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HEAVY METAL CONTAMINATION AND ACCUMULATION IN SOIL AND WILD PLANT SPECIES FROM INDUSTRIAL AREA OF ISLAMABAD, PAKISTAN

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Abstract

This study was designed to assess total contents of 6 toxic metals viz., Pb, Cu, Zn, Co, Ni, and Cr in the soil and plant samples of 16 plant species collected from industrial zone of Islamabad, Pakistan. The concentration, transfer and accumulation of metals from soil to roots and shoots was evaluated in terms of Biological Concentration Factor (BCF), Translocation Factor (TF) and Bioaccumulation Coefficient (BAC). Total metal concentrations of Pb, Zn, Cu, Co, Ni, and Cr in soils varied between 2.0-29.0, 61.9-172.6, 8.9 to 357.4, 7.3-24.7, 41.4-59.3, and 40.2-927.2 mg/kg. Total metal concentrations pattern in roots were: Cu>Cr>Zn>Ni>Pb>Co. Grasses showed relatively higher total Zn concentration. Accumulation of Cu was highest in shoots followed by Zn, Cr, Pb, Co and Ni. None of plant species were identified as hyperaccumulator; however, based on BCFs, TFs, and BACs values, most of the studied species have potential for phytostabilization and phytoextraction. *Parthenium hysterophoirus* L., and *Amaranthus viridis* L., is suggested for phytoextraction of Pb and Ni, whereas, *Partulaca oleracea* L., *Brachiaria reptans* (L.) Gard. & Hubb., *Solanum nigrum* L., and *Xanthium stromarium* L., for phytostabilization of soils contaminated with Pb and Cu.

Introduction

Phytoremediation is one of the promising methods for reclamation of soils contaminated with toxic metals by using hyperaccumulator plants (Baker *et al*., 2000; Ghosh & Singh, 2005; La'zaro *et al.*, 2006). More than 400 plant species belonging to 45 plant families have been identified and reported from temperate to tropical regions with the ability to tolerate and hyperaccumulate trace elements (Baker & Brooks, 1989). These plants have been considered suitable for soil stabilization and extraction of heavy metals (Madejon *et al*., 2002). Hyperaccumulator plants can play a key role in the fate of the pollutants of contaminated matrixes *via* their root systems.

The use of plant species to decontaminate and remediate polluted soils with heavy metals is non-existence in Pakistan. Transfer of toxic elements from soils to plants in industrial areas is of great concern (Malik & Hussain 2006). To our knowledge there has not been any study that has identified heavy metal accumulator or tolerant plant species from contaminated soils. In this study, 16 plant species belonging to 11 families were investigated for metals such as lead, zinc, nickel, copper, cobalt and chromium from industrial zone of Islamabad. The aim of the present study was to assess the total metal concentration of selected metals in the soils and plant samples. Species which have the potential for phytoremediation process such as phytostabilization and phytoextraction were also identified.

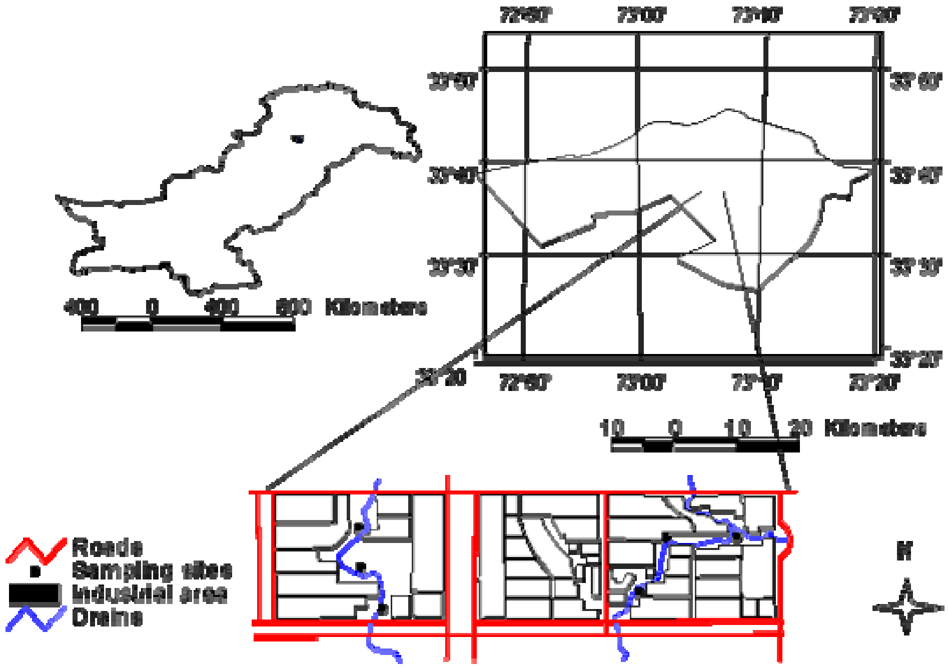

Fig. 1. Location of study showing study site.

Materials and Methods

Industrial zone of Islamabad city, the capital of Pakistan was established in 1963 and lies between 33°-28' and 33°-58' north latitude and 72°–48' and 73°–22' east longitude at an elevation of 480-550m (a.s.l). It houses more than 200 different industrial units which spreads over 625 acres of land. Plants growing in the nearby zone of industrial areas along various industrial units exhibiting increased concentrations of heavy metals, serving in many cases as biomonitors/accumulators of pollution load. Six sites were selected for the collection of plant and soil samples (Fig. 1).

Plant species collected were the most common/dominant species at these sites. A total of 16 species such as *Amaranthus viridis* L., *Brachiaria reptans* (L.) Gard. & Hubb., *Cannabis sativa* L., *Cenchrus pennisetiformis* Hochst. and Steud. ex Steud., *Chenopodium album* L., *Cynodon dactylon* (L.) Pers., *Cyprus rotundus* L., *Dactyloctenium aegyptium* (L.) P. Beauv., *Elusine indica* (L.) Gaerth., *Ipomoea hederacea* Jacq., *Malvastrum coromandelianum* (Linn.) Garcke., *Parthenium hysterophoirus* L., *Partulaca oleracea* L., *Ricinus communis* L**.,** *Solanum nigrum* L., and *Xanthium stromarium* L., were collected in August and September in 2006. A total of 6-10 plant samples including roots, stems and leaves of each species were collected from each site and mixed to form a composite sample, placed in labelled bags and transported to Environmental Biology Laboratory for further analysis. Before analysis, from each plant roots and mixture of stems and leaves were carefully removed and washed (for 2-3 minutes approximately) with tap water and with deionized water (Behropur B25) to remove any soil and surface dust. Plant samples were dried at room temperature for two weeks, pulverized and passed through 2mm stainless steel sieve. Soil samples (3–5 replicates), at 0–20 cm depth from rhizosphere of each plant, were taken from each site from where plant sample was rooted. Soil samples (a composite mixture) were air dried at room temperature for two weeks, crushed and pulverised to pass through 2-mm sieve. For each soil sample, soil pH, TDS, EC, texture and heavy metals viz., Pb, Cu, Zn, Co, Ni and Cr were measured. Soil pH was determined using portable pH meter (Thermo Orien 240A) in a 1:2.5 soil–water suspension. Total Dissolved Solids and EC was measured using conductivity meter (Hi 8033 Hanna Hungry). The proportion of percent sand, silt and clay of the soil samples were calculated to determine soil textural class using Bouycous hydrometer method. Acid digests of each soil sample were prepared using USEPA 3051A (1998) method. Digestion of soil samples were carried out by nitric acid (69% purity) and hydrochloric acid (28% purity). Soil sample measuring 0.5g (10: 3v/v) and 2 g (10:3-5, v/v) of plant sample was digested in a mixture of concentrated nitric acid and hydrochloric acid for 30 minutes using Microwave Accelerated Reaction System (MARS, CEM®). Soil and plant sample digests were used to measure total concentration of Pb, Cu, Zn, Co, Ni and Cr using a Fast Sequential Atomic Absorption Spectrometer (Varian 240AA FS). Standard Reference Material (SRM) of National Institute and Technology (NIST, 2709 San Joaquin Soil and 1547Peach leaves) and internal reference materials were used for precision, quality assurance and control (QA/QC) for selected metal measurements. Average values of three replicates were taken for each determination. The precision of analytical procedures was expressed as Relative Standard Deviation (RSD) which ranged from 5-10% and was calculated from the standard deviation divided by the mean. The recovery rates of studied metals were within 90±10%. Chemicals, stock solutions and reagents were obtained from Sigma/Fluka/Merck and were of analytical grade. All glassware before use were washed with distilled water, soaked in nitric acid (30%) overnight, rinsed in deionized water and air-dried.

Biological Concentration Factor (BCF) was calculated as metal concentration ratio of plant roots to soil given in equation 1 (Yoon *et al*., 2006). Translocation Factor (TF) was described as ratio of heavy metals in plant shoot to that in plant root given in equation 2 (Cui *et al*., 2007; Li *et al*., 2007). Biological Accumulation Coefficient (BAC) was calculated as ratio of heavy metal in shoots to that in soil given in equation 3 (Li *et al*., 2007; Cui *et al*., 2007).

$$\text{BCF} = [Metals]_{root} \big/ [Metals]_{soil} \quad (1)$$

$$\text{TF} = [Metals]_{shoot} \big/ [Metals]_{root} \quad (2)$$

$$\text{BAC} = [Metals]_{shoot} \big/ [Metals]_{soil} \quad (3)$$

Results

Site 1 was sandy loam with pH of 8.4, EC of 1.8 mS/cm and TDS 120 ppm. Soil of three sites viz., 2, 5 and 6 was loamy sand and was a dominant soil texture class with pH varied from 7.8-8.5, EC ranged between 0.11-0.12 mS/cm and TDS varied between 70-80 ppm. Sites 3 and 4 were characterised by sandy clay loam, the second dominant soil texture class with average pH of 8.45, EC 0.09 mS/cm and TDS 60 ppm. Higher concentration of Zn was found at site 4 followed by site 3 and site 1. Maximum contents of Cr was present at site 1 which was 927.2 (mg/kg) and minimum concentration was observed at site 5 (40.24 mg/kg). Total Pb concentration varied from 2.0–29.0 (mg/kg) whereas Co contents ranged from 7.26-24.73 (mg/kg) at site 2 and 3 respectively. Total concentration of Cu was found between 8.88-357.40 mg/kg at site 3 and 2. Maximum total content of Ni was recorded at site 2 (57.5 mg/kg) and minimum at site 4 (41.4 mg/kg).

Total concentration of selected metals in plants roots and shoots is given in Table 1. In plant roots, the Cu total concentration was highest in *C. pennisetiformis* (416.9 mg/kg) and lowest in *D. aegyptium* (7.5 mg/kg). In general total Cu concentrations in all plant samples were greater in roots than shoots. Total Pb concentration in roots ranged between 1.0 mg/kg and 43.0 mg/kg in *P. hysterophoirus* and *A. viridis* whereas Zn total concentration varied between 18.5 mg/kg in *M. coromandelianum* and 135.1 mg/kg in *A. viridis*. Among plant species with higher Zn concentration, grasses showed relatively higher contents. Highest concentration was found in *E. indica* (117.9 mg/kg) followed by *C. pennisetiformis* (113.7 mg/kg), *D. aegyptium* (112.2 mg/kg) and *C. dactylon* (52.2 mg/kg), respectively. Total Co contents in roots varied between 7.1 mg/kg in *E. indica* and 39.5 mg/kg in *P. oleracea*. Similarly, *C. rotundus* also had higher concentration of Co in roots. Cr concentration varied between 8.8 mg/kg in *A. viridis* and 184.3 mg/kg in *C. pennisetiformis*. In addition to *C. pennisetiformis*, *R. communis* also contained higher concentration of Cr.

The results indicated that accumulation of Pb, Cu, Zn, Ni, Co and Cr in none of the shoots of the plant species studied was more than 1000 mg/kg, however, it varied greatly among plants species and from different sites. Total Cu concentration in shoots varied significantly between plant species. Minimum contents were found in *C. rotundus* (3.4 mg/kg) and maximum in *P. oleracea* (171.8 mg/kg). Total Zn contents ranged between 17.3 mg/kg and 135.3 mg/kg in *M. coromandelianum* and *A. viridis,* respectively whereas *S. nigrum* and *P. oleracea* had minimum of 11.0 mg/kg and *C. dactylon* had maximum of 41.0 mg/kg of Pb concentration in their shoots. Total concentration of Ni, Co and Cr ranged between 6.2-18.3 mg/kg, 9.5–24.6 mg/kg and 2.1–76.9 mg/kg, respectively.

Most of plant species had BCF or TF>1, although the concentration of heavy metals remained below 1000 mg/kg. In general, BCF values of Cu and Pb was highest as compared to other metals (Table 2). The BCF values of *P. oleracea*, *S. nigrum* and *X. stromarium* was highest for Cu (25.4, 14.8 and 14.2) and *B. reptans* for Pb (18.5). *A. viridis*, *C. sativa*, *C. album*, *C. dactylon*, *D. aegyptium*, *M. coromandelianum* had BCF>1 for Pb and *I. hederacea*, *P. oleracea*, and *X. stromarium* had BCF >1 only for Cu. *C. rotundus* had BCF>1 for Zn and Pb (1.2 and 2.5). *B. reptans*, *C. pennisetiformis*, *E. indica* and *S. nigrum* had BCF>1 for three heavy metals (Pb, Cu and Zn). *B. reptans* had BCF values of 1.3, 2.2 and 18.5 for Cu, Zn and Pb, *C. pennisetiformis* had BCF values of 1.0, 1.2, and 1.3 for Zn, Cu and Pb, and *S. nigrum* had BCF values of 1.0, 1.7 and 14.8. None of plant species had BCF >1 for Ni, Cu and Cr, respectively.

Among the plant species screened for Pb, Cu, Zn, Ni, Co and Cr, most of the species were efficient to take up and translocate more that one heavy metal from roots to shoots (Table 2). Variations between TF values were found (Table 2). The highest TF value was found for *P. hysterophoirus* and *A. viridis* were 23.0 for Pb and 20.7 for Ni. *P. hysterophoirus* was efficient in translocateing metals such as Pb, Cu, Ni, Zn, Cr, and Cu from roots to shoots at site 1 and 2. *P. oleracea* had translocated metals such as Pb, Zn, Ni, and Co. *A. viridis* showed TF>1 for Pb, Zn, Ni, Co and Cr. Plant species such as *B. reptans, C. sativa, C. pennisetiformis, C. album, I. hederacea*, *M. coromandelianum* and *R. communis* and X. stromarium showed TF>1 for Zn and Cr, Pb and Zn, Pb and Co, Zn and Co, Pb and Ni, Co and Cr, and Pb and Ni respectively. *C. dactylon*, *C. rotundus*, *D. aegyptium*, *E. indica* and *S. nigrum* also showed TF>1 for one metal (Table 2).

Table 1. Total heavy metals concentration (mg/kg) in roots and shoots of plant species.

Scientific name	Site #	Root Pb	Shoot Pb	Root Cu	Shoot Cu	Root Zn	Shoot Zn	Root Ni	Shoot Ni	Root Co	Shoot Co	Root Cr	Shoot Cr
Amaranthus viridis L.	1	43.0	15.0	18.5	13.4	29.2	50.1	0.5	9.7	12.5	14.9	8.8	21.2
	2	8.0	39.0	45.2	8.9	39.7	63.2	8.1	8.0	26.7	22.9	28.8	15.9
Brachiaria reptans (L.) Gard. & Hubb.	5	37.0	28.0	40.2	8.6	135.1	135.3	24.1	16.7	30.1	24.2	17.9	21.7
Cannabis sativa L.	1	29.0	30.0	29.0	18.2	27.0	43.9	13.6	11.3	24.7	14.8	29.7	14.5
Cenchrus pennisetiformis L. Hochst. and Steud.ex Steud	1	23.0	28.0	41.8	11.8	90.5	54.8	14.5	10.6	9.3	22.2	52.6	42.3
	2	38.0	16.0	416.9	64.1	113.7	95.8	46.6	13.4	26.7	23.3	184.3	46.7
Chenopodium album L.	2	32.0	32.0	13.9	5.1	24.9	33.5	7.2	6.7	9.6	9.7	10.5	2.1
Cynodon dactylon (L.) Pers.	4	18.0	41.0	159.4	8.3	52.2	35.5	10.1	6.6	29.3	9.5	27.6	11.2
Cyprus rotundus L.	6	33.0	20.0	23.6	3.4	73.3	36.3	27.5	16.4	34.3	24.1	16.5	21.0
Dactyloctenium aegyptium (L.) P. Beauv.	1	29.0	20.0	7.5	6.7	112.2	93.2	16.5	6.4	9.4	10.3	44.6	11.8
Elusine indica (L.) Gaerth	6	42.0	18.0	37.9	12.9	117.9	74.7	20.6	12.2	7.1	20.1	25.8	23.7
Ipomea hederacea Jacq.	3	9.0	15.0	19.8	17.0	61.4	39.6	7.8	8.2	22.3	16.8	14.3	9.2
Malvestrum coromandialinum (Linn.) Garcke	1	37.0	16.0	23.2	13.6	18.5	17.3	7.8	11.2	8.5	14.9	18.5	49.7
	2	32.0	27.0	23.2	16.1	45.8	38.5	12.2	9.1	9.6	24.6	18.1	17.8
Parthenium hysterophoirus L.	1	13.0	36.0	59.3	111.6	29.2	70.9	7.0	18.2	29.0	19.2	34.2	76.9
	2	1.0	23.0	59.3	38.5	21.3	34.6	5.6	13.1	26.0	21.3	31.7	32.7
Partulaca oleracea L.	2	10.0	11.0	190.7	171.8	26.5	26.5	2.1	6.2	8.3	20.2	26.4	14.9
	3	8.0	19.0	225.7	35.5	28.6	28.6	2.2	9.5	39.5	17.6	18.8	9.8
Ricinus communis L.	2	19.0	20.0	171.7	15.7	109.8	47.9	11.5	11.6	27.2	17.2	56.3	14.2
Solanum nigrum L.	3	20.0	11.0	131.3	22.4	134.4	50.6	7.8	8.0	18.5	15.8	81.2	8.9
Xanthium stromarium L.	3	8.0	21.0	126.3	15.4	66.2	28.3	5.5	10.9	28.4	18.4	25.9	10.1

Table 2. Translocation factor (TF), biological concentration factor (BCF) and biological accumulation coefficient (BAC) of plant species of selected metals.

Scientific name	Sites	TF_{Pb}	TF_{Cu}	TF_{Zn}	TF_{Ni}	TF_{Co}	TF_{Cr}	BCF_{Pb}	BCF_{Cu}	BCF_{Zn}	BAC_{Pb}	BAC_{Cu}	BAC_{Zn}	BAC_{Co}
Amaranthus viridis L.	1				**20.7**	1.2	2.4	2.0						1.1
	2	4.9		1.6	1.0						1.3			3.1
Brachiaria reptans (L.) Gard. & Hubb.	5			1.0			1.2	**18.5**	1.3	2.2	**14.0**		2.2	1.2
Canabis sativa L.	1	1.0		1.6				1.4			1.4			1.1
Cenchrus pennisetiformis Hochst. and Steud.ex Steud	1	1.2				2.4		1.1			1.3			1.7
	2							1.3	1.2	1.0				3.2
Chenopodium album L.	2			1.3		1.0		1.1			1.1			1.3
Cynodon dactylon (L.) Pers.	4	2.3						2.0			4.6			
Cyprus rotundus L.	6						1.3	2.5		1.2	1.5			1.3
Dactyloctenium aegyptium (L.) P. Beauv.	1					1.1		1.4			1.0			
Elusine indica (L.) Gaerth.	6					2.8		3.2	1.6	1.9	1.4		1.2	1.1
Ipomea hederacea Jacq.	3	1.7			1.1				2.2		1.3	1.9		
Malvestrum coromandialinum (Linn.) Garcke	1				1.4	1.7	2.7	1.8						1.1
	2					2.6	1.0	1.1						3.4
Parthenium hysterophoirus L.	1	2.8	1.9	2.4	2.6		2.2				1.7			1.4
	2	**23.0**		1.6	2.3		1.0							2.9
Partulaca oleracea L.	2	1.1		1.0	2.9	2.4								2.8
	3	2.4		1.0	4.4				**25.4**		1.6	4.0		
Ricinus communis L.	2	1.1			1.0									2.4
Solanum nigrum L.	3				1.0			1.7	**14.8**	1.0		2.5		
Xanthium stromarium L.	3	2.6			2.0				**14.2**		1.8	1.7		

Very high TF, BCF and BAC values are highlighted Bold. None of the species had BCF for Ni, Co and Cr >1 and BAC for Ni and Cr >1.

Table 2 indicated the all plant species screened for total metal concentration showed value of BAF>1 for one or more heavy metals except Ni and Cr where it varied between 0.11-0.40 and 0.02-0.56. Six species such as *A. viridis*, *C. pennisetiformis*, *M. coromandelianum*, *P. hysterophoirus*, *P. oleracea* and *R. communis* had BAC>3. BAC values for Pb and Co was >1 for most of species whereas the BAC values of two species such as *B. reptans* and *E. indica* were >1 for Zn which were 2.2 and 1.2 respectively. Highest BAC value of Pb was found for *B. reptans* (14.0) and *C. dactylon* (4.6). *P. oleracea* showed highest BAC value for Cu. BAC value for Co was highest for *M. coromandelianum.*

Discussion

Accumulation of selected metals varied greatly among plants species and uptake of an element by a plant is primarily dependent on the plant species, its inherent controls, and the soil quality (Chunilall *et al*., 2005). Large number of factors control metal accumulation and bioavailability associated with soil and climatic conditions, plant genotype and agronomic management, including: active/passive transfer processes, sequestration and speciation, redox states, the type of plant root system and the response of plants to elements in relation to seasonal cycles (Kabata-Pendias & Pendias, 1984). Structure of the sediment has also been considered very important that affect the extent of the metals taken up by the plants. Clay particles also play an important role in availability of the metals. Metal solubility in soils is predominantly controlled by pH, amount of metals cations exchange capacity, organic carbon content and oxidation state of the system (Ghosh & Singh, 2005). The results indicated that soils of study area were sandy clay loam, loamy sand and sandy loam and were basic in nature with pH greater than 7.5 with low EC and TDS. Higher pH values may result in greater retention of metals and their lower solubility in the soils of study area. High soil pH can stabilize soil toxic elements, resulting in decreased leaching effects of the soils toxic elements. Moreover, toxic elements may also become stabilized due to high soil pH which may result in less element concentrations in the soil solution. This may restrain the absorbability of the elements from the soil solution and translocation into plant tissues (Liu *et al*., 2005).

The results showed that most of plant species accumulated higher concentration of Pb, Cu and Zn than normal limits in shoots. The normal level in shoots of plants for Pb, Cu and Zn as given by Zu *et al*., (2004) are 5, 10 and 100 mg/kg. Zn, Cu and Co are essential to plant growth and needed in small (micro) quantities, however, their excessive concentration in plant tissues may cause toxic symptoms. Cu concentration >40 mg/kg of dry matter could induce toxicity in plants and cause toxic effects in animals (i.e. sheep) feeding on them (Annenkov, 1982). These nutrients are vital physiologically and are important constituents of enzymes thus critical for number of plant functions and health. The availability of micronutrients to plants is dependent on many soil characteristics. Soil pH plays important role in micronutrients availability to the plants which is greatly reduced at higher pH. Thus, higher values of pH in this study played an essential role in availability of micronutrients to plants. Total concentration of Cu in shoots of *A. viridis*, *C. sativa*, *C. pennisetiformis, E. indica*, *I. hederacea*, *M. coromandelianum*, *P. hysterophoirus*, *P. oleracea*, *R. communis*, *S. nigrum* and *X. stromarium* was greater than normal limit. Cui *et al*., (2007) reported total concentration of 101.9 mg/kg and 97.0 mg/kg of Pb, 104.7 mg/ kg, 154.9 mg/kg of Zn and 27.7 mg/kg and 28.1 mg/kg of Cu in roots and shoots of *Chenopodium accuminatum* Willd. In the present study, total concentration of Cu in shoots and roots and of *C. album* were 5.1 mg/kg and 13.9 mg/kg which were lower in comparison to study of Cui *et al*., (2007) in *C. accuminatum*. Similarly, the total concentration of Pb and Zn in shoots and roots of *C. album* was also less than Cu concentration in shoots and roots of *C. accuminatum* (Cui *et al*., 2007). Plants varied widely in their tolerance and toxicity to Cu which may cause chlorosis. The availability of Cu^{+2} in soil is generally linked with soil pH, texture, and interactions with other nutrients. Increased soil pH may also reduce the availability of Cu^{+2} to plants through increased adsorption at cation exchange sites. Leached podzolic sands and calcareous sands tend to have lower levels of Cu^{+2}. In the present study, total Pb concentration in shoots of all plant species was well above normal limit of 5 mg/kg and ranged between 11.0 to 39.0 mg/kg thus could have toxic effects on photosynthetic activity of plants. Total of Zn content in *B. reptans* also exceeded normal level of Zn in shoots. In non-tolerant plants, Zn toxicity is apparent in soils with high Zn content which could effect inhibition of root elongation and chlorosis of young leaves. Soil pH, soil organic matter and soil hydrology primarily govern the availability of Zn^{+2}. High pH may result in Zn precipitation as $ZnFe_2O_4$ or $ZnSiO_4$ which become unavailable for plant uptake. Soil organic matter can either increase or decrease the availability of Zn^{+2} by binding it or increasing its mobility. Presence of plant species in the study area with high level of Cu, Zn and Pb in shoots above the normal limits suggested their adaptation to contaminated soils and possibly has developed mechanism for metal detoxification (Ghosh & Singh, 2005).

TF, BCF and BAC values >1 had been used to evaluate the potential of plant species for phytoextraction and phytostabilization (Yoon *et al*., 2006; Li *et al*., 2007). The results indicated that *P. hysterophoirus* and *A. viridis* had highest TF values for Pb (23.0) and Ni (20.7). High root to shoot translocation of these metals indicated that these plants have vital characteristics to be used in phyto-extraction of these metals as indicated by Ghosh & Singh (2005) and La´zaro *et al*., (2006). Plant species with slow plant growth, shallow root system and small biomass production are not generally preferred for phytoremediation. These two species had high biomass and based on high TF values could have enormous potential to be used for phyto-extraction of Pb and Ni than other species which also showed TF>1 for different metals. A sequence of decreasing TF values: Pb>Ni>Co>Cr>Zn and >Cu was found for plant species. It is easy for plants species with TF>1 to translocate metals from roots to shoots than those which restrict metals in their roots. High metal accumulation may be attributed to well develop detoxification mechanism based on sequestration of heavy metal ions in vacuoles, by binding them on appropriate ligands such as organic acids, proteins and peptides in the presence of enzymes that can function at high level of metalicions (Cui *et al*., 2007) and metal exclusion strategies of plant species (Ghosh & Singh, 2005). Plant species with high TF values were considered suitable for phytoextraction generally requires translocation of heavy metals in easily harvestable plant parts i.e. shoots (Yoon *et al*., 2006). According to Ghosh & Singh (2005) phyto-extraction is a process to remove the contamination from soil without destroying soil structure and fertility. The results highlighted that number of plant species had TF>1 for Pb and Ni in comparison to other metals in particular Cu which was only accumulated in *P. hysterophoirus* with TF value of 1.9. The results showed that it was easy for *P. hysterophoirus* and *P. oleracea* to translocate five (Pb, Cu, Zn, Ni and Cr) and four (Pb, Zn, Ni and Co) metals from roots to shoots. TF value for *C. album* varied between 1.0-1.3 for Pb, Zn and Co. The TF values for *C. album* were lower (>1) for Cu compared to TF value for Cu of *C. accuminatum* which was >1 (Cui *et al*., 2007). *B. reptans* (Zn and Cr), *C. sativa* (Pb and Zn), *C. pennisetiformis* (Pb and Co), *I. hederacea* (Pb and Ni), *M. coromandelianum* (Co and Cr) and *R. communis* (Pb and Ni) had TF values >1 for two heavy metals. Cui *et al*., (2007) found TF values >1 of Zn for *S. nigrum* whereas in the present study TF value was 0.4 which was lower than values indicated by Cui *et al*., (2007). Similarly, Li *et al.,* (2007) reported TF values <1 for *Solanum bigeminatum.* Cui *et al*., (2007) considered *C. accuminatum* as an appropriate species for Cu, Cd and *S. nigrum* for Zn and Cd extraction to remediate polluted soils. The species which have ability of to tolerate and accumulate heavy metals may be useful for phyto-stabilization and phyto-extraction (Yoon *et al*., 2006). However, based on the present results *S. nigrum* is not suitable for phytoextraction as it has TF<1 whereas *C. album* can be considered for phytoextraction for Pb, Zn and Co. Although, Del-Río-Celestino *et al*., (2006) considered *C. album* suitable for phytoextraction of Pb contaminated soils based on TF values. TF value of Ni for *S. nigrum* was >1 indicating its potential for phytoextraction.

Phyto-stabilisation is a process which depends on roots ability to limit the contaminant mobility and bio-availability in the soils which occurs through the sorption, precipitation, complexation or metal valance reduction (Ghosh & Singh, 2005). Heavy metals tolerant species with high BCF and low TF can be used for phyto-stabilisation of contaminated soils. Species such as *B. reptans, S. nigrum P. oleracea* and *X. stromarium* showed very high BCF values (18.5 for Pb, 14.8, 25.4 for Cu; 14.2 for Cu) indicating that these species retains metals in their roots and limit metal mobility from roots to shoots once absorbed by roots of plants (Cui *et al*., 2007). The elevated concentration of heavy metals in roots and low translocation in above ground parts indicated their suitability for phyto-stabilisation. The results indicated that a total of 12 species with BCF>1 and TF<1 may be useful for phyto-stabilisation of one, two or three metals contaminated sites of the study area. These species included *B. reptans*, *E. indica*, and *S.nigrum* with BCF >1 and TF<1 for Pb, Cu and Zn. *C. pennisetiformis,* and *C. rotundus* with BCF >1 and TF<1 for Zn and Cu and Pb and Zn. *A. viridis, C. sativa, C. album, D. aegyptium* and *M. coromandelianum* with BCF >1 and TF<1 for Pb and *I. hederacea, P. oleracea* and *X. stromarium* with BCF>1 and TF<1 for Cu respectively.

Bioaccumulation factor (BAC) of studied plant species were highest for Pb, followed by Cu, Zn, and Co. Fifteen species showed BAC values >1 for one, two or three metals viz., Pb, Cu, Zn and Co. Based on higher BAC values, *B. reptans* and *E. indica* was most efficient in accumulating three metals viz., Pb, Zn and Co. *P. oleracea*, *X. stromarium* and *I. hederacea* had potential to accumulate Pb and Cu whereas *A. viridis* (site 2), *B. reptans* (site 1), *P. hysterophoirus, C. pennisetiformis* (site 1), *C. album* and *C. rotundus* (Pb and Co). Plant species such as *A. viridis* at site 1 (Co), *C. pennisetiformis* at site 2 (Co), *P. hysterophoirus* at site 2 (Co), *C. dactylon* (Pb), *D. aegyptium* (Pb), *M. coromandelianum* (Co), *R. communis* (Co) and *S. nigrum* (Cu) have the ability to accumulate only one metal. Wei *et al*., (2006) reported *S. nigrum* as hyper-accumulator of Cd. In the present study, the BAC value of *S. nigrum* was 2.5 for Cu indicated its potential for accumulation of Cu. The BAC of *C. dactylon* was very high for Pb (BAC = 4.6) and based on Pb tolerance this species can be used for phytoremediation processes. There are many reports about *C. dactylon* where it has been identified to accumulate heavy metal in shoots. For example, Shu *et al*., (2000) have considered *C. dactylon* suitable for reclamation of Pb/Zn mine wastelands. Similarly, Archer & Caldwell (2004) also found *C. dactylon* as an accumulator of Pb, Cu, and Cd and considered this species suitable for phytostabilization. Low growth habit makes it ideal for providing a dense mat on the soil surface which can prevent erosion and at the same time remove heavy metals from the soil. It spreads by both tillering and seedling which makes its establishment easy (Archer & Caldwell, 2004). The results of this study also highlighted that grasses such as *C. dactylon, C. pennisetiformis, B. reptans* and *E. indica* had higher BAC values compared to other plant species. Grasses have been more preferable in use for phyto-accumulation than shrubs or trees because of high growth rate, more adaptability to stress environment and high biomass.

In general the results indicated that none of the plant species were identified as hyperaccumulator because all species accumulated Pb, Cu, Zn, Ni, Co and Cr less than 1000 mg/kg (Baker & Brooks, 1989). However, based on BCFs, TFs, and BAC values plant species were identified which have the potential for phytostabilization and phytoextraction. *B. reptans*, *S. nigrum P. oleracea* and *X. stromarium* had very high BCF values and could be useful for phytostabilization of soils contaminated with Cu and Pb. Most of the species were efficient to take up and translocate more than one metal from roots to shoots. Based on highest TF value *P. hysterophoirus* and *A. viridis* can be used for phytoextraction of Pb and Ni. The results also find *P. hysterophoirus* the most efficient species in translocateing Pb, Cu, Ni, Zn, Cr, and Cu from roots to shoots at site 1 and 2. The results highlighted that grasses such as *B. reptans, C. dactylon*, and *C. pennisetiformis* based on their high BAC values could be used to remediate soils with Pb and Co toxicity. The results of this study also indicated that there is an increasing need for further research on the mechanisms whereby such plants are able to survive in contaminated soils. Furthermore, studies are needed to determine the growth performance, biomass production and metal accumulation of these species in metal contaminated soils for their better management and conservation.

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