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 Martély, 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.


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 Martély (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 m³ 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): ‘Béda 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


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
roots, or were excluder. Three species, *Lycopus europaeus*, *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).

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

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 phytorextraction of Zn from the bioavailable (EDTA-extractable) fraction in the dredged slurry sediment.

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References

