HOW SOIL AMENDMENTS AFFECT TOXIC ELEMENTS MOBILITY AND WILLOW GROWTH IN HIGHLY MULTI-CONTAMINATED SOIL

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Introduction

Willow growth is limited on strongly polluted soils because of toxicity of some contaminants (Vysloužilová et al., 2006; Jensen et al., 2009). Therefore, investigation of appropriate soil amendments that decrease toxic elements mobility and thus improve plant growth is necessary for these soil conditions. The aim of this study was to compare different soil amendments (quick lime, dolomite, rock phosphate, superphosphate, meat and bone meal) and choose the best measure for *in-situ* immobilization in highly multi-contaminated soil.

Methods

The efficiency of liming and phosphorus amendments on Cd, Pb, and Zn mobility, plant growth and toxic elements distribution between organs of *Salix* × *smithiana*Willd. was assessed in a 4-year pot experiment with weakly acidic soil extremely contaminated by toxic elements (54 mg Cd kg^{-1}, 3305 mg Pb kg^{-1}, 6172 mg Zn kg^{-1}). Application of soil amendments into soil was performed before planting of cuttings in the amounts per kg of a soil: 21.9 g lime (L), 68.1 g dolomite (D), 26.6 g rock phosphate (RP), 38.2 g superphosphate (S), and 107.1 g meat and bone meal (MBM). Doses were chosen so that the applied amount of Ca and P was the same with using different soil amendments (i.e. 15 g Ca kg^{-1} soil/ 3 g P kg^{-1} soil). Each treatment (Tr) including control soil (C, without any amendments) was carried out in four replicates. The concentrations of toxic elements in biomass after digestion, as well in soil extracts were determined by ICP-OES.

Results

The $CaCl_2$-extractable Cd and Zn concentrations were negatively correlated with soil pH (Cd r=–0.923, p<0.01; Zn r=–0.936, p<0.01) in most of treatments (except MBM treatment). Lime treatment confirmed the highest neutralization ability in soil after four growing seasons (Table 1). For traditional phosphorus amendments are important immobilization mechanism, i.e. precipitation with phosphates but it is not crucial for mobile Cd and Zn or for monitored Pb fractions. The quality of organic matter played probably key role in meat and bone meal treatment. Acid-extractable soil concentrations of toxic elements did not correlate with soil pH.

Table 1. The effect of treatment on soil pH_{CaCl2}, $CaCl_2$-extractable (Ca, 0.01 mol l^{-1} $CaCl_2$ solution – 1/10 w/v) and acid-extractable (AA, 0.11 mol l^{-1} CH_3COOH solution – 1/20 w/v) concentrations of toxic elements (mg kg^{-1}, mean±SE).

Tr	pH	Cd/Ca	Pb/Ca	Zn/Ca	Cd/AA	Pb/AA	Zn/AA
C	5.8d±0.03	3.2b±0.1	<0.2b	173b±8	19ab±1	30c±2	1991a±86
L	7.7a±0.05	0.1d±0.01	<0.2b	4.2c±1.0	20ab±0.4	58b±1	1779a±96
D	6.7b±0.01	1.4c±0.1	<0.2b	45c±4	21a±1	72a±4	2129a±78
RP	6.6b±0.01	1.5c±0.04	<0.2b	50c±4	17bc±1	30c±2	2121a±95
S	5.4e±0.1	2.6b±0.2	<0.2b	193b±21	16c±1	14d±1	2009a±109
MBM	6.3c±0.1	12.4a±0.5	1.5a±0.2	754a±36	20ab±0.4	33c±3	2063a±21

limit of detection (mg kg^{-1}): Pb – 0.2

The willow cuttings died during the first growing season in the meat and bone meal treatment (Table 2) as a result of high mobility of toxic elements. Soil amendments like lime, dolomite and rock phosphate tended to increase in organ biomass. The leaf and stump biomass was affected by soil pH (leaf: r=–0.711, p<0.01; stump: r=–0.614, p<0.01). The leaf biomass was negatively correlated also with Cd and Zn mobility (Cd/Ca r=–0.602, p<0.01; Zn/Ca r=–0.477, p=0.034).

Table 2. The effect of treatment on dry mass of organ biomass (g plant^{-1} DW; mean ± SE).

Tr	Fine roots	Stumps	Leaves
C	3.2a±2.0	21ab±5	2.7b±1.3
L	21a±15	46a±7	15a±1.5
D	23.5a±3	23ab±10	8.7ab±3.7
RP	29a±22	23ab±1	10ab±1
S	2.8a±0.4	17b±3	4.4b±1.8
MBM	died	died	died

The highest concentrations of toxic elements were recorded in fine roots (Table 3). The Cd and Zn concentrations increased in order stumps < leaves < fine roots and the Pb concentration increased in order leaves < stumps < fine roots. Only lime application tended to considerable decrease concentrations of toxic elements in plant organs.

Table 3. The effect of treatment on total concentrations (mg kg^{-1}, mean ± SE) of toxic elements in organ biomass.

Tr	Fine roots			Stumps			Leaves		
	Cd	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn
C	119a±33	1065ab±63	5749a±455	20ab±1	16a±7	819a±68	50a±1	0.2a±0.03	3092ab±86
L	56a±7	999b±270	2541b±156	13b±2	12a±8	402a±78	44a±4	0.3a±0.1	2782b±139
D	100a±1	1420ab±56	4846a±98	25a±3	14a±5	651a±112	45a±6	0.2a±0.04	2440b±157
RP	138a±27	2375a±448	5051a±562	21ab±1	12a±3	626a±64	51a±6	0.3a±0.1	2852b±199
S	49a±2	392b±39	6250a±91	12b±2	4.5a±1.5	641a±197	42a±5	<0.4a	3784a±310
MBM	-	-	-	-	-	-	-	-	-

Conclusion

The *S.* × *smithiana* is considered as good accumulator for Cd, Pb and Zn in highly contaminated soils. Lime application was confirmed as the best measure for highly contaminated soils that restrict Cd and Zn mobility and improve plant growth. Dolomite and rock phosphate application was less suitable measure and meat and bone meal application was unsuitable for these soil conditions.

References

Vysloužilová, M.; Puschenreiter, M.; Wieshammer, G.; Wenzel, W.W. (2006) Rhizosphere characteristics, heavy metal accumulation and growth performance of two willow (*Salix* × *rubens*) clones. *Plant Soil Environ., 52*, 353-361.

Jensen, J.K.; Holm, P.E.; Nejrup, J.; Larsen, M.B.; Borggaard, O.K. (2009) The potential of willow for remediation of heavy metal polluted calcareous urban soils. *Environ Pollut., 157*, 931-937.