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Removal of Heavy Metals by Native Accumulator Plants

ABDOLKARIM CHEHREGANI[1] AND BEHROUZ E. MALAYERI
Department of Biology, Faculty of Science, Bu-Ali Sina University, Hamedan, Iran
[1]Correspondence author's e-mail: chehregani@basu.ac.ir

ABSTRACT

Heavy metals are one of the most important environmental pollutants. In recent years, many low cost sorbets such as algae, fungi, bacteria and plants have been investigated for their biosorption capacity towards heavy metals. The aim of this study was to determine the heavy metals accumulation capacity of native plants for phytoremediation. A lead (Pb) main was selected near Malayer city as a waste pool polluted area. Concentrations of heavy metals were determined in soils and plants grown near waste pools. Data showed that amounts of heavy metals in waste pools of the main were several times more than normal soils. Plants growing in this area including *Euphorbia cheiradenia*, *Scariola orientals*, *Centaurea virgata*, *Gundelia tournefortii* and *Eleagnum angustifolia* could accumulate heavy metals in different organs. *E. cheiradenia* belonging to *Euphorbiacea* was more effective accumulator with effective accumulating Pb, Zn, Cu, Ni and Cd. *E. cheiradenia* was selected for soil detoxification in the experimental plots that contained soils of waste pools resulted mining. The amounts of some heavy metals decreased several times during two years phytoremediation. It is recommended that *E. cheiradenia* may be introduced as an effective plant for soil detoxification and phytoremediation in heavy metals polluted soils.

Key Words: Heavy metal accumulators; Polluted soils; Detoxification; Phytoremediation; *E. cheirandenia*

INTRODUCTION

The current pattern of industrial activity is altering natural flow of material and introducing novel chemicals into the environment (Faisal & Hasnain, 2004; Sadeghi *et al*., 2006). The rate at which effluents are discharged into the environment especially water bodies is increasing as a result of urbanization. Most of these effluents contain toxic substances especially heavy metals (Lone *et al*., 2003; Igwe & Abia, 2006). Heavy metals make a significant contribution to environment as a result of human activities such as mining, smelting, electroplating, energy and fuel production, power transmission, intensive agriculture, sludge dumping and melting operations. Some heavy metals e.g., Mn, Fe, Cu, Zn, Mo and Ni are essential as micronutrient for microorganisms, plants and animals (Welch, 1995) while others have no known biological function. All heavy metals at high concentrations have strong toxic effects and regarded as environmental pollutants (Nedelkoska & Doran, 2000; Chehregani *et al.*, 2005).

Industrial activities cause fast and considerable degradation of soil and vegetation cover, which necessitate pursuing the methods of managing derelict industrial lands. On such polluted lands vegetation plays increasingly important ecological and sanitary roles (Antonkiewicz & Jasiewicz, 2002). Proper management of plants from such areas may significantly contribute to restoring the natural environment. Numerous efforts have been recently undertaken to find methods of cleaning soil from heavy metals, e.g., phytoremediation (Antonkiewicz & Jasiewicz, 2002; Igwe & Abia, 2003). Not surprisingly, the phytoremediation, as an environmental cleanup technology, was initially proposed for the remediation of metal-contaminated soil (Chaney, 1983; Baker *et al*., 1991; Baker *et al*., 1995; Keller *et al*., 2003).

The phytoremediation of heavy metals is a cost-effective green technology based on the use of metal-accumulating plants to remove toxic metals, including radio-nuclides from soil and water. The identification of metal hyperaccumulators capable of accumulating extraordinarily high metal levels, demonstrates that plants have the genetic potential to clean up contaminated soil. During 19th century, Baumann (1885) identified plants capable of accumulating uncommonly high Zn. Byers (1935) documented the accumulation of selenium in *Astragalus* spp. Phytoremediation has recently become a subject of intense public and scientific interest and a topic of many recent researches (Raskin *et al*., 1997; Dahmani-Muller, 2000; Igwe & Abia, 2003). Ability to select plant species either resistant to or can accumulate great amounts of heavy metals would certainly facilitate reclamation of contaminated area (Bizly *et al*., 2000; Lasat, 2002). Aim of this research was to find native accumulator plants and to examine their ability in phytoremediation at polluted soils.

MATERIAL AND METHODS

Sampling site. An old waste pool of Pb main was selected as polluted area near the Malayer city. Plants that were grown at this polluted area were collected and determined for their characteristics. Concentration of heavy metals were determined in soils of waste pools and compared with normal soils. We determined amounts of heavy metals in different parts of plants and chose some of them as accumulator plants. A more effective accumulator plant was selected for removing of soil heavy metals in an experimental phytoremedation.

Heavy metals determination. Heavy metals were determined in soil samples before and after phytoremediation. From each plot, 10 samples of the soil (depth 10 - 15 cm) were taken and sieved through a 1 cm sieve. To estimate the total heavy metals in the plants, samples (roots, shoots, leaves & fruits) were dried at 105˚C for 24 h in acid-washed and pre-weighed volumetric 100 mL conical flasks. The content (1 g) was digested in 20 mL of boiling concentrated (65%) nitric acid (special pure for spectroscopy). The solution was boiled on a hot plate until light fumes were given off. The samples were cooled down and then the digests were filled up to 100 mL with deionized water and left overnight to allow the remaining soil particles to settle. Finally, 20 mL of each sample solution were used to determine heavy metal concentration using the flame atomic absorption method for Pb, Cu and Zn and graphite furnace technique for Cd measurement (Aanalyst 800, Perkin-Elmer). The concentrations of metals were analyzed also by AAS. In those cases, Chinese Soil 4 [Promochem GmbH, Germany, No. GBW07404, certified concentration Cd = 0.35, Cu = 40.5, Pb = 58.5, Zn = 210] was used as a reference material.

Phytoremediation. Plant species of this area were studied exactly. Among of these plants, ones collected that accumulate heavy metals considerably (Table I). *E. cheiradenia* belonging to *Euphorbiaceae* that is a common and native plant in this area was used as an accumulator plant for this study. We compared composition of polluted and non-polluted soil before and after phytoremediation. For this aim *Euphorbia* plants were grown in original polluted and non-polluted areas. Concentration of heavy metals including Cd, Pb, Ni, Cu, Zn and Fe were determined after maturation and ripening of plants. Only the fully ripe plants were harvested. Ten plots were selected in polluted area randomly and separated from around by plastic plates. All plants removed from plots and only *Euphorbian* plants were maintained, which were harvested and deposited in end of growing period. They grew in next year from underground gemma. Heavy metals were determined in soil of plots, before starting study and after two years of phytoremediation.

RESULTS

Heavy metal evaluation results. Evaluation of heavy metals in soils of waste pool (in the main) and non-polluted soils (out of main) showed that amounts of some heavy metals in the waste pool of the main are several times more than natural areas (Table I). Plants that were more popular and could grow in this polluted soil, at the waste poll of main, were collected and analyzed for scientific name and classification (Table II). Determination of heavy metals in plant organs showed that some of them acted as accumulator plants (Table III). Results showed that *E. cheiradenia, R. lutea, S. excelsa, S. orientalis, C. oblonga* and *C. virgata* accumulated Zn, but *R. lutea* and *E. cheiradenia* were more effective. *E. cheiradenia, C. virgata, S. orientalis* and *C. draba* were able to accumulate Pb. Our study indicates that some species including *E. macroclada, C. virgata, S. orientalis* and *C. congestum* had accumulated Cu considerably. Also amount of Cd in some plants including *Onosma kotschyi, Hultemia persica, Stipa lessingiana, S. excelsa, C. virgata* and *R. lutea* were more than others (Table III). Although amount of Ni was very little in most plants, *R. lutea, E. cheiradenia* and *E. macroclada* accumulated greater than others. These plants accumulated concentration of Ni several times greater than soil (Table I). Analysis of Fe in experimental plants showed that *R. lutea, E. macroclada, C. virgata, G. tourneforti* and *E. cheiradenia* were more accumulator than others and they are Fe hyperaccumulators (Table III).

Phytoremediation results. *E. cheirandenia* was chosen as a more effective plant regarding as heavy metal accumulator for this study, because it is a common plant that can accumulate most of heavy metals effectively (Table III). Concentrations of some heavy metals were determined in *E. cheirandenia* that were grown in polluted and non-polluted soils. Data showed that concentration of some heavy metals in plants that were grown in polluted soils were 10 – 100 several times greater than non-polluted soils. This data showed that *E. cheirandenia* can absorbed and accumulate Pb, Cd, Zn, Cu and Ni efficiently.

After two years of phytoremediation using *E. cheirandenia* as an accumulator plant, concentrations of heavy metals were evaluated in soils. Data showed that concentration of all heavy metals were decreased considerably. Decrease in the amount of Pb, Cd and Zn were more evident (Table IV).

DISCUSSION

Problems caused by heavy metals contamination of arable soil include phytotoxic effects of certain elements such as Cd and Pb and also Zn and Cu, which are well known as micronutrient elements, however and cause several phytotoxicity of critical endogenous levels are exceeded (Mengel & Kirkby, 1982; Susarla *et al.*, 2002; Chehregani *et al*., 2005). Another serious problem is posed by the uptake of potentially noxious elements by food or forage plant species and their transfer to the food chain (Kloke, 1980). All heavy metals at high concentrations have strong toxic effects (Nedelkoska & Doran, 2000). The use of plants for environmental restoration is an emerging technology and plants capable of accumulating high levels of metals are grown in contaminated soils (Lasat, 2002).

According to our results, we can introduce following plants as heavy metal accumulator: *E. cheiradenia, R. lutea, S. excelsa, S. orientalis, C. oblonga* and *C. virgata.* But there are some differences regarding their ability as accumulating. Our study indicates that *E. macroclada, C.*

Table I. Concentration of some heavy metals (ppm) in natural soils and waste pools of a Lead main. Each data represent means of 15 samples

	Cd	Zn	Pb	Ni	Cu
Waste pool	42.40	2400	13500	95.20	1014
Normal soil	0.20	181	67	78.00	10.00

Table II. Accumulator species regarding biological absorption sufficiency (BAC) that were grown on the waste polls of the Lead main

Pb		**Ni**	
Euphorbia cheiradenia	0.16	Euphorbia cheiradenia	0.18
Scariola orientalis	0.12	Euphorbia macroclada	0.16
Cardaria draba	0.11	Juglans regia	0.15
Gundelia tournefortii	0.09	Populus alba	0.12
Centaurea virgata lam.	0.08	Salix excelsa	0.11
Eleagnus angustifolia	0.06	Scariola orientalis	0.11
Zn		**Cd**	
Euphorbia cheiradenia	1.39	Marrubium vulgare.	0.49
Cardaria draba	1.19	Euphorbia cheiradenia	0.38
Scariola orientalis	1.09	Reseda lutea	0.30
Cydonia oblonga	1.06	Ziziphora tenuior	0.22
Centaurea virgata lam.	0.94	Salix excelsa	0.21
Eleagnus angustifolia	0.73	Tamarix ramosisma	0.20
Cu		**Fe**	
Euphorbia macroclada	0.16	Reseda lutea	0.49
Reseda lutea	0.14	Euphorbia macroclada	0.38
Ziziphora tenuior	0.12	Hultemia persica	0.30
Onosma kotschyi	0.12	Gundelia tournefortii	0.22
Scariola orientalis	0.11	Salix excelsa	0.21
Achillea filipendalina	0.10	Cardaria draba	0.20

Table III. Concentration of some heavy metals (ppm) in shoots of studied plants

Species	Pb	Zn	Cd	Cu	Ni	Fe
Achillea filipendalina	135.00	38.00	2.00	40.00	6.00	1479
Biebersteinia multifida	23.00	ND	7.00	20.00	4.00	480
Cardaria draba	776.00	1600.00	2.40	26.40	8.40	1324
Centaurea virgata	590.00	1262.00	2.20	36.65	6.30	944
Cydonia oblonga	310.67	1428.00	1.80	22.93	7.40	460
Dendrostellaria lessertii	353.00	139.00	2.00	28.00	7.00	800
Eleagnus angustifolia	404.00	980.00	0.80	9.60	5.20	148
Euphorbia cheiradenia	1138.00	1873.00	2.35	65.00	14.25	1040
Euphorbia macroclada	81.67	326.67	3.00	25.95	13.00	2261
Gundelia tournefortii	652.00	820.00	2.30	24.00	8.40	1952
Hultemia persica	62.00	48.00	3.00	23.00	8.00	580
Juglans regia	214.33	598.67	1.60	22.20	11.93	340
Leutea petidaris	25.00	--	3.00	19.00	4.00	246
Marrubium vulgare.	78.00	58.00	9.00	34.00	4.00	540
Myostis caespitosa	61.00	62.00	2.00	24.00	5.00	80
Onosma kotschyi	39.00	151.00	3.00	47.00	6.00	160
Phragmites australis	0.00	91.00	2.00	24.00	7.00	480
Populus alba	42.50	234.50	3.00	28.50	10.00	307.5
Reseda lutea	371.50	233.00	5.50	57.50	7.00	5490
Salix excelsa	404.00	685.67	3.93	35.13	9.13	1891
Scariola orientalis	884.00	1468.00	2.60	43.40	8.60	1000
Smymium cordifolium	4.00	20.00	3 .00	24.90	7.00	400
Stipa lessingiana	68.00	39.50	ND	22.50	7.50	673.5
Tamarix ramosisma	125.50	107.50	3.67	30.75	6.75	582.5
Ziziphora tenuior	228.00	55.00	4.00	50.00	7.00	1060

Table IV. Comparison beween concentration of some heavy metals (ppm) before and after phytoremedation by using *Euphorbia cheirandenia*

Metals (ppm) Samples	Cd	Zn	Pb	Ni	Cu
Before phytoremedation	42.2	2400	13500	95.2	1014
After phytoremedation	11.88	496.67	250.75	63.2	269.9
Normal soil	0.20	181.00	67.00	78.00	10.00

virgata, S. orientalis and *C. congestum* had accumulated Cu considerably. We can regard *Onosma kotschyi*, *Hultemia persica*, *Stipa lessingiana*, *Salix excelsa*, *Centaurea virgata* and *Reseda lutea* as Cd accumulators (Table III). We for the first time report that although *E. cheiradenia* and *C. virgata* both are hyperaccumulators, *E. cheiradenia* is more effective regarding metal accumulating.

We had delaminated ability of *E. cheiradenia* in the removing of heavy metals from polluted soils. After two years maintenance of *E. cheiradenian* plants in plots, amount of heavy metals were compared with control-polluted soils. Data showed that the concentrations of Pb, Ni and Zn were more than Cd and Fe (Table IV). We suggest *E. cheiradenia* for removing and detoxification of heavy metals, especially Pb, Ni, Cu & Zn, from polluted soils. *E. cheiradenia* is a xerophytes plant that growth in non-sufficient and poor soils. Phytoremediation has recently become a subject of intense public and scientific interest and a topic for many recent researches (Raskin *et al*., 1994; Salt *et al*., 1995; Cunningham *et al.*, 1995; Cunningham & Ow, 1996; Raskin *et al*., 1997). We propose native accumulator plants for phytoremediation including, *E. cheiradenia*, because of its efficiency to remove heavy metals.

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