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The potential of Razan-Hamadan highway indigenous plant species for the phytoremediation of lead contaminated land

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Abstract

Phytoremediation is the use of vegetation for in situ treatment of contaminated soils, sediments and water. To assess the potential of the native plant species for phytoremediation, plant samples were collected from Razan-Hamadan roadside areas in Iran that have lead pollution from automotive emissions. Samples were taken in autumn and spring of 2002 and analysed for total lead by atomic absorption spectrophotometry. Lead concentrations in plants ranged from 7.83 to 30.46 mg kg^{-1} in shoot organs and from 1.8 to 26.7 mg kg^{-1} in root organs. Bioaccumulation of Pb in shoot organs of Salsola species, Artemisia herba-alba, Eremopyrum cistans, Aegilops crassa, Chenopodium murale and Glycyrrhiza glabra was significantly higher that in their root organs. However both Lepidium species and Kochia scoparia accumulated higher Pb in root organs. The Salsola species accumulated Pb in their organs more than the other plants. Lead bioaccumulation in Sasola kali was higher in autumn. Of 10 plant species, only two species of chenopodiaceae (S.iberica and S.kali), with higher enrichment and translocation factors seemed more suitable for phytoremediation of arid soils.

Keywords: phytoremediation, lead pollution, roadside soils.

Introduction

Phytoremediation is a promising new method that uses green plants to assimilate or detoxify metals and organic chemicals. The term was first coined in 1991 to describe the use of plants to accumulate metals from soil and groundwater (Licht *et al*., 1995). It is a relatively inexpensive form of ecological engineering that has proven effective in some cases (Blaylock *et al*., 1997). Although microorganisms have also been tested for remediation potential plants have shown the greater ability to withstand and accumulate high concentrations of toxic metals and chemicals (Gadd and White, 1993; Ahmann *et al*., 1997). Plants that accumulate metals to high concentrations are sometimes referred to as ‘‘hyperaccumulators’’. The term was first used by Brooks *et al*. (1977) to describe those plants that take up and accumulate more than 1000 mg metal g^{-1} dry mass.

There have been few reports about lead hyperaccumulating plants. Indian mustard (*Brassica juncea*) was studied by Blaylock *et al*. (1997) for Pb uptake in contaminated soils. It was able to accumulate up to 1.5% Pb in the shoots in soils containing 600 mg kg^{-1} of Pb. It was reported that *Thlaspi rotundifhm* hyperaccumulated Pb, however it was shown that *Zea mays* accumulated higher Pb levels in controlled tests if soil pH and P were low (Huang and Cunningham, 1996).

High lead concentrations in roadside soils and vegetation, such as grass have been recognized by many workers (Page and Ganji, 1971; Ho and Tai, 1988; Onyari *et al*., 1991; Munch, 1993; Yassoglou *et al*., 1987) lead concentrations in soil may reach as high as 3000 mg kg^{-1} (Goyer, 1988).

Our previous study has shown that lead content in both roadside of Razan-Hamadan highway soils is very high. Total Pb contents of samples decreased with distance from the roadsides. The highest mean lead concentration of roadside may exceed 180 mg kg^{-1}, while the background concentration is less than 20 mg kg^{-1}. The highest mean lead concentrations were found in soil samples taken 10 meters form both roadsides. They were 84.83 ±2.23 mg kg^{-1} in soil samples taken 10 meters from the west side of the road, and 180 ±16.36 mg kg^{-1} in soil samples taken 10 meters from the east side of the road. The lowest concentrations were measured in 200 meters form west (49.5±2.23 mg kg^{-1}) and east (57.17±16.36 mg kg^{-1}) of the road. Total Pb concentration was high on east of the road rather than west of the road. There were high significant differences between sample sites for total Pb concentration ($P<0.001$). Total Pb content of soil samples decreased exponentially with increase of distance from the roadsides. This decrease was more intense in soil samples taken from west roadside. It may be related to the direction of wind breezing from southwest to northeast (Ebrahimi and Safari Sinegani, 2004).

Iran has a rich plant biodiversity, hence it has good potential to provide suitable species for phytoremediation of heavy metal contaminated land. The large scale phytoremediation of metal pollutants from soils requires plant species that have high biomass, are rapidly growing and accumulate metals. The concentration of metal in the harvestable plant tissue must be significantly higher than in the soil in order to ensure that the volume of contaminated plant material generated by the phytoremediation is less than the original volume of the contaminated soil (Salt, 2000).

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This study reports the search for Pb accumulating plants from the indigenous species growing in highly Pb-polluted areas in northwestern Iran. The potential of such plants as phytoremediation species is also discussed.

Materials and Methods

The experimental site is in Hamadan province, on the northwestern of Iran. It is located above 1700 m over sea level at 34 °, 48 ' North and 48 °, 31 ' East. The regional climate is arid-cold, with annual precipitation of 322 mm. Mean daily maximum temperatures is 34.1 °C and minimum temperatures is –7.6 °C. The dominant native plants grown on the Pb-polluted pasture were *Salsola iberica, S. kali, Chenopodium murale, Kochia scoparia, Lepidium vesicarium, Lepidium draba, Descurainia sophia, Artemisia herba-alba, Achillea micrantha, Eremopyrum cistans, Aegilops crassa,* and *Glycyrrhiza glabra*. Some selected physical and chemical properties of Razan-Hamadan roadside soil are given in Table 1. These soil characteristics were measured according to methods of soil analysis published by SSSA (Page *et al*., 1992; Klute *et al*., 1986). In both sides of Razan-Hamadan highway plant samples were taken from 20 m far from the highway. During the 2 seasons (autumn and spring) of 2002, samples were taken from root and shoot plant organs separately with 3 replicates. They were washed with distilled water, and dried at 80 °C during 24 hours. They were ground and stored in glass containers until analysis. Each sample of root or shoot organs separately analyzed for Pb concentration with dry ash method. Total Pb of samples was solved in 2N HCl and analyzed by atomic absorption on a Varian instrument at 283.3 nm using an air-acetylene flame (Ramos *et al*., 1994). Translocation factors (shoot / root ratios) and enrichment factors of Pb (shoot / soil ratios) were also studied in some of the native plants of Razan- hamadan roadside soil. All the statistical analyses were performed on the SAS 6.12 software.

Table 1. Some chemical and physical properties of Razan- hamadan roadside soil.

Texture	Clay (%)	Silt (%)	Sand (%)	OM (%)	EC dS m^{-1}	pH	ECC (%)	CEC cmolc kg^{-1}	Total Pb (mg kg^{-1})	Avail. Pb (mg kg^{-1})
Clay	41.8	16.8	41.4	1.58	1.2	7.81	19	12	83.16	3.03

Results and Discussion

Figures 1 and 2 show Pb concentration in shoot and root organs of the plants. Most of the plants contained lead concentrations in their leaves above the normal range of 0.2–20 mg kg^{-1} (Alloway, 1990; Pendias and Pendias, 1992). Lead concentration in shoot and root organs of a few sampled native plants has reached the critical levels (30-300 mg kg^{-1}). The highest lead contents may exceed 30.46 mg kg^{-1} in the shoot organs of *S.iberica* and 26.7 mg kg^{-1} in the root organs of same plant, while the lowest concentration is less than 7.83 mg kg^{-1} in the shoot organs of *C. murale* and 1.8 mg kg^{-1} in the root organs of same plant.

The study of the Pb contents of *S. kali* in both seasons of 2003 has shown that Pb concentration in root and shoot organs of the plants in autumn was significantly higher than in spring (Figure 1 and 2). The lead contents in shoot and root organs of the sampled plants were significantly different. Some plants accumulated Pb in shoot organs more than in root organs and vice versa. The order of Pb bioaccumulation in shoot organs of the plants was *S. iberica> S. kali> L. draba> E. cistans> A. herba-alba> L. vesicarium> A. crassa> K. scoparia> G. glabra> C. murale.* This order for Pb bioaccumulation in root organs of the plants is different. The order of Pb bioaccumulation in root organs of the plants was *L. draba> S. iberica> L. vesicarium> K. scoparia> S. kali> A. herba-alba> E. cistans> A. crassa> G. glabra> C. murale*.

Of 10 plant species studied here, only two species of chenopodiaceae (*S. iberica and S. kali*) and one species of cruciferae (*L. draba*) seemed suitable for phytoremediation of arid soils.

Plant species were judged as being suited for phytoremediation based on several criteria including: wide distribution, high above-ground biomass, high bioaccumulation factors (hyperaccumulators), short life cycles, and high propagation rates. Indian mustard (*Brassica juncea*) was studied by Blaylock *et al*. (1997) for Pb uptake in contaminated soils. Indian mustard was able to accumulate up to 1.5 % Pb in the shoots in soils containing 600 mg kg^{-1} of Pb. It was reported that *Thlaspi rotundifhm* hyperaccumulated Pb, however it was shown that *Zea mays* accumulated higher Pb levels in controlled tests if soil pH and P were low (Huang and Cunningham, 1996).

Although the level of Pb bioaccumulation in the studied plants was markedly lower than that one can call them as hyperaccumulator, but our previous study (Ebrahimi and Safari Sinegani, 2004) has shown that lead contents in both roadside of Razan-Hamadan highway soils is moderately high. The highest Pb concentration of the

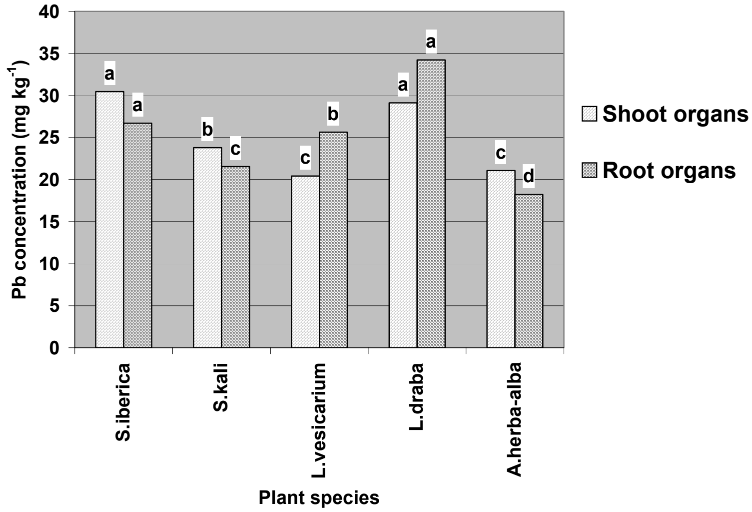

Figure 1. Lead concentration in shoot and root organs of different plant species in spring. Plant with different data label showed different Pb levels at p=0.05

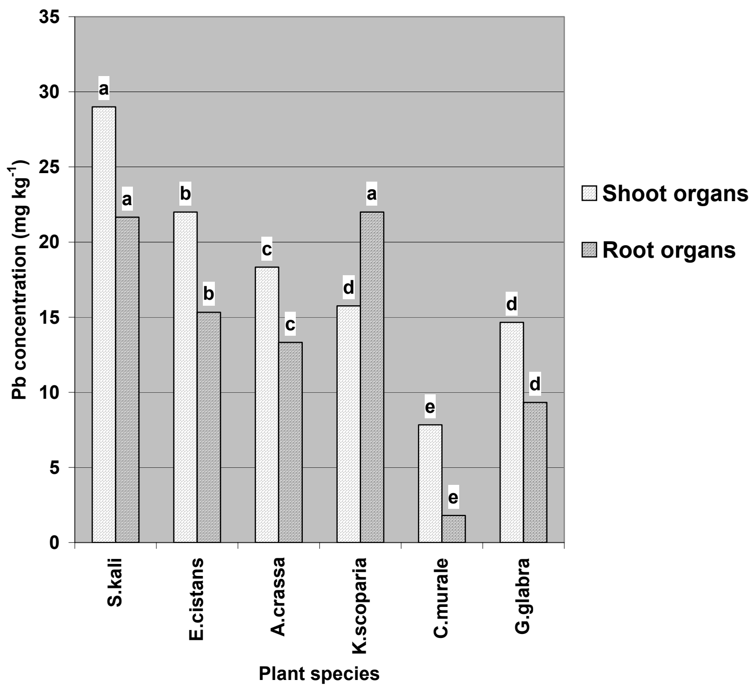

Figure 2. Lead concentration in shoot and root organs of different plant species in fall. Plant with different data label showed different Pb levels at p=0.05

roadside may exceed 180 mg kg^{-1}. Available Pb in these soils was also relatively low (in DTPA extract, 3.03±0.28 mg kg^{-1}). However *S. iberica* accumulated 30.46 mg Pb kg^{-1} in the shoot organs and 26.7 mg Pb kg^{-1} in the root organs. Its enrichment factor was considerable higher than the other plant. Lead enrichment factors of this plant species based on total concentration in soil and available concentration in soil were 0.37 and 10.1, respectively (Table 2). *Salsola kali* was another powerful plant to accumulate Pb in its shoot and root organs. Lead enrichment factors of this plant species based on total concentration in soil and available concentration in soil were 0.29 and 7.85 in spring respectively those increased to 0.35 and 9.57 in fall. Translocation factors of Pb in these plants were relatively high. Although translocation factors of Pb in some plant species (e.g. *A. herba-alba, E. cistans, A. crassa, G. glabra,* and especially *C. murale*) were relatively high, lead enrichment factors of these plant species were considerably lower than those for *S. iberica* and *S. kali* (Tables 2 and 3).

Table 2. Translocation factors (shoot/root ratios) and enrichment factors of Pb in some of the native plants of Razan-hamadan roadside soil in spring.

	Translocation factors	Metal enrichment factor based on	
		Total concentration in soil	Available concentration in soil
S. iberica	1.14	0.37	10.1
S. kali	1.1	0.29	7.85
L. vesicarium	0.8	0.25	6.74
L. draba	0.85	0.35	9.61
A. herba-alba	1.16	0.25	6.95

Table 3. Translocation factors (shoot/root ratios) and enrichment factors of in some of the native plants of Razan-hamadan roadside soil in fall.

	Translocation factors	Metal enrichment factor based on	
		Total concentration in soil	Available concentration in soil
S. kali	1.34	0.35	9.57
E. cistans	1.44	0.26	7.26
A. crassa	1.38	0.22	6.05
K. scoparia	0.72	0.19	5.2
C. murale	4.35	0.09	2.58
G. glabra	1.57	0.18	4.84

Rosa *et al*., 2004 has also shown that tumbleweed (*Salsola kali*) uptake and translocate cadmium easily to shoot organs as a potential Cd-hyperaccumulator desert plant species. Among plants studied here both of *Salsola* species (*S. iberica* and *S. kali*) are suggested for future study on Pb phytoremediation of arid soils.

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