African Journal of Agricultural Research Vol. 7(22), pp. 3293-3301, 12 June, 2012
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR12.165
ISSN 1991-637X ©2012 Academic Journals

Full Length Research Paper

Potential of *Vicia faba* and *Brassica arvensis* for phytoextraction of soil contaminated with cadmium, lead and nickel

Roya Karimi[1], Mostafa Chorom[1], Sina Solhi[2], Mahmood Solhi[3]* and Abdollah safe[4]

[1]Department of Soil Science, College of Agriculture, Ahwaz University, Ahwaz, Iran.
[2]Department of Geomorphology, College of geography, Isfahan University, Isfahan, Iran.
[3]Department of Soil and Water, Isfahan Agricultural and Natural Resource Research Center, Isfahan, Iran.
[4]Department of Geomorphology, College of geography, Isfahan University, Isfahan, Iran.

Accepted 3 May, 2012

The use of plant species to remove pollutants from soils is generally defined as phytoextraction. In order to evaluate phytoextraction of contaminated soils, a pot experiment was conducted using two plants Broad bean (*Vicia faba*), Wild mustard (*Brassica arvensis*) and three kinds of heavy metals (Cd, Pb, and Ni) with 3 levels in a completely randomized factorial design with three replications. A reverse relationship was found between heavy metal concentration in treatments and biomass production of selected plants. Accumulation of Pb was found more in the roots while accumulation of Cd and Ni was more in the aerial parts. The maximum translocation factor value was obtained for nickel and cadmium in wild mustard. The highest transfer coefficient observed for nickel and cadmium where the lowest transfer coefficient observed for Lead. Uptake index showed that wild mustard had a better potential for cadmium phytoextraction.

Key words: Phytoexraction, cadmium, lead, nickel, broad bean, wild mustard.

INTRODUCTION

In recent years, rapid growth in human population is one of the major causes of environmental pollution (Ahmad et al., 2011). Due to global industrialization in the twentieth century, heavy metal contaminations of soil, water and air posed various uncompromising and fatal effects on stability and human's ecosystem (Karimi et al., 2010). Furthermore, the human activities such as mining, irrigation with waste water, traffic and the application of sewage sludge to agricultural lands increased the release of heavy metal into our ecosystems, causing serious environmental problems posing threats to human health. Similar effects of Cadmium and Lead on plants have been reported elsewhere (Nwoko, 2010). Although, many metals are essential for cell function (that is, Cu, Mn, Zn, Ni), all of the heavy metals were toxic at higher concentration (Wuana et al., 2010). Unlike organic contaminants (pesticides and herbicides), heavy metals are not biologically degradable, and therefore, can remain in environmental bodies for a long time (Karami ands Zulkifili, 2010). There are generally many methods of soil clean-up such as thermal desorption, isolation and containment, mechanical separation, oxidation-reduction, solvent extraction or soil flushing that have proven to be effective in small areas, require special equipments and are intensive labors (Karami et al., 2010; Yanai et al., 2006). In contrast, phytoremediation is clean, simple, cost effective, non-environmentally disruptive in green technology, and most importantly, its by-products can find a range of other uses (Sarma, 2011). Thus, this technique is an eco-friendly approach for remediation of contaminated soil and water using plants comprised of two components, one by the root colonizing microbes and the other by plant themselves, with accumulation of the toxic compounds and exchange of this compound to further non-toxic metabolites (Sarma, 2011; Gardea-Torresdey

*Corresponding author. E-mail: msolhi@yahoo.com. Tel: +98-311-7753408. Fax: +98-311-7757022.

et al., 2005). Approximately, 400 plant species from at least 45 plant families have been so far, reported to hyper accumulate metals (Gosh et al., 2005). Hyper accumulators are metallophytic plant species capable of accumulating metals at levels 100-fold greater than those typically measured in shoots of the common non-accumulator plants and belong to the natural vegetation of metal-enriched soils (Barcelo and Poschenrider, 2003). Thus, a hyper accumulator plant will concentrate more than 10 mg kg^{-1} Hg, 100 mg kg^{-1} Cd, 1000 mg kg^{-1} Co, Cr, Cu and Pb; 1000 mg kg^{-1} Zn and Ni (Lasat, 2002). Some of the plant families are Brassicaceae, Fabaceae, Euphorbiaceae, Astrraceae, Lamiaceae, Poaceae and Scrophulariaceae (Sarma, 2011; Dushenkov, 2003). Metal hyper accumulation occurs in approximately, 0.2% of all angiosperms and is particularly well represented in the Brassicaceae (Kramer, 2010). However, hyper accumulators have several beneficial characteristics, but may tend to be slow growing and produce low biomass and years or decades that are needed to clean up contaminated sites (Lasat, 2000). Furthermore, plants used for phytoextraction should be fast growing, easily propagated, and able to accumulate the target metals (Ederli et al., 2004; Chaoui and Ferjani, 2005). Data indicated that canola (*B. napus*) and radish (*Raphanus sativus*) are moderately tolerant to heavy metals and that radish plant is more so tolerable than canola (Marchiol et al., 2004; Bidar et al., 2007) mentioned that in plant species, metals were preferentially accumulated in root more than in shoots, as follow: Cd>Zn>Pb. Ahmad et al. (2011) showed that in soil, forage and seed Pb, Cd and Cr concentration increased consistently with increase in the treatment level of sewage water. Root and leaves Cd concentrations of *Enchinochloa polytachya* were 299 ± 13.93 and 233 ± 8.77 mg kg^{-1} (on a dry weight basis), respectively (Solis-Dominguez et al., 2007). Paula Caraiman and Macoveanu (2011) reported that the recommended plants for phytoremediation of soil contaminated with Cadmium and Zinc, under the greenhouse condition are rape and fescue. Wuana and Okieimen (2010) in their studies determined that corn (*Zea mays L*.) is a widely grown staple cereal with promising attributes of a heavy metal accumulator. The objective of the present study was the evaluation of the potential of Broad bean and Wild mustard plants for the phytoextraction of Cd, Pb and Ni in a contaminated soil.

MATERIALS AND METHODS

Site description

The soil samples (Entisol and Soil Survey Staff, 2003) collected from the surface horizon (Ap: 0 to 30 cm) of Research Farm located in college of Agricultural of Shahid Chamran University around Ahwaz City (Southwest of Ahwaz in side west of Karoon river). Site is located at 700 km South of Tehran (Iran) with coordination of 31°20' N longitude, and 48°40' E latitude, and average temperature of 25°C, average annual precipitation of 200 mm and elevation of 20 m from sea level.

Treatments and statistical design

The experiment was conducted using a completely randomized factorial design containing three replications with two plants species and seven soil treatments. Fifty four pots were prepared for different treatments. The soil was artificially contaminated with Cd, Pb and Ni, which were added to the root environment as aqueous solution of Cd $(NO_3)_2.4H_2O$, Pb $(NO_3)_2$ and $NiCl_2.6H_2O$ in two doses at the beginning of the experiment. The concentration of Cd, Pb and Ni selected for the treatments were (50 and 100), (500 and 1000) and (250 and 500) mg kg^{-1} of dry weight of soil respectively which are higher than the upper metal concentration level in soil were considered toxic to plants (Orcutt and Nilsen, 2000). The zero level of heavy metals treatment was considered as the control (C). Cd, Pb and Ni concentration were selected based on previous studies of uptake heavy metals by plants (Piechalak et al., 2002; Yoon et al., 2006; Kabat et al., 2011; Pas et al., 2000). The treatments were mixed uniformly with soil and incubated in laboratory at the temperature range of 25°C for 3 weeks. After incubation 5.0 kg of soil which was properly mixed and placed in each plastic pot and fertilized with a rate of 50.0 mg N kg^{-1} dry soil as urea, 50.0 mg P kg^{-1} as diammonium phosphate and 50.0 mg K kg^{-1} as potassium sulphate for Broad bean plant; and with a rate of 75.0 mg N kg^{-1} dry soil as urea, 50.0 mg P kg^{-1} as diammonium phosphate and 75.0 mg K kg^{-1} as potassium sulphate for Wild mustard. Six seeds of Broad bean plant (*Vicia faba*) and Wild mustard plant (*Brassica arvensis*) were sown in separate plastic pots to a depth of 0.5 to 4 cm and watered daily till seed germination. When the seedling developed 2 or 4 leaves, they were thinned out to retain three uniform plants per pot and allowed to grown for 70 days (December to February) in Chamran University greenhouse. Plants were watered with dionized water and soil moisture was maintained at 80% of field capacity based on temperature changes and relative moisture in order to avoid leakage of water from the pots.

Samples collection and analyses

Plants were harvested and divided into roots and shoots, washed respectively with tap water, dionized water, 0.05 M HCl and rinsed with dionized water. After washing, plant samples were oven-dried at 75°C for 24 h to constant for dry weight. Dried plant tissues were ground with an agate mortar to pass from a 35 mesh screen and 0.5 g of sub-samples were digested in 10 to 15 ml of concentrated HNO_3, and 5 ml mixture of concentrated H_2SO_4 and $HClO_4$ acid (4: 1) at 120°C until a transparent solution was obtained (Allen et al., 1986). The solution was filtered through Whatman No. 42 filter paper and the solution was diluted to 100 ml with dionized water. Soil samples were collected from each pot after harvesting and were air-dried at room temperature for two days, and then, passed through a sieve of 2 mm mesh size to prepare for chemical analysis. Physical and chemical properties of the soil were determined using standard methods (Sparks, 1996). Soil pH measured in soil saturation and Electrical Conductivity (EC) was measured in saturation extract. Organic carbon of the soil sample was determined by Walkley and Black's rapid titration method (Allison, 1973). Clay, silt and sand percentage were determined by hydrometer method (Day, 1965). The extraction values of Ca and Mg were assessed in the NH_4OAc-EDTA extraction, accounting for soil cation exchange capacity. Potassium and sodium concentration were measured using emission absorption flame. N and P were determined by the kjeldahl digestion and molybdenum blue method, respectively (Meers et al., 2007). The extractable concentration Cd, Pb and Ni in soil were determined by using diethylene –tetramine-penta-acetic [DTPA] (Lindsay and Norvell, 1978). The extraction solution contains 0.005 M DTPA, 0.01 M $CaCl.H_2O$ and 0.1 M triethanol amin (TEA). 20 g of air dried soil were placed to polyethylene bottle; 40 ml of extractant was added and shaken for

Table 1. Physicochemical characteristic of studied soil.

EC_e (dsm^{-1})	pH (%)	OC (%)	T.N.V (%)	$CaSO_4$ (%)	SP (%)	N (%)	P ($mgkg^{-1}$)	K ($mgkg^{-1}$)
2.7	7.5	0.57	0.98	0.41	35.6	0.02	3	6.02

Na ($meql^{-1}$)	Ca ($meql^{-1}$)	Mg ($meql^{-1}$)	CEC ($cmol^{+}kg^{-1}$)	Sand (%)	Silt (%)	Clay (%)
46	25	10.2	10.4	51.1	27.5	21.4

O.C-Organic Carbon; T. N. V-Total Neutralizing Value; CEC- Cation Exchange Capacity.

2.0 h. Then this mixture filtered through Whatman filter paper No. 42. The Cd, Pb and Ni concentration of soils and plants were measured using Flame Atomic Absorption Spectrophotometry (FAAS) Perkin Elmer model, 2380. Three replication of entire sample were run to ensure precision of the determination.

Statistical analyses

All the statistical analyses [ANOVA and Least Significant Difference (LSD) test for comparison of means] were carried out with software SAS (Statistical Analysis System) V.9.1 to compare treatment effects on heavy metal content in soil, and also at plant tissues and species. Differences at P>0.05 levels were considered significant. The coefficient of variation (CV) was calculated to express the variability in metal concentration within the samples.

RESULTS AND DISCUSSION

The selected soil was found to be sandy clay loam, with low organic carbon. It was slightly saline, with neutral pH and lacked of nutrient elements and heavy metal. Some physicochemical characteristics of the soil sample collected from this study are shown in Table 1.

Effects of treatments on biomass production

Plant height was significantly affected by heavy metal treatments as there was a consistent decrease in this growth attribute with increase in the level of heavy metal that has been earlier reported by other researchers (Kafeel et al., 2011). This contracting result clearly indicated that heavy metal amendment caused heavy metal stress in the soil environment, which led to reduction in the plant growth, biomass accumulation and yield during the present study. Plant biomass can be used as an indicator for the overall health of plants growing in the presence of heavy metals.

The largest values of dry biomass production occurred in control treatment both for Broad bean (10.7 g per pot) and Wild mustard (7.8 g per pot). The dry biomass of both plants decreased with increase in values of heavy metal level, although, decreased significantly only at Cd and Ni treatments for Broad bean and Pb for Wild mustard. Dry biomass coefficient (DBC) is defined as ratio of shoot dry biomass of a specific treatment to the maximum values of dry biomass among all treatments (Signal, 2007). The DBC of three metals in plants varied in order of Pb < Ni < Cd (Table 3). The largest DBC for metals were 0.88, 0.84 and 0.62 for Cd, Ni and Pb, respectively.

The ANOVA analysis was used for comparison of data extracted from different treatments with control. The significant differences ($p<0.05$) for biomass production among the treatments are shown in Tables 2 and 3. A reverse relationship was found between heavy metal concentration in treatment and biomass production of selected plants. The least values of shoot and root dry biomass occurred for Wild mustard in treatments of Cd, Pb and Ni. Shoot biomass of Wild mustard and Broad bean decreased significantly at all treatments, whereas root biomass decreased significantly only for Wild mustard as compared to those grown in untreated soil (Table 2).

Effects of treatments on heavy metal concentration in shoot and root of plants

Pb concentrations in roots are significantly higher in Broad bean versus Wild mustard. As shown in Table 4, exposed Broad bean and Wild mustard metal concentration were higher in roots versus shoots ($P<0.05$). Direct relation was found for each metal between concentrations added and tissue concentration during the study period (Table 4) such that with increase in levels of treated heavy metal, the concentration within shoots and roots of plants increased proportionally. Singh and Sinha (2005) reported that accumulation of Cr, Zn and Mn in all parts of *Brassica juncea* grown at increasing tannery sludge amendment ratios. Maximum Cd and Ni concentrations were found in shoots of Wild mustard, whereas for Broad bean, the maximum shoot heavy metal concentration occurred in the Pb treatments. Heavy metal uptake in plants increased with increasing heavy metal rates availability. Although, the increasing rate of Cd and Ni concentrations in roots of Broad bean was more than Wild mustard, but the absolute root Pb concentration of Broad bean were higher than that of Wild mustard. The maximum concentrations of Cd, Pb and Ni (mg kg^{-1}) in roots of Broad bean were 623, 1057 and 658.7, and the highest concentration of their heavy

Table 2. Shoot and root dry biomass of plant in different treatments (g).

Plants	Treatments[1]	́Shoot	Root
Broad bean	Cd 50	7.1[a]	2.3[a]
	Cd 100	5.2[b]	1.5[a]
	Pb 500	4.7[b]	1.7[a]
	Pb 1000	5.4[b]	1.1[a]
	Ni 250	6.7[a]	2.3[a]
	Ni 500	4.2[b]	1.8[a]
	Control	8.1[a]	2.6[a]
Wild mustard	Cd 50	2.3[c]	0.3[bc]
	Cd 100	2.0[c]	0.3[bc]
	Pb 500	3.9[b]	0.3[bc]
	Pb 1000	1.6[c]	0.1[c]
	Ni 250	2.1[c]	0.2[c]
	Ni 500	1.6[c]	0.2[c]
	Control	7.0[a]	0.8[b]

[1]-Cd50 and Cd 100 stand for 50 and 100 mg Cadmium per 1000 g dry soil, Pb500 and Pb 1000 stand for 500 and 1000 mg Lead per 1000 g dry Soil, Ni250 and Ni 500 stand for 250 and 500 mg Nickel per 1000 g dry soil and C stand for Control; [a] Different letters indicates significant differences between different treatments (p<0.05) according to LSD test.

Table 3. Dry biomass (DB) and dry biomass coefficient (DBC) of plants in different treatments.

Plants	Treatments	DB(g)	DBC
Broad bean	Cd 100	6.7[b]	0.63
	Pb 500	6.6[b]	0.62
	Pb 1000	6.4[b]	0.60
	Ni 250	9.0[a]	0.84
	Ni 500	6.0[b]	0.56
	Control	10.7[a]	1.00
Wild mustard	Cd 50	2.6[d]	0.34
	Cd 100	2.3[d]	0.30
	Pb 500	4.2[c]	0.54
	Pb 1000	1.7[d]	0.22
	Ni 250	2.3[d]	0.29
	Ni 500	1.8[d]	0.23
	Control	7.8[b]	1.00

[1]-Cd50 and Cd 100 stand for 50 and 100 mg Cadmium per 1000 g dry soil, Pb500 and Pb 1000 stand for 500 and 1000 mg Lead per 1000 g dry Soil, Ni250 and Ni 500 stand for 250 and 500 mg Nickel per 1000 g dry soil and C stand for Control; [a] Different letters indicates significant differences between different treatments (p<0.05) according to LSD test.

metals (mg kg^{-1}) in roots of Wild mustard were 456.7, 356.3 and 392, respectively. The values of heavy metals removal calculated for Wild mustard were significantly lower than Broad bean. The results showed that the metal concentrations in underground parts were generally higher than that in aboveground parts. But it is also varied considerably with plant species and the kind of metals (Liu et al., 2007). According to Peralta-Videa et al. (2004) has reported the concentration of heavy metals in shoot dry tissues of alfalfa was 1209 mg kg^{-1} for Cd, 887 mg kg^{-1} for Cu and 645 mg kg^{-1} for Zn. In these plant species, metals were preferentially accumulated in roots than in shoots as follows: Pb > Ni > Cd (Battaglia et al., 2007; Fuentes et al., 2004; Gupta et al., 2007). This result suggested the existence of different metal sequestration mechanisms in roots, which could be selectively metal, activated and preferentially induced depending on the considered plant species. Other

Table 4. Heavy metal concentration of soil and plant (mg kg^{-1}).

Plants	Treatments	Soil DTPA Extr. (HM)	Shoot (HM)	Root (HM)
Broad bean	Cd 50	40.0^{e}	13.7^{e}	516.7^{bc}
	Cd 100	74.0^{c}	28.2^{e}	623.0^{b}
	Pb 500	$390.0^{.b}$	102.0^{c}	768.7^{b}
	Pb 1000	770.3^{a}	126.7^{c}	1057^{a}
	Ni 250	42.4^{e}	60.0^{d}	410.7^{c}
	Ni 500	63.7^{d}	103.3^{c}	658.7^{b}
Wild Mustard	Cd 50	37.5^{e}	143.8^{b}	311.2^{d}
	Cd 100	75.0^{c}	314.3^{a}	456.7^{c}
	Pb 500	360.9^{b}	61.3^{d}	298.5^{d}
	Pb 1000	775.7^{a}	111.7^{c}	356.3^{d}
	Ni 250	61.0^{d}	157.0^{b}	365.0^{d}
	Ni 500	84.5^{c}	143.2^{b}	392.0^{d}

[1]-Cd50 and Cd 100 stand for 50 and 100 mg Cadmium per 1000 g dry soil, Pb500 and Pb 1000 stand for 500 and 1000 mg Lead per 1000 g dry Soil, Ni250 and Ni 500 stand for 250 and 500 mg Nickel per 1000 g dry soil and C stand for Control[,a] Different letters indicates significant differences between different treatments (p<0.05) according to LSD test.

authors have suggested that some plants could possess a mechanism which limits the translocation of metals to shoots (Antosiewicz, 1992). Now, it is well established that plant species differently responded in a metal concentration and/or exposure time manner, as already shown in pea (*Pisum sativum*) and wheat (*Triticum durum*) (Dixit et al., 2001; Milone et al., 2003). These results indicate that Broad bean might be effective in phytoextracting Lead from contaminated soils, while Wild mustard had a better potential for accumulation of Cd and Ni.

Table 4 summarizes the metal concentrations in roots and shoots of two plant selected species growing in contaminated soils. The ANOVA analysis showed significant differences in shoot and root heavy metal concentration of Broad bean and Wild mustard (P<0.05). Increasing concentration of heavy metals due to treatments led to increase in concentration of Cd, Pb and Ni in plants. In general, the metal content in plants increased with the increase in metal concentration in soil, and the metal accumulation in root was always significantly higher than that in shoots for Broad bean and Wild mustard. The roots of Broad bean from the contaminated soils showed higher Pb content (mg kg^{-1} DW) as compared to Cd and Ni.

Uptake of plants

Metal removal of potential accumulators is greatly related to the biomass production and metal concentration of areal tissues, for this purpose shoot dry biomass also was considered. In this regard, Uptake Index (UI) which is obtained by multiplying shoot dry biomass coefficient by shoot metal concentration was calculated. UI is a relative criterion having the capability of ranking the treatments based on their respective metal removal. The larger metal UI means the higher potential of metal removal. In general, UI of heavy metals in all treatment were increased with induced levels of heavy metal, except Pb treatment for Wild mustard. The largest amount of Pb and Ni in UI were obtained for Broad bean. However, maximum Cd in UI was found for Wild mustard (Figure 3). Transfer coefficients were calculated by determining the ratio of mg kg^{-1} dry weight of metal in the plant tissue to the mg kg^{-1} quantity of metal in the dried soil that the plant was grown in (TC: shoot/soil). The results showed significant (P<0.05) differences for TC of heavy metals in the selected plants, such that contamination treatment decreased metal transfer from soils to shoots of Broad bean and Wild mustard, except for Cd that had an inverse effect on Wild mustard (Figure 2).

In general, heavy metal accumulation was more in roots than shoots under treating heavy metal contamination. The translocation factor (TF) indicated the plant's ability to translocate heavy metals from the roots to the harvestable aerial part (Mattina et al., 2003). It was calculated on a dry weight basis by dividing the metal concentration in shoot by the metal concentration in root. TF values of more than 1 suggested that heavy metals readily transported from roots to shoots, whereas, values less than 1 signify more accumulation of heavy metals in root. In the present study, TF values for all the treatments were less than 1 indicating high accumulation of heavy metals in roots which may be due to complexation of heavy metals with the sulphydryl groups in the root cells. Singh et al. (2004) also showed similar conclusion in their research. Cd, Pb and Ni shoot/root (TF) ratios of Wild mustard were significantly greater than Broad bean in all treatments (Figure 1), that shows less resistance in

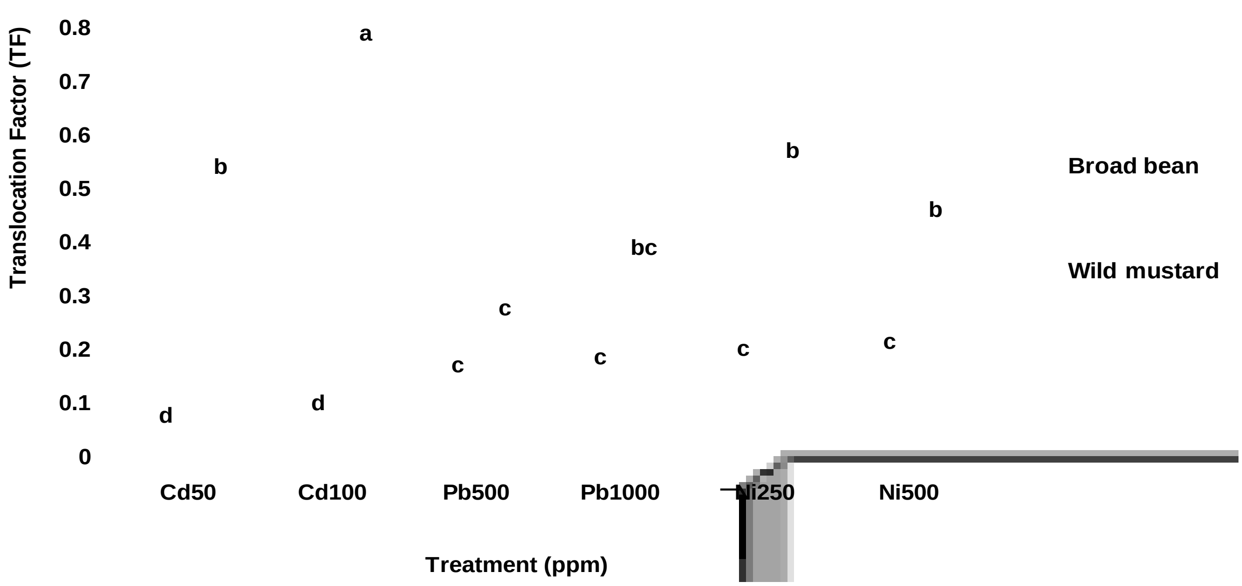

Figure 1. The TF average of Cd, Pb and Ni of Wild mustard and Broad bean.

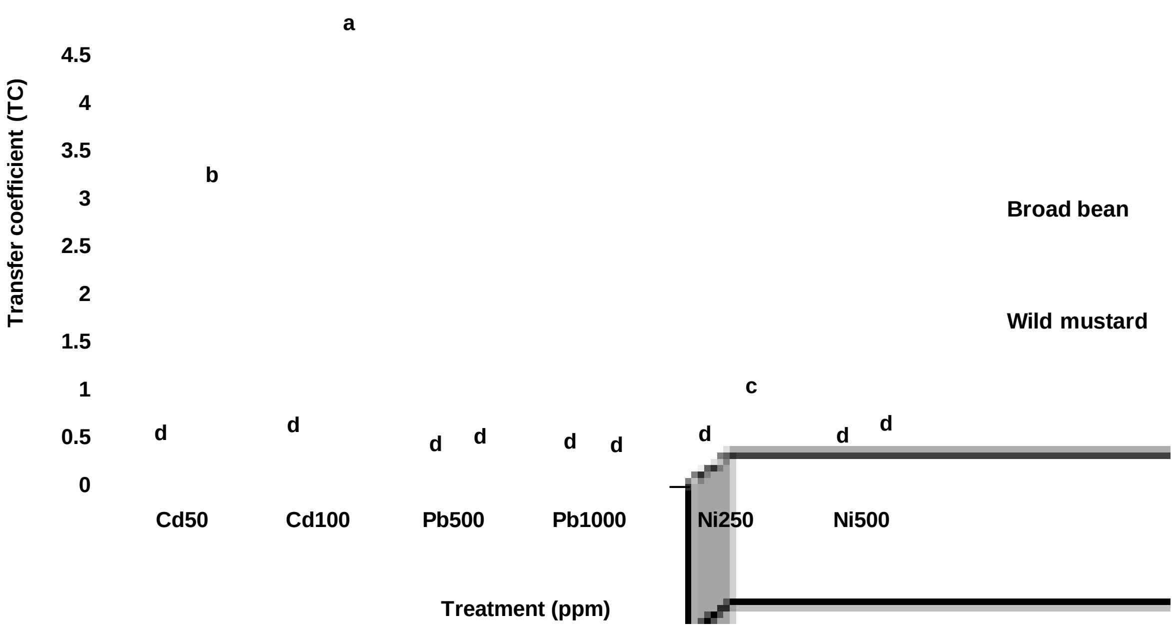

Figure 2. The TC average of Cd, Pb and Ni of Wild mustard and Broad bean.

translocation of heavy metals from root toward shoots in Wild mustard. The TF of Cd and Ni in Wild mustard were greater than TF of Pb, although, Pb and Ni of TF in Broad bean were greater than TF of Cd. Gupta et al. (2007) findings was also in agreement with this suggestion. Metal translocation from roots to shoots were differently affected by contamination in Broad bean and Wild mustard (Figure 1), such that contamination treatment decreased metal translocation from roots to shoots of Broad bean, while it had an inverse effect on Wild mustard. Zheng et al. (2007) also reported similar findings in their work.

Toxicity symptoms

Toxicity symptoms (For example, discoloration, pigmentation, yellowing and stunting) were assessed by eye throughout the experiment, with observation on two main plant species. The presence of Cd^{2+} in the medium

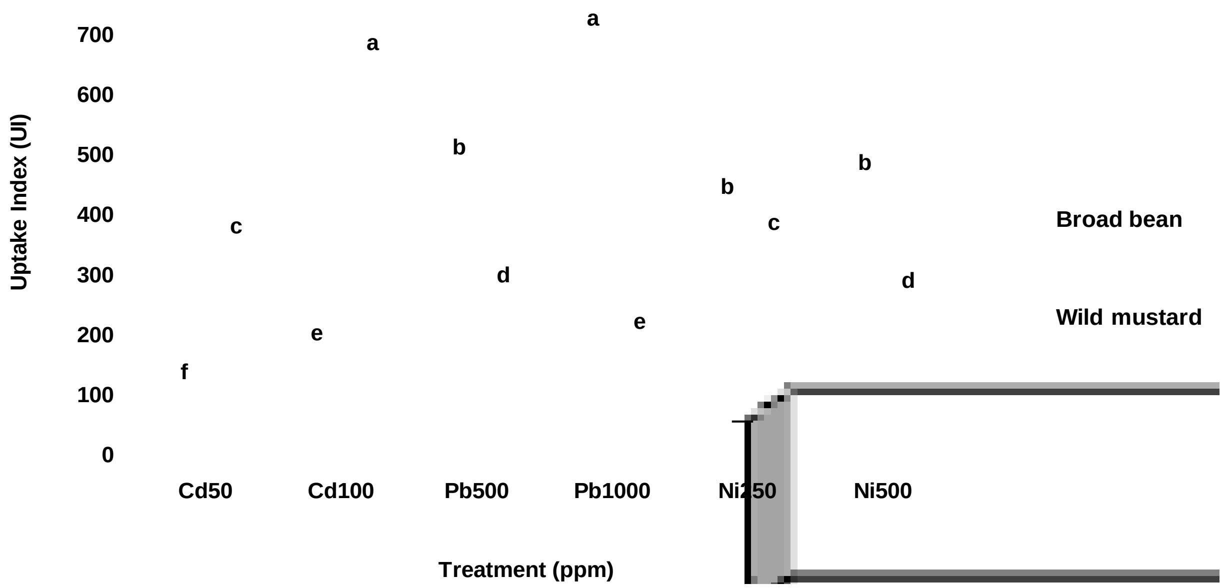

Figure 3. The UI average of Cd, Pb and Ni of Wild mustard and Broad bean.

results in symptoms of direct toxicity in leaves, such as chlorosis and necrosis probably due to accumulation of Cd^{2+} in leaf tissues (Ghanaya et al., 2007). Another consequence of the presence of Cd^{2+} in the medium is growth inhibition (Sarma, 2011). Cd is reported to damage the photosynthetic apparatus, decrease chlorophyll content and inhibit the stomatal regulation. The major storage site for Zn and Cd in plants is cell wall of roots, vacuoles of epidermis and bundle sheet of leaves (Sarma, 2011). One of the main pathways of Lead to enter the plant is through the roots by crossing the cell's plasma membranes via voltage gated calcium ion channels. This may inhibit calcium uptake through competition for the ion channels. In general, the tendency of translocation of Lead from root toward shoot is low and Lead tends to be sequestered in the root cells. Furthermore, Pb toxicity symptoms of Pb may appear in the form of growth inhibition. Symptoms of Ni toxicity reduce plant growth and chlorotic symptoms (Everhart et al., 2006).

Conclusion

A suitable plant for phytoremediation should possess the following characteristics: 1) ability to accumulate metals preferably in the aerial parts; 2) tolerance to metal concentration accumulated, 3) fast growth and high biomass; 4) wide spread highly branched root system; 5) easy harvest ability (Eapen and Souzan, 2005). In this regard, plant species, type of metals and soil metal concentration determine the phytoextraction potential. As evident in our study, the Wild mustard could be very effective in phytoextraction of Cd from modestly contaminated soils with heavy metals. These results confirmed that Wild mustard is a hyper-accumulator Cd which grows moderately, and has substantial biomass, wide distribution and a potential for the phytoremediation of metal contaminated soils. A plant recognized as Cd hyper-accumulator, should have a concentration of more than 100 ppm of the metal in its shoot (Lasat, 2002). In particular, in our experimental conditions, we verified a metal removal which appeared to be consistent with the results reported by Clemente et al. (2005) and Arduini (2006). There is great potential for using Broad bean in the remediation of Pb contaminated soil. In addition, this species has a strong tolerance to Pb growing normally on higher Lead concentration medium (Shen et al., 2004). These results are in accordance with the report of Gupta et al. (2007) about metals accumulation in the *Phaseolus vulgaris*. In particular, Broad bean compensated lower metal content in shoots with higher biomass production when compared to hyper-accumulators, which have higher element content but lower aboveground biomass resulting in similar remediation capability.

Our studies in pots clearly demonstrated that Wild mustard and Broad bean have an unusual ability not only to accumulate Cd and Ni in its roots but also to translocate it to the harvestable parts. Besides this, Broad bean highlights as a plant species that could be useful in phytoremediation of soils contaminated with Pb. Uptake index (UI) is a criterion that reflects both the amount of shoot metal concentration (aerial part) and biomass production. As such, UI is a suitable coefficient for comparing the ability of metal phytoextraction in studied plants (Wild mustard and Broad bean). Based on UI, it could be suggested that Broad bean was suitable for Nickel and Lead removal from a contaminated soil where Wild mustard had a better potential for Cadmium phytoextraction.

ACKNOWLEDGEMENTS

This work was a part of MS dissertation at the Department of Soil Science, Ahvaz University. We are grateful to Dr. A. Aieneband and laboratory technician, Mr. Kajbaf for their valuable help. The contribution of the reviewers is also appreciated.

REFERENCES

Ahmad K, Ejaz A, Azam M, Iqbal KZ, Ashraf M, Quraing FA, Fardous A, Gondal S, Bayat A, Elahi VE (2011). Lead, cadmium and chromium contents of canola irrigated with sewage water. Pak. J. Bot., 43(2): 1403-1410.

Allen SE, Grimshaw HM, Rowland AP (1986). Chemical analysis. In: Moore, P.D., Chapman, S.B. (Eds.), Methods in plant Ecology. Blackwell Scientific Publication, Oxford, London, pp. 285-344.

Allison FA (1973). Soil Organic Matter and Its Role in Crop Production. Elsievier, Amsterdam.

Antosiewicz DM (1992). Adaptation of plants to an environment polluted with heavy metals. Acta Societatis Botanicorum Poloniae, 61: 271-299.

Arduini I, Ercoli L, Mariotti M, Masoni A (2006). Response of miscanthus to toxic cadmium applications during the period of maximum growth. Environ. Exp. Bot., 55: 29-40.

Barcelo J, Poschenrider C (2003). Phytoremediation: principles and perspectives. Contributions to Sci., 2(3): 333-344.

Battaglia A, Nardi E, Petroino C, Pietroletti BM (2007). Reduction of Pb and Zn bioavilable forms in metal polluted soils due to paper mill sludge addition effects on Pb and Zn transferability to barely. Bioresour. Technol., 98: 2993-2999.

Bidar G, Garcon G, Pruvot C, Dewaele D, Cazier F, Douay F, Shirali P (2007). Behavior of *Trifolium repens* and *Lolium perenne* growing in a heavy metal contaminated field: plant metal concentration and phytotoxicity. Environ. Pollut., 147: 546-553.

Caraiman C, Macoveanu PM (2011). Decontamination of polluted soil with cadmium and zinc using greenhouse phytoremediation. Environ. Eng. Manag. J., 10(3): 349-355.

Chaoui A, Ferjani E (2005). Effects of cadmium and copper on an antioxidant capacities, lignification and auxin degradation in leaves of pea (*Pisum sativum L.*) seedlings. C.R. Biol., 328: 21-31.

Clemenet RD, Walker J, Pilar Bernal M (2005). Uptake of heavy metals and as by Brassica Juncea grown in a contaminated soil in Spain: The effect of soil amendments. Environ. Pollut., 138: 46-58.

Day PR (1965). Particle Fractionation and Particle Size Analysis. In C.A. Black (ed.), Method of Soil Analysis Part 1. American Society of Agronomy, Madison, Wisconsin, USA, pp. 545-565.

Dixit V, Pandey V, Shyam R (2001). Differential antioxidative responses to cadmium in roots and leaves of pea (*Pisum sativum L.cv.Azad*). J. Exper. Bot., 52(358): 1101-1109.

Dushenkov D (2003). Trends in phytoremediation of radionuclides. Plant Soil, 249: 167-175.

Eapen S, Souzan SFD (2005). Prospects of genetic engineering of plants for phytoremediation of toxic metals. Biotechnol. Adv., 23: 97-114.

Ederli L, Reale L, Ferranti F, Pasqualini S (2004). Responses induced by high concentration of cadmium in *Phragmites anstralis* roots. Plant Physiol., 121: 66-74.

Everhart JL, Mc Near JR, Peltier D, Vander E, Lilie D (2006). Assessing nickel bioavailability in smelter-contaminated soils. Sci. Total Environ., 367: 732-744.

Fuentes A, Llorens M, Saez J, Mesequer VF (2004). Phytotoxicity and heavy metals speciation of stabilized sewage sludeges. J. Hazardous Mat., 108: 161-169.

Gardea-Tottesdey JL, Peralta-Videa JR, de la Rosa G, Parsons JG (2005). Phytoremediation of heavy metals and study of the metal coordination by X-ray absorption spectroscopy. Coordination Chem. Rev., 249(17-18): 1797-1810.

Ghanaya T, Slama I, Messedi D, Grignon C, Abdelly C (2007). Effects of Cd^{+2} on K^{+}, Cu^{+2} and N uptake in two halophytes *Sesuvium portulacastrum* and *Mesembry anthemum* crystallinum: Consequences on growth. Chemosphere, 67: 72-79.

Gupta AK, Dwivedi S, Sinha S, Tripthi RD, Rai UN, Singh SN (2007). Metal accumulation and growth performance of Phaseolus vulgaris grown in fly ash amended soil. Broresource Technol., pp. 1-4.

Karami A, Zulkifili Hj S (2010). Phytoremediation of heavy metals with several efficiency enhancer methods. Afr. J. Biotechnol., 9(25): 3689-3698.

Kramer U (2010). Metal hyperaccumulation in plants. Ann. Rev. Plant Biol., 61: 517-534.

Lasat MM (2000). Phytoextraction of metals from contaminated soil: a review of plant/soil/metal interaction and assessment of pertinent agronomic issues. J. Hazard. Subst. Res., 2: 1-25.

Lasat MM (2002). Phytoextraction of toxic metals: a review of biological mechanisms. J. Environ. Qual., 31: 109-120.

Lindsay WL, Norvell WA (1978). Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Liu J, Dong Y, Xu H, Wang D, Xu J (2007). Accumulation of Cd, Pb and Zn by 19 wetland plant species in constructed wetland. J. Hazardous Mat., pp. 1-7.

Marchiol L, Assolari S, Sacco P, Zerbi G (2004). Phytoextraction of heavy metals by canola (*Brassica napus*) and radish (*Raphanus sativus*) grown on multicontaminated soil. Environ. Pollut., 132: 21-27.

Mattina MJI, Lannucci-Berger W, Musante C, White JC (2003). Concurrent plant uptake of heavy metals and persistent organic pollutants from soil. Environ. Pollut., 124: 375-378.

Meers E, Vandecasteele B, Ruttens A, Vangronsveld J, Tack FMG (2007). Potential of five willow species (*Salix* spp.) for phytoextraction of heavy metals. Environ. Exp. Bot., 60: 57-68.

Milone MT, Sgherri C, Clijsters H, Navarilzzo F (2003). Antioxidative responses of wheat treated with realistic concentration of cadmium. Environ. Exper. Bot., 50(3): 265-276.

Nwoko OC (2010). Trends in phytoremediation of toxic elemental and organic pollutants. Afr. J. Biotechnol., 9(37): 6010-6016.

Pas JI, Jones W (2000). The handbook of trace element. ST. Lucie press Bocarton, Florida.

Peralta -Videa JR, de la Rosa G, Gonzalez JH, Gardea – Torresdey JL (2004). Effects of the growth stage on the heavy metal tolerance of alfalfa plants Adv. Environ. Res., 8: 679-685.

Piechalak A, Tomaszewska B, Baralikiewicz D, Malecka A (2002). Accumulation and detoxification of lead ions in legumes. Phytochemistry, 60: 153-162.

Sarma H (2011). Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. J. Environ. Sci. Technol., 4(2): 118-138.

Shen WS, Cao XZ, Jin Y (2004). Ecological Destruction and Reconstruction of Minelands. China Environmental Science Press, Beijing (in chinese).

Shen ZG, Zhao FJ, McGrath SP (1997). Uptake and Transport of Zinc in the Hyperaccumulator *Thlaspi caerulescens* and Nonhyperaccumulator *Thlaspi ochroleucum*. Plant Cell Environ., 20: 898-906.

Singh S, Sinha S (2004). Scanning electron microscopic studies and growth response of the plant of *Helianthus annus* L. grown on tannery sludge amended soil. Environ. Int., 30: 389-395.

Singh S, Sinha S (2005). Accumulation of metals and its effects in *Brassica juncea* (L.) Czern. (cv. Rohini) grown on various amendments of tannery waste. Ecotoxicol. Environ. Safety, 62: 118-127.

Singh RP, Agrawal M (2007). Effects of sewage sludge amendment on heavy metal accumulation and consequent responses of Beta vulgaris plants. Chemosphere, 67: 2229-2240.

Soil Survey Staff (2003). Keys of Soil Taxonomy. United States Department of Agriculture, Natural Resources Conservation Service, 9th edition.

Soils-Dominguez FA, Gonza'lez-Cha'vez MC, Carrillo-Gonza'lez R, Rodriguez-Va'zquez R (2007). Accumulation and localization of cadmium in *Echinochloa polystachya* grown within a hydroponic system. J. Hazardous Mat., 141: 630-636.
Sparks DL, editor. Methods of soil analysis: chemical method. SSSA, Madison, WI: SSSA Book Series: 1996.
Wang F, Lin X, Yin R (2005). Heavy metal uptake by arbuscular mycorrhizas of Elsholtzia splendens and the potential for phytoremediation of contaminated soil. Plant Soil, 269: 225-232.
Walkley A, Black CA (1934). An Examination of the Degtareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci., 37: 29--38.
Wenger K, Gupta SK, Furrer G, Schulin R (20020. Zinc Extraction Potential of Two Common Crop Plants, *Nicotiana tabacum* and *Zea mays*. Plant Soil, 242: 217-225.
Wuana RA, Okieimen FE (2010). Phytoremediation potential of maize (*Zea mays* L.). review. Afr. J. Gen. Agric., 6(4): 275-287.
Yanai J, Zhao F, Mc Grath S, Kosaki T (2006). Effects of soil characteristics in Cd uptake by the hyperaccumulator *Thlaspi caerulescens* Hance. Environ. Pollut., 139: 167-175.
Yoon J, Cao X, Zhou Q, Q.Ma L (2006). Accumulation of Pb, Cu and Zn in native plants growing on contaminated florida site. Sci. Total Environ., 368: 456-464.
Zheng N, Wang Q, Zheng D (2007). Health risk of Hg, Pb, Cd, Zn and Cu to the inhibitants around Huludo zinc plant in china via consumption of vegetables. Sci. Total Environ., pp. 1-9.