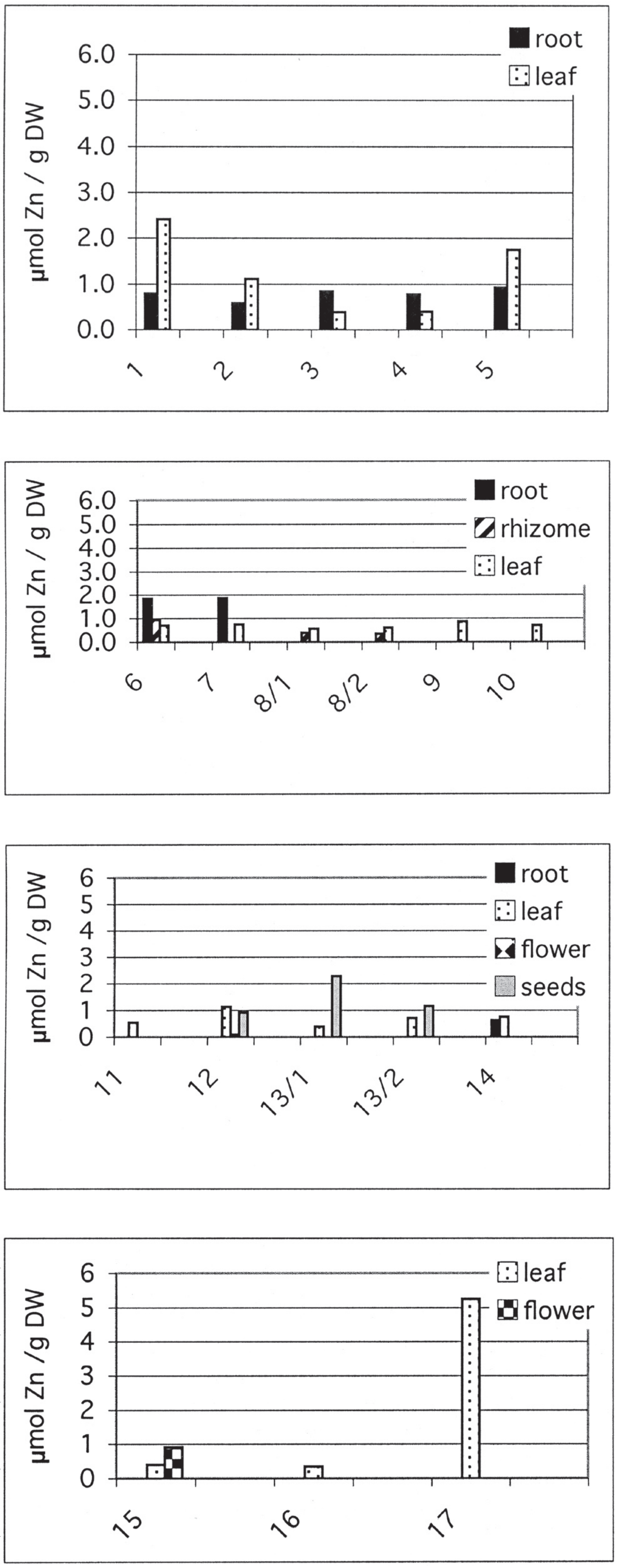

Figure 1. Accumulation of Zn in plant species and parts grown on and at the slurry dredged from the oxbow lake at Mártély. Numbers mark species as described above.

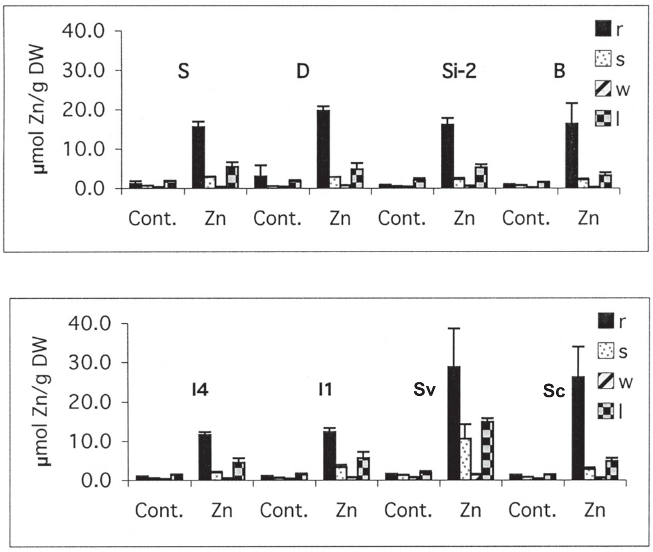

Figure 2. Zn accumulation by Salix species and clones, and the allocation of Zn within the plant. Control (Cont) treatments contained no Zn in the nutrient solution, while at Zn tretament, the growth solution was supplemented with 100 μM Zn (as chloride). Symbols for plant parts: r, root; s, new shoot; w, woody sample from the cutting, l, leaves. Clones of *Salix alba:* S, 'Sárvár-1'; D, 'Drávamenti'; Si-2, 'SI 2/61', B, 'Bédai egyenes'; I4, 'I 4/59'; I1, 1/59'. Sv, *Salix viminalis*; Sc, *Salix caprea*.

roots, or were excluder. Three species, *Lycopus europeaus, Gnaphalium uliginosum* and *Salix alba* showed Zn accumulation in their leaves, however, most of the species were excluders or retained Zn in their roots (e.g. *Daucus carota* and *Lythrum sp.).*

Table 1. Heavy metal concentrations of dredged sediment deposit at Mártély oxbow lake (ppm).

Element	Concentration, extraction by aqua regia	Environmental limit value for soil extraction by aqua regia	Concentration, extraction by EDTA	Environmental limit value for soil extraction by EDTA
Cr	**162.1 - 192.1**	**75**	**6.0 - 7.45**	**3**
Cu	61.4 .75.6	75	26.6 - 33.1	40
Fe	5099 - 6275	-	539-550	-
Mn	950-1189	-	383 - 398	-
Ni	52 -61	40	3.26 -4.05	20
Cd	0.54 - 1.77	1	0.44 - 0.80	-
Pb	**87.3 - 105**	**100**	**41.7 - 50.5**	**25**
Zn	**243 - 283**	**200**	**38.4 - 44.0**	**20**

Bold characters: metal concentrations above the limit value.

Metal uptake and translocation in *Salix* sp. under laboratory conditions

Since the highest metal accumulation was found in *Salix alba*, cuttings of 6 six clones of this species, plus *S. viminalis* and *S. caprea* were studied for their metal accumulation capabilities.

Results in Figure 2 confirm that the best Zn accumulator in the roots, and the best translocator to the leaves was *S. viminalis*. Of the *S. alba* clones, "Drávamenti" showed the best performance. These species and clones will be cultivated on the dredged sediment in long-term experiment.

Comparing data for Zn accumulation in leaves in *Salix* species and lines in Figure 2 and that for *Salix alba* in Figure 1, it can be seen that Zn concentrations built up in laboratory experiments (15-30 µmol/g DW) were 3 to 6-fold higher than that in the field (5 µmol/g DW). On this basis it can be concluded that the potential capacity for Zn accumulation of the *Salix* species and clones investigated is high enough to apply them for phytoextraction of Zn from the bioavailable (EDTA-extractable) fraction in the dredged slurry sediment.

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