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Full Length Research Paper

Assessment of heavy metal accumulation and their translocation in plant species

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Industrial processes are causing continuous discharges of effluents into open drains which enter into the soil that is being contaminated from variety of pollutants including heavy metals. The natural vegetation along the drains is under metal contamination stress. In this research work natural vegetation was primarily focused to study the accumulation of heavy metals in the plants growing in this polluted area assuming that soil has increasingly become contaminated due to discharge of industrial effluents. The purpose was to evaluate inter-population variations to estimate potential range of metal uptake and to direct the selection of the species to ensure optimal accumulation. Soil and plant sampling was carried out from the three selected sites. Seven metals (Cd, Cr, Cu, Pb, Zn, Mn and Ni) were analyzed in soil and as well as in plant tissues. For plant tissue analysis, the underground and above ground parts were separately analyzed. However, soil analysis was conducted by taking composite samples and diethylene triamine pentaacetic acid (DTPA) extractable heavy metal contents were determined. The soil up to 30 cm depth and near the drain was found to have significantly higher metal concentrations than the non contaminated sites and has low organic matter and pH while high EC was observed in the study area. Bioconcentration factor showed considerable extent of root to shoot translocation of metals among species analyzed for phytoaccumulation. The maximum accumulation being *Sylibum marianum* (Cr, in the whole plant but Mn and Zn in the shoot tissues only), *Rumex dentatus* (Pb and Ni in both tissues while Cd, Zn, Ni and Cu in the root tissues), *Cannabis sativa* (Cd and Cu in the root tissues only). The revegetation and colonization of these species would be an appropriate choice in such metal polluted soils.

Key words: Heavy metals, plant species, heavy metal tolerance, phytoextraction.

INTRODUCTION

Pollution is a threat for the survival of mankind and the most important dispute of our era (Wang et al., 2004). Soil contamination due to dispersal of industrial and urban wastes is a major environmental concern. The cause of the contamination is a presence of wide range of inorganic and organic compounds. These compounds may be the combustible substances, heavy metals, explosives hazardous wastes and petroleum products (Ghosh and Singh, 2005). Heavy metals are the main constituent of the inorganic contaminants. Though the heavy metals are vital but at higher concentration these metals can produce toxic effects as their free radicals cause the oxidative strain. So the elevated concentrations of heavy metals render the soil inappropriate for the growth of plants and ultimately wipe out the biodiversity (Adriano, 1986; Alloway, 1990).

The effluents discharged from the industries directly entered into the open surfaces and cause contamination of natural ecology. The effluents discharged from the textile industries increase the turbidity of water bodies due to usage of dyes and chemicals (Aslam et al., 2004). This ultimately reduces the photosynthetic practices and cause variation in the natural habitat. It has been documented that in Pakistan about 9000 million gallons of effluents from industrial sectors are discharged daily into the water bodies (Saleemi, 1993). In many urban areas of Pakistan, the industrial set ups are made without

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Environmental Impact Assessment and Environmental Management and Planning (Mastoi et al., 1997; Gulfraz et al., 2003). This may become a human, planning, economic and ecological concern in Pakistan (Hussain et al., 1996; Khan, 2001). Because of the unplanned Industrial sectors rigorous problems are arising in big cities like Karachi, Lahore, Rawalpindi and Islamabad (Ambreen, 1993). Moreover, the effluents and the solid wastes are continuously adding into the nearby areas and the streams (Irshad et al., 1997). The waste materials released from the industries enters into the river water which then ultimately used by the farmers for irrigation purposes. These heavy metals from the contaminated water entered into human bodies through food chain and unpleasant effects may produce (Stein et al., 1999).

Phytosociological studies envisage the existing vegetation structure, species diversity and soil plant relationship. Sites that continuously receive polluted water definitely show a gradual change in composition of natural vegetation (Ali et al., 2004). Heavy metal contaminated land is increasingly becoming an environmental, health, economic and planning issue in Pakistan (Khan, 2001). Vegetation of an area is prominent indicator of the deteriorating soil conditions and natural habitat and is quite sensitive to such an extent that any change in physical and chemical properties of soil due to agricultural exploitation or contaminant addition by effluents and waste disposal, can alter its structure and composition.

The plants that are not deep rooted are highly affected by the heavy metals because the metals remain in the top soils and do not leached deeper (Yin et al., 2009; Zupančič et al., 2009). Sites recently contaminated or polluted over a long period often show interesting vegetation development processes (Kimmerer, 1984). The pollutants affecting the natural distribution of plants in the contaminated sites was determined by carrying out phytosociological study of the area in comparison with the sites not under such influence (Michler and Arnold, 1999).

The edaphic characteristics and the quality of water prevail the features of the area are considered unconventional vegetation dynamics. The bioavailability of metal ions can be increased by the addition of organic matter in soils during the flowering period (Santos et al., 2009). These issues gain much importance when the vegetation succession is studied. The areas which are continuously receiving the polluted water supply reflect the steady change in the vegetation structure of that area. The species richness and the cover of the plant may have positive and negative effects (Ali et al., 2004).

The natural vegetation always poses a response to the depreciation of soil condition (Amiro and Courtin, 1981). Some plant species show a decline in their number but to some extent while other species show survival mechanism. These species are considered as a good choice to such circumstances (Chaudhri, 1952). Actually the understanding of the procedures is the main thing which shows a discrepancy with the environmental gradient. Moreover, the prophecy of the phytosociolosical drift decides the composition of the species in communities (Franklin, 1995; Cairns, 2001).

Research studies have identified heavy metals as a potential threat to the environment, but in Pakistan, little work has been carried out in remediation of these metals. Detailed studies have been carried out on the soil plant relationship in other countries but very little work has been carried out regarding the description of vegetation in Pakistan so much work needs to be undertaken in this area.

The present research work aimed to: i) Determine the status of soil heavy metal contamination in industrial area of Rawalpindi and the extent to which these can transfer from soil to plants. ii) Evaluate adverse effects of contaminants on natural vegetation by studying the phytosociological aspects. iii) Quantify the selectivity and uptake of heavy metals by natural vegetation emphasizing the underground or above ground plant parts (stem, leaves and roots) involved in heavy metal accumulation.

MATERIALS AND METHODS

Koh-e-Noor textile mill, located in Rawalpindi was selected for detailed phytosociological study and heavy metal assessment in soil and plants present in study area. Entire area was divided into three sites. Site 1 was located near the drain, site 2 at 300 m away from the drain and the site 3 was present at 600 m away from the drain. Frequency, density and canopy cover of each species were recorded and converted to their relative values following the methods of Curtis and McIntosh (1951) and Stephenson (1986). Quadrat method (Krebs, 1978) was used for sampling of plants and soil. Samples were taken from three different depths (that is, 15 cm, 30cm and 60cm).

Soil analysis

The soil samples were air dried, mixed and sieved (2 mm) prior to determine the physical characteristics. The particle size analysis was carried out using Bouyoucos soil hydrometer (Sheldrick and Wang, 1993). Soil water content was determined by gravimetric method. The percentage soil water content was calculated by using the formula derived by Davis et al., (1973). The pH of soil saturated paste was measured with the help of glass electrode by using pH meter model Oyster-10, (Hussain, 1989; Jackson, 1962). Electrical conductivity (EC) of the soil saturated paste was determined by EC meter model JENCO-3173 (Hussain, 1989; Jackson, 1962). Modified Walkley-Black technique was used for the determination of organic matter percentage in the samples (Nelson and Sommer, 1982).

Soil metal concentration

The phytoavailable metal concentration in soil was determined because several studies indicated correlation between the soluble heavy metal concentration in soil and heavy metal concentration in plants (Brummer et al., 1986; Schmidt, 2003; Commission of the European Communities, 2002). Concentration of phytoavailable Cd, Cr, Cu, Pb, Zn, Mn and Ni in the soil samples were determined following DTPA (diethylene triamine pentaacetic acid) extraction

Table 1. Importance Value Index (IVI) of the Plant species, observed at three Sites.

Species Name	Site 1	Site 2	Site 3
Cannabis sativa L.	92.48	86.09	80.36
Silybum marianum Gaertn.	42.32	57.55	60.85
Rumex dentatus L.	20.14	55.33	50.29
Ricinus communis L.	45.61	-	-
Euphorbia helioscopea L.	-	20.94	-
Sonchus oleracea L.	-	-	9.87
Parthenium hysterophorus L.	-	4.84	-
Geranium albiflorum Ledeb.	9.03	6.55	-
Urtica pilulifera L.	9.03	-	-
Oxalis corniculata L.	-	4.84	-
Fumaria indica (Hausskn.) Pugsley.	-	8.42	-
Chenopodium album L.	-	8.94	32.28
Withania somnifera (L.) Dunal.	-	7.94	-
Dicanthium annulatum (Forssk.) Stapf	39.91	22.11	17.84
Imperata cylindrica (L.) P. Beauv.	-	6.58	12.62
Brachiaria reptans (L.) Stapf	13.17	-	-
Triticum aestivum L.	-	-	6.33
Avena fatua L.	28.32	12.75	25.36
Convolvulus arvensis L.	-	-	7.25

Table 2. Edaphic characteristics of the study area.

Site	Soil texture	pH	EC* dS m^{-1}	O.M† (%)	Water content (%)
Site 1	Clay loam	6.5 ± 0.25	0.27 ± 0.03	0.5 ± 0.02	12.7 ± 0.44
Site 2	Clay loam	7.4 ± 0.64	0.17 ± 0.02	0.57 ± 0.03	10.2 ± 0.61
Site 3	Clay loam	7.8 ± 0.06	0.16 ± 0.02	0.62 ± 0.03	7.2 ± 0.67

Values are mean ± SD.
* = Electrical conductivity; † = Organic matter.

method, developed by Lindsay and Norvel (1978).

Plant tissue analysis

Following identification, the plants were separated into stem, root and leaves. Metal concentration in plant tissues was determined by using the wet digestion method. The metal accumulation of each plant species was determined by the Bioconcentration factor (BCF) as described by Baker et al. (1994) and Raskin et al. (1994).

RESULTS AND DISCUSSION

The vegetation observed at the contaminated site differs from the vegetation observed at the less contaminated and uncontaminated. Phytosociology of the study area showed *Cannabis sativa* dominance along with *Silybum marianum* and *Rumex dentatus* (Table 1), while the other species were evenly distributed near the drains. Mix vegetation was observed away from the drains or where the soil was least contaminated. The comparatively less vegetation was observed near the drains (site 1) than the other sites.

The soil physical and chemical characteristics are reported in Table 2. The soil samples collected from the sites showed clay loam type in texture. The soil of the site 1 showed low organic matter (0.5%) while sites 2 and 3 showed comparatively high organic matter percentage. The water content was 12.7% in the site 1 and 10.2 and 7.2% in the other two sites. Electrical conductivity was relatively high (0.27dS m^{-1}) when compared to the other sites. The pH of the site 1 was low (6.5) than site 2 and 3 (7.5 and 7.8 respectively).

The phytoavailable heavy metal concentrations present in three depths and in the three sites are tabulated in Table 3. Soil concentration of Cd in site 3 was the highest (0.107 ± 0.005) at 30 cm while 60 cm depth contained least accumulation at site 1 (0.063 ± 0.041). Cr concentration was found to be the highest at 15 cm (0.859 ± 0.314), while 60 cm (0.185 ± 0.310) depth contained least accumulation in soil of site 1.

Table 3. Basic statistics for concentration (µg g^{-1}) of DTPA extractable heavy metals in the three depths of soil samples collected from three sites.

Soil Depths	Site 1	Site 2	Site 3
15 cm	**Mean ± S.D***	**Mean ± S.D***	**Mean ± S.D***
Cd	0.078 ± 0.117	0.075 ± 0.003	0.103 ± 0.002
Cr	0.859 ± 0.314	0.013 ± 0.015	0.472 ± 0.716
Cu	1.580 ± 0.079	0.752 ± 0.076	0.520 ± 0.045
Pb	2.586 ± 0.241	3.468 ± 0.396	3.801 ± 0.528
Zn	8.037 ± 1.943	3.103 ± 0.250	9.230 ± 0.233
Mn	3.305 ± 0.486	1.088 ± 1.119	0.627 ± 0.467
Ni	5.027 ± 0.437	2.062 ± 1.222	4.279 ± 1.501
30 cm			
Cd	0.074 ± 0.001	0.069 ± 0.005	0.107 ± 0.005
Cr	0.478 ± 0.199	0.067 ± 0.015	0.488 ± 0.043
Cu	2.175 ± 0.060	0.576 ± 0.055	0.433 ± 0.053
Pb	3.043 ± 0.201	3.255 ± 0.109	2.854 ± 0.222
Zn	11.517 ± 0.906	2.320 ± 0.092	5.500 ± 0.375
Mn	2.269 ± 0.250	0.470 ± 0.039	0.526 ± 0.394
Ni	3.362 ± 0.667	2.352 ± 1.105	5.146 ± 0.137
60 cm			
Cd	0.063 ± 0.041	0.074 ± 0.032	0.064 ± 0.032
Cr	0.185 ± 0.310	0.791 ± 1.255	0.061 ± 0.105
Cu	2.199 ± 0.137	0.567 ± 0.104	0.519 ± 0.041
Pb	2.776 ± 0.172	3.303 ± 0.065	2.453 ± 0.056
Zn	9.983 ± 2.405	2.210 ± 0.115	5.273 ± 0.844
Mn	2.091 ± 0.252	0.577 ± 0.227	0.902 ± 0.174
Ni	3.906 ± 0.117	1.709 ± 0.055	2.875 ± 0.858

*S.D. = Standard deviation.

The maximum amount of Copper was found in site 1 at 60 cm (2.199 ± 0.137). This maximum range was followed by 30 cm (2.175 ± 0.060). The site 3 contained least concentration of Cu at all the depths of soil. The Cu accumulation in soil in the three layers of site 1 significantly higher than the site 2 and site 3. The maximum accumulation of lead while considering both the soil depths and the three sites was observed in site 2 followed by the site 1 and then site 3. Zn in site 1 was found to be the lowest at 15 cm while highest at 30 cm present. In site 2 the highest were found to be at 15 cm than at 30 cm and 60 cm soil depths. The same pattern of Zn concentration was seemed in site 3. Soil concentration of Mn in site 1 was the highest at 15 cm (3.305 ± 0.486), while 60 cm depths contained least accumulation (2.091 ± 0.252).

In case of Site 2, the amount of Mn was higher in 15 cm (1.088 ± 1.119) and 30 cm depth accumulated least concentration of Mn (0.470 ± 0.039). Similar results were found in case of site 3. The maximum Ni concentration was observed at site 1 and in all the soil depths except at 30 cm of site 3 while lesser concentration of Ni was experienced at site 2.

The means and standard deviations for plant tissue heavy metal analysis are summarized in Table 4. All the plants showed minimum accumulation of Cd in their leaves, stem and root tissues. In the site 1 maximum accumulation was observed in *S. marianum* in its tissues (0.061 µg g^{-1} in leaves, 0.03 µg g^{-1} in stem and 0.062 µg g^{-1} in the root). While in site 2, *C. sativa* had highest mean concentrations of Cd in its tissues (0.040 µg g^{-1} in leaves and 0.064 µg g^{-1} in stem tissues) but root tissues for maximum mean Cd concentration was found in *S. marianum* (0.054 µg g^{-1} having standard deviation of 0.007). And in site 3 *Cannabis sativa* accumulated much concentration in its leaf and stem tissues while root tissue of *R. dentatus* has highest mean concentration. As far as the mean concentration of Cr is concerned, *C. sativa* and *S. marianum* present at site 3, showed maximum concentration in leaves and root tissues while stem of *R. dentatus* has highest Cr concentration at site 2.

Regarding Cu, *Cannabis sativa* showed maximum concentration in both leaf and stem tissues at site 1 while *R. dentatus* accumulated much Cu in root tissues at site 3. *R. dentatus* showed maximum Pb accumulation in leaf and root tissues at site 3 and 2 respectively. But *S. marianum* demonstrated maximum Pb accumulation in stem tissues. *S. marianum* showed maximum Zn accu-

Table 4. Metal concentrations (µg g^{-1} ± S.D*) in the vegetation samples, during the year 2005.

Site	Species name	Cd			Cr		
		Leaves	Stems	Roots	Leaves	Stems	Roots
Site 1	*Cannabis sativa*	0.024±0.031	0.035±0.033	0.056±0.003	0.861±0.809	0.048±0.083	0.006±0.010
	Silybum marianum	0.061±0.017	0.030±0.002	0.062±0.003	0.884±0.269	0.415±0.244	0.537±0.060
	Rumex dentatus	0.058±0.123	0.038±0.014	0.057±0.015	0.519±0.026	0.418±0.025	0.445±0.108
Site 2	*Cannabis Sativa*	0.040±0.032	0.064±0.016	0.024±0.012	0.479±0.830	0.255±0.267	0.723±0.311
	Silybum marianum	0.039±0.020	0.023±0.013	0.054±0.007	0.416±0.165	0.389±0.502	0.954±0.104
	Rumex dentatus	0.021±0.009	0.023±0.024	0.035±0.005	0.490±0.359	0.647±0.065	0.264±0.229
Site 3	*Cannabis Sativa*	0.054±0.001	0.048±0.013	0.073±0.023	0.998±0.360	0.134±0.233	0.103±0.178
	Silybum marianum	0.045±0.022	0.025±0.023	0.023±0.002	0.574±0.677	0.266±0.011	1.021±0.977
	Rumex dentatus	0.036±0.002	0.046±0.012	0.079±0.017	0.505±0.157	0.522±0.250	0.276±0.009

Site	Species name	Cu			Pb		
		Leaves	Stems	Roots	Leaves	Stems	Roots
Site 1	*Cannabis sativa*	0.625±0.290	0.675±0.607	0.013±0.013	0.360±0.033	0.502±0.155	0.450±0.179
	Silybum marianum	0.119±0.042	0.455±0.386	0.063±0.054	0.524±0.097	0.728±0.413	0.281±0.246
	Rumex dentatus	0.571±0.253	0.167±0.104	0.141±0.034	0.570±0.009	0.480±0.293	0.433±0.163
Site 2	*Cannabis Sativa*	0.581±0.337	0.042±0.036	0.033±0.029	0.259±0.202	0.477±0.260	0.121±0.209
	Silybum marianum	0.159±0.060	0.168±0.013	0.009±0.010	0.253±0.129	0.675±0.428	0.386±0.223
	Rumex dentatus	0.337±0.191	0.003±0.005	0.001±0.001	0.474±0.254	0.411±0.360	0.945±0.390
Site 3	*Cannabis Sativa*	0.002±0.004	0.035±0.021	0.018±0.031	0.565±0.084	0.614±0.180	0.499±0.281
	Silybum marianum	0.054±0.013	0.053±0.035	0.021±0.036	0.513±0.045	0.511±0.087	0.599±0.376
	Rumex dentatus	0.086±0.002	0.015±0.013	0.108±0.017	0.757±0.285	0.615±0.127	0.313±0.048

Site	Species name	Zn			Mn		
		Leaves	Stems	Roots	Leaves	Stems	Roots
Site 1	*Cannabis sativa*	0.151±0.024	0.142±0.056	0.325±0.014	1.728±0.570	1.262±0.157	1.816±0.966
	Silybum marianum	0.143±0.055	0.226±0.010	0.535±0.213	22.53±1.925	1.937±1.361	2.654±0.124
	Rumex dentatus	0.129±0.084	0.101±0.020	0.613±0.222	12.732±9.976	0.206±0.357	3.249±0.095
Site 2	*Cannabis Sativa*	0.255±0.013	0.226±0.012	0.342±0.065	1.771±0.515	0.002±0.003	2.958±0.215
	Silybum marianum	0.234±0.012	0.238±0.010	0.334±0.026	1.766±1.178	2.034±0.573	1.137±0.009
	Rumex dentatus	0.198±0.107	0.125±0.014	0.420±0.040	1.668±0.832	7.398±4.348	0.401±0.695
Site 3	*Cannabis Sativa*	0.278±0.156	0.002±0.004	0.302±0.111	2..373±1.055	13.143±8.903	1.987±3.441
	Silybum marianum	0.623±0.324	0.340±0.154	0.036±0.063	2.320±0.907	2.388±0.214	3.013±0.139
	Rumex dentatus	0.026±0.044	0.001±0.002	0.309±0.051	1.839±1.071	1.040±0.694	2.717±0.150

Site	Species name	Ni		
		Leaves	Stems	Roots
Site 1	*Cannabis sativa*	1.150±0.645	1.270±0.610	5.342±0.310
	Silybum marianum	2.119±0.535	2.940±1.451	5.568±0.398
	Rumex dentatus	3.763±0.324	4.882±0.844	6.090±0.082
Site 2	*Cannabis Sativa*	3.333±0.741	2.582±1.847	3.646±0.078
	Silybum marianum	2.579±2.483	4.692±0.887	6.030±0.258
	Rumex dentatus	6.023±1.205	5.856±0.414	5.419±0.374
Site 3	*Cannabis Sativa*	4.533±0.534	4.077±0.499	4.902±0.737
	Silybum marianum	3.844±0.697	5.428±0.054	3.818±0.804
	Rumex dentatus	5.239±1.002	4.925±0.631	5.372±0.422

*S.D =Standard deviation.

Table 5. Phytoaccumulation of heavy metals (µg g^{-1}) and Bioconcentration Factor (BCF) of shoot and root in the three plants and in all three sites.

Species	Site	Cd		Cr		Cu		Pb		Zn		Mn		Ni	
		BCF Root	BCF Shoot	BCF Root	BCF Shoot	BCF Root	BCF Shoot	BCF Root	BCF Shoot	BCF Root	BCF Shoot	BCF Root	BCF Shoot	BCF Root	BCF Shoot
Cannabis sativa	1	0.260	0.274	0.004	0.597	0.002	0.218	0.054	0.103	0.011	0.010	0.237	0.390	0.434	0.197
	2	0.168	0.727	0.992	0.853	0.017	0.329	0.012	0.073	0.045	0.063	0.302	0.181	0.595	0.966
	3	0.266	0.372	0.101	0.129	0.012	0.025	0.059	0.141	0.015	0.013	0.967	0.737	0.399	0.700
Silybum marianum	1	0.288	0.423	0.353	0.853	0.011	0.096	0.033	0.149	0.018	0.012	0.346	3.192	0.453	0.411
	2	0.378	0.434	1.109	0.936	0.005	0.173	0.037	0.093	0.044	0.062	0.116	0.388	0.985	1.187
	3	0.084	0.256	1.000	0.819	0.014	0.073	0.071	0.102	0.002	0.048	1.466	2.290	0.310	0.754
Rumex dentatus	1	0.405	0.447	0.292	0.616	0.024	0.124	0.052	0.125	0.021	0.008	0.430	1.688	0.495	0.703
	2	0.245	0.308	0.307	0.859	0.000	0.211	0.094	0.088	0.055	0.042	0.041	0.925	0.885	1.940
	3	0.288	0.299	0.270	0.810	0.073	0.058	0.037	0.164	0.015	0.001	1.322	1.401	0.437	0.826

mulation in leaf and stem tissues at site 3 and *R. denta-tus* has highest Zn concentration in root at site 1. The elevated concentrations of Mn were observed in the leaves of *S. marianum*, in root tissues of *R. dentatus* and in stem of *C. sativa* at site 1 and 3 respectively.

The BCF values of both root and shoot of the plants are reported in Table 5. The BCF value of cadmium was highest in both root (0.405 µg g^{-1}) and shoot (0.447 µg g^{-1}) of *R. dentatus*. This indicates that *R. dentatus* has the ability to extract Cadmium in its tissues. But no plant showed hyperaccumulation of Cd in their tissues. In case of Cr, the maximum BCF value was observed in the tissues of *S. marianum* at site 2 (0.936 µg g^{-1} for shoot and 1.109 µg g^{-1} for root tissues) and site 3 (0.819 µg g^{-1} for shoot and 1.00 µg g^{-1} for root tissues), but at site 1 the BCF value was much less than the other two sites. The value of BCF in this plant was higher in root as compared to the shoot tissue. The overall less translocation of Cu from root to shoot tissues was observed in the three plants. Our results showed more accumulation of Pb in shoot rather than roots. This shows more translocation of this metal from root to the shoot. It also appeared that mostly the uncontaminated area (Site 3), had high BCF values than the contaminated areas. No plants have the ability to hyperaccumulate Zn metal from contaminated areas. For all the three plants observed, the levels in the extraction were consistently low at site 1, while the greater levels of plant available zinc were detected at less contaminated and uncontaminated sites. For manganese, *C. sativa* showed maximum accumulation at site 3 as its BCF values (0.737 µg g^{-1} for shoot and 0.967 µg g^{-1} for root) were greater when compared to the other two sites. The BCF value of Manganese in the year 2005 was highest in both shoot (2.290 µg g^{-1}) and root (1.466 µg g^{-1}) of *S. marianum* at site 3. While at site 3, *S. marianum* and *R. dentatus* (1.401 µg g^{-1} and 1.322 µg g^{-1} for shoot and root tissues respectively) showed efficient accumulation of Mn both at site 3. All three plants showed maximum accumulation of Ni in site 2. Only the *S. marianum* (1.187 µg g^{-1}) and *R. dentatus* (1.940 µg g^{-1}) have the BCF values greater than 1.00, but only in the shoot tissues.

The vegetation of an area is a prominent indicator of the deterioration of the soil conditions and natural habitat. The changes in the physico-chemical properties of the soil, addition of waste disposal and industrial effluents alter the vegetation of an area to a great extent (Kabata-Pendias and Pendias, 1992; Schuster and Diekmann, 2003). These reasons were found sufficient to alter the vegetation structure of both the contaminated and uncontaminated sites (Martin and Coughtrey, 1981; Robinson et al., 1996). Reclamation and the remediation efforts have gained the world's considerable importance and mitigation measures are urgently needed (Buschmann et al., 2008). And now stress is on maximum utilization of native plant species to reclaim contaminated area (Glick, 2003; Mitch, 2002; Pulford and Watson, 2003; Salt et al., 1998; Ximénez-Embún et al., 2002; Yanqun et al., 2005; Zhuang et al., 2008).

McGrath and Lane (1989) reported no deeper movement of heavy metals and concluded that this may be due to the lateral movement of soil caused by the cultivation and only a very small

fraction of the metal content of the soil is leached per year and are retained in the top soils for several hundred years (Holm et al., 1998). Moreover, McGrath et al. (2002) estimated that 80% of the metal load remained in the top soil. Examination of the soil profiles showed little evidence of downward movement (McBride, 1997). Martin and Coughtrey (1981) also concluded that the superficial layers of soil contain high concentration of metals while at greater depth the concentrations progressively lower.

Zhao et al. (2002) has reported rare hyperaccumulation Cd. This may due to the reason that Cd poses some toxic effects on plants (Anderson et al., 2004). The possible explanation would be the lack of unavailability of Cd and Pb, due to the high affinity of these metals to organic matter (Kabata-Pendias and Pendias, 1991; McBride, 2001; Merritt and Erich, 2003; Nigam et al., 2001; Strawn and Sparks, 2000). So, the plants having metal resistance may be a better choice in this regard and the plants that are already growing on a soil contaminated with cadmium can be a better choice to grow on contaminated soils because such species are in fact showing metal tolerance.

Shanker et al. (2005) suggested that Cr moved in the xylem of the tissues and the availability of the Cr to the plant did not depend upon the soil properties and distribution of this element (Golovatyj et al., 1999). The overall low Cu concentration was observed in both shoot and root tissues by Zheljazkov et al. (2006). The possible explanation would be the lack of unavailability of Cu. The absorbance and accumulation of heavy metals in the plant tissues depends on metal concentration and chemical forms in soil (Shen et al., 2002). Very little amount of Pb is extracted from soil. There found some complexity in the availability of this metal. The factors involved in the phytoavailability of this metal are, organic matter, soil pH, plant roots and other soil conditions (Zimdahl and Hassett, 1977). But the limited potential of Pb phytoextraction is due to low soil mobility and little tendency for Pb uptake into root (Lasat, 2002). The unconventional behavior of Pb uptake and accumulation is well renowned (Barry and Clark, 1978; Reeves and Brooks, 1983). It may be due to the reason that plants respond differently to soil Pb content as compared to the other metals (Huang et al., 1997). Some other reason might be the high susceptibility of lead to change into sorption form in soil matrix. Moreover, root membrane barrier cannot be overlooked because the mechanism of Pb transport from soil to root tissue is not clear (Blaylock et al., 1997).

Zarcinas et al. (2003) reported positive relationship for Pb in plant samples, followed by Zn regarding soil and plant heavy metal interaction. The greater levels of plant available zinc were detected at less contaminated and uncontaminated sites. Taking this into account, many plants were at least reasonably efficient in accumulating metals. But, the hyperaccumulation may not be possible due to the low amount of readily available metals in the soil environment (Chaudhry, 1999). Chaudhry (1999) also concluded high biomagnification ratio for Mn and reported *Poa labillardieri, Baeckea utilis, Lomandra longifolia* and *Acacia melanoxylon* as efficient accumulator of nickel.

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