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Phytoextraction Potential of *Datura Inoxia* for the Removal of Selected Heavy Metals in Soil Samples

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Abstract: ***A pot experiment was conducted to identify the efficiency of Datura inoxia for remediation of cadmium(II) and chromium(VI) contaminated soils. In this experiment plants were grown for 45 days with 5 levels of test concentrations [TC1(0), TC2(25), TC3(50), TC4(75) and TC5(100) respectively. Growth studies and metal accumulation in plant and soil samples were determined. Results showed that at higher concentration of metals, the plant length and biomass effected. Maximum uptake of cadmium and chromium were found to be in TC4 soils on day 45. Basing on the results it can be concluded that metal uptake was increased with increased dosage of cadmium and chromium concentrations. BCF and TF values were found to be >1 for cadmium(II) contaminated soils whereas, BCF >1 and TF <1in chromium contaminated soils indicating the selected plant species Datura inoxia could be good accumulator for cadmium contaminated soils.***

Keywords: Shoot length, Bioconcentration Factor, metal uptake, phytoextraction

1. Introduction

Heavy metal pollution is one of the most dangerous problems of the world [1]. Natural processes such as volcanic eruptions and human activities such as fossil fuel industries, sewage sludge, fertilizers and metal working industries are the major sources of heavy metal contamination [2]. In environment the most common heavy metals are cadmium, chromium, copper, mercury, lead and nickel [3-4]. Heavy metals can sustain for longer period and bioaccumulate in the environment. Thus, the half-life of these toxic metals will be very high [5]. Chromium(VI) and cadmium(II) are most dangerous metals even at low concentrations they can effect plants, animals and also human health [6]. Anthropogenic activities such as mining, tobacco smoking, smelting and refining of non-ferrous metals are the major sources of cadmium [7]. The major health effects of cadmium(II) are formation of kidney stones due to disturbances in calcium metabolism and occupational health hazards such as softening of the bones and osteoporosis. High uptake of chromium(VI) is responsible for several health effects in human beings such as respiratory problems, haemolysis, skin rashes, acute renal failure, weakened immune systems, kidney and liver damage, alteration of genetic material, lung cancer, kidney and liver damage, Pulmonary fibrosis and acute renal failure [8].

At present, there are numerous physical and chemical procedures such as chemical precipitation, ion exchange, reverse osmosis and solvent extraction to remove the heavy metals from various contaminated sources which are costly, less efficient and also change the soil properties and responsible for long term risks such as leaching and ground water pollution[9-10]. Several approaches have been studied for the development of more efficient methods in removing metal pollution and the phytoremediation process is found to be more practicable over other techniques.

Phytoremediation is a cost effective innovative technology that utilizes plant species for decontamination of soil [11-14]. The key to successful phytoremediation is the potential of plants to transport heavy metals from the soil into their above ground parts (root, shoot and leaves) and uptake from their underground roots [15-16]. The selection of plants is very important and the plants which can survive in unfavorable conditions with high growth rate and biomass and accumulate toxic levels of metals in their aerial parts (shoots) can be considered as ideal plants for phytoextraction [17]. It is recommended to use the native plant species which are less competitive under local conditions and reduce the metal concentration to an acceptable level for normal plant growth [18]. Indian mustard and sunflower are considered as hyperaccumulators because of their fast growth, high biomass, and high tolerance and accumulation of metals [19]. To consider the plants as hyperaccumulators the bioconcentration factor and Translocation factor should reach > 1 to indicate that the concentration of heavy metals above ground is greater than that below ground (roots). Therefore, it can be concluded that this criteria is more crucial in phytoextraction. Previous research shows that there is growing interest of searching for a variety of plants for the removal of heavy metals including *Thlaspi caerluescens[20], Lonicera japonica[21], Solanum nigrum L[22], Sedum alfered[23] and Brassica junceae[24]* The utilization of the remarkable ability of plants to remove pollutants from the environment is at present a fascinating field of research.The aim of the present study was to investigate the ability of metal uptake of *Datura inoxia* from cadmium(II) and chromium(VI) contaminated soils.

2. Materials and Methods

A pot study experiment was conducted to identify the growth and metal uptake by selected plant species *Datura inoxia* from cadmium(II) and chromium(VI) contaminated soils. The experiment was comprised of 5 dosages of cadmium(II) and chromium(VI) with different test concentrations TC1 (control), TC2 (25), TC3 (50), TC4 (75) and TC5 (100) ppm. The plastic pots were filled with 5 kg of soil amended with known concentrations of $CdCl_2$ and $K_2Cr_2O_7$. Healthy and similar size of *Datura inoxia* seedlings were collected from uncontaminated sites and no additional fertilizers were used during the experiment. The plants were grown for 45 days under natural conditions. Growth studies of plant i.e., plant height (cm) (root and shoot) and biomass (g) (dry matter) of individual plant species were recorded by harvesting plants at regular interval of 15 days of a total period of 45 days. The accumulation of cadmium(II) and chromium(VI) concentrations in plant samples was determined by washing the plant samples thoroughly with tap water and deionised water to remove the dust particles and dried for 2 days in oven at70ºC. The dried plant samples was powdered and stored for the metal analysis. The metals in plant and soils samples were determined by acid digestion procedure [25-26]. Homogenous tissue samples were digested in 3:1 HNO3:HCLO4 (v/v) solution on a hot plate at 150- 175ºC for about two hours until clear liquid was obtained. Metals such as cadmium(II) and chromium(VI) were determined using flame atomic absorption spectrophotometer (Spectra 250Plus). Average values of three replicates were taken for each experiment. The analytical procedure was expressed as standard deviation and standard error. All the chemicals and reagents were analytical grade and obtained from merck. Bioconcentration Factor was calculated as metal concentration ratio of plants roots to soil [27]. Translocation Factor was described as ratio of heavy metal in plant shoots that in plant root [28-29].

3. Results and Discussion

In cadmium(II) contaminated soils shoot system of the plant shown significant difference relative to control. Shoot length and Shoot dry matter were decreased as the dosages of chromium(VI) increases in soil. There was a gradual reduction in seedling length with an increase in the concentration of metals chromium(VI) with a maximum reduction of at TC4 compared to control (**Table 1 a &b).** The direct influence of metals on the cellular metabolism of shoots may lead to the reduction of seedling length in metal stressed seedlings [30] .The tallest plants were found in control pots. The maximum reduction in shoot length and shoot dry matter observed were 12.2cm and 2 mg/kg in TC4 soils on day 45 and day 15 respectively. As shown in **Table 1 a &** the maximum values in root length and root dry matter observed were 6.3cm and 3.5mg/kg in TC1 soils on day 30 and day 45. The mean values have increased from control to TC1 and thereafter reduced in TC2 to TC4 soils which shown inhibitory effect on root system with increase in the dosage of chromium(VI) concentrations in soils.

Table 1a: Shoot length, Root length, in different test concentrations on different harvest days *in* chromium(VI) contaminated soils

	Shoot length					Root Length				
	C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4
Day 15	2.3 ±1.02	2.5 ±1.0	3 ±0.98	2.1 ±0.65	2 ±2.30	3 ±2.0	3.1 ±2.08	2.5 ±2.04	2.2 ±2.15	2 ±2.30
Day 30	13 ±2.36	13 ±2.51	13.1 ±1.0	12.7 ±1.32	12.5 ±1.52	7 ±1.23	6.3 ±1.82	4.2 ±1.02	3 ±0.	3.1 ±0.7
Day 45	16 ±0.9	12.3 ±1.23	12.5 ±1.25	12.5 ±0.36	12.2 ±0.05	6 ±0.36	6.2 ±1.20	4.1 ±1.36	3 ±1.64	3 ±1.85

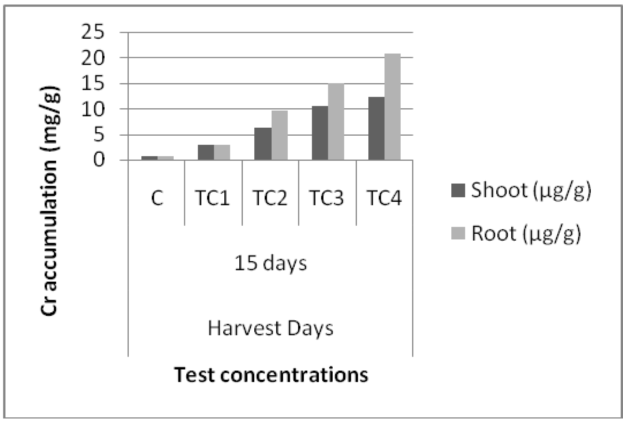
Results are means ±SD(n=5)

Table 1b: Shoot biomass and Root biomass in different test concentrations on different harvest days in chromium (VI) contaminated soils

Shoot dry matter					Root dry matter				
C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4
0.6 ±2.82	0.5 ±0.09	0.57 ±1.03	0.54 ±1.05	0.4 ±1.63	0.5 ±1.20	0.43 ±1.36	0.41 ±0.98	0.35 ±1.63	0.3 ±1.5
3 ±1.24	2.5 ±1.25	2.3 ±1.56	2 ±1.62	1.5 ±1.84	1.5 ±1.24	1.3 ±1.69	1 ±1.24	0.8 ±1.96	0.7 ±1.36
4 ±0.65	3.5 ±0.96	3 ±0.85	2.7 ±0.99	2.5 ±0.08	1.9 ±0.87	1.6 ±0.14	1.2 ±0.96	1 ±0.98	0.4 ±0.99

Results are means ±SD(n=5)

The maximum accumulation by roots and shoots were 19.3 mg/kg & 22.9 mg/kg in TC4 soils on day 45 as shown in **Table 2 and Figure 1a-c**. Accumulation of chromium(VI) was found higher in root rather than in shoot. The possible reason might be that there were some other physiological reasons responsible for this phenomenon. The mean values have increased with increased soil chromium(VI) on all harvest days and shown no significant reduction, relative to control.



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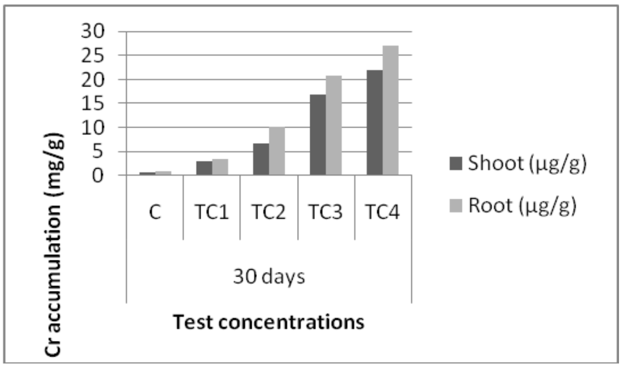

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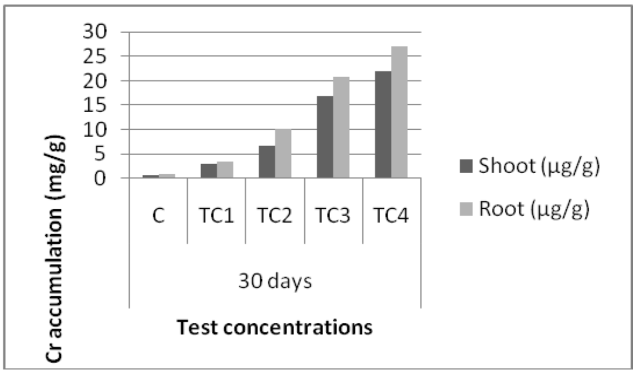


1c

Figure 1 a-c: Accumulations of chromium(VI) in shoot and root in different concentrations on day 15 – 45

Table 2: Chromium (VI)accumulations in soils, shoot and root, Bioconcentration factor (BCF) and Translocation factor (TF) in different test concentrations on different harvest days

Chromium(VI) Accumulation	Harvest Days														
	15 days					30 days					45 days				
	C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4
Shoot (µg/g)	0.6 ±0.09	3 ±0.02	6.21 ±0.05	10.5 ±0.06	12.2 ±0.04	0.7 ±0.06	2.9 ±0.03	6.8 ±0.07	16.9 ±0.04	21.9 ±0.06	0.9 ±0.04	4.89 ±0.04	13.6 ±0.06	17.8 ±0.04	22.9 ±0.09
Root (µg/g)	0.7 ±0.04	2.8 ±0.06	9.6 ±0.04	14.9 ±0.05	20.8 ±0.04	0.89 ±0.06	3.56 ±0.05	10.1 ±0.04	20.8 ±0.08	26.9 ±0.02	1.3 ±0.09	7.2 ±0.04	15.1 ±0.06	23.6 ±0.048	19.3 ±0.04
BCF of Shoot	0.80	0.80	0.68	0.64	0.71	0.78	0.53	0.65	0.94	1.18	0.75	0.68	1.13	0.90	1.14
BCF of Root	1.00	0.75	1.05	0.90	1.22	0.99	0.65	0.96	1.16	1.45	1.08	1.00	1.26	1.20	0.96
TF	0.80	1.07	0.65	0.70	0.59	0.79	0.81	0.67	0.81	0.81	0.69	0.68	0.90	0.75	1.19

Results are Means ±SD(n=5)

In cadmium(II) contaminated soils during the period of observation, no toxic symptoms were observed in any test concentrations, shoot length and shoot dry matter showed no significant reduction relative to control. The mean values have increased showing no inhibitory effect with increases soil cadmium(II) on all harvest days **(Table 3 a &b)**. The maximum shoot length and shoot dry matter were 28.5cm and 3.5 mg/kg in TC4 soils on day 45 respectively. However the root length and root dry matter were significantly reduced in TC4 soils. The maximum reduction was observed on day 45. The mean values have decreased shown the inhibitory effect on root length and root dry matter with increase in the dosage of cadmium(II) concentration in soil which is proved in the earlier reports. The increase in growth parameters at low concentration of cadmium could be due to the presence of the phenomenon of hormesis, a dose dependent response of the seedlings where the low dose stimulates the growth while high dose suppresses the growth [31-33].

Table 3a: Shoot length, Root length, in different test concentrations on different harvest days *in* cadmium(II) contaminated soils

	Shoot length					**Root Length**			
Days	**C**	**TC1**	**TC2**	**TC3**	**TC4**	**C**	**TC1**	**TC2**	**TC3**
Day 15	10.1 ±2.03	18.19 ±2.36	20.8 ±2.45	21.9 ±3.65	23 ±3.54	2.8 ±2.47	2.7 ±3.47	2.7 ±2.0	2 ±2.53
Day 30	17.9 ±2.05	22 ±2.35	24.9 ±245	27 ±3.14	28 ±2.01	4.01 ±2.45	2.5 ±2.36	2.6 ±2.0	1.9 ±2.14
Day 45	20.5 ±2.65	24.5 ±2.15	25 ±2.08	27 ±2.09	28.5 ±2.03	6.8 ±2.09	2 ±2.69	2.6 ±2.14	1.8 ±2.98

Results are means ±SD(n=5)

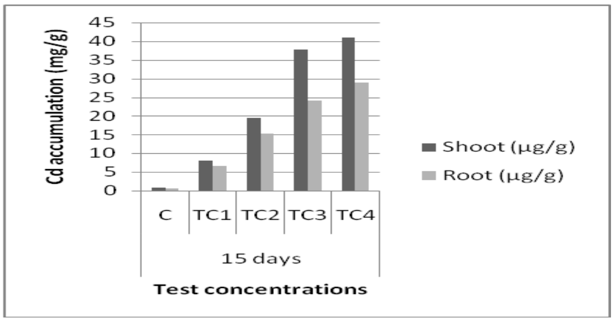
Table 3b: Shoot biomass and Root biomass in different test concentrations on different harvest days in cadmium(II) contaminated soils

Shoot dry matter					**Root dry matter**				
C	**TC1**	**TC2**	**TC3**	**TC4**	**C**	**TC1**	**TC2**	**TC3**	**TC4**
2	2.5	2.7	3	3	1	0.65	0.45	0.4	0.38

±3.20	±2.45	±2.12	±2.04	±3.25	±3.74	±2.08	±2.00	±2.36	±2.54
2.7 ±2.04	2.9 ±3.65	2.9 ±3.23	3.2 ±3.04	3.1 ±3.62	0.98 ±3.85	0.54 ±3.62	0.43 ±2.45	0.38 ±2.36	0.35 ±2.85
2.9 ±3.87	3 ±2.98	3.1 ±3.45	3.5 ±2.95	3.4 ±2.85	0.78 ±2.36	0.23 ±2.38	0.43 ±2.98	0.37 ±3.65	0.35 ±3.21

Results are means ±SD(n=5)

The maximum accumulation by roots and shoots were 30 mg/kg & 28.5mg/kg in TC4 soils on day 45. The mean values have increased with increased dosage of cadmium(II) concentrations in soil. Accumulation of cadmium(II)was found higher in shoots rather than in roots **(Table 4 & Figures 2 a-c).** The shoot metal concentration of plants can partially reflect the efficiency of plants on the remediation of soil heavy metals. Thus, the ratio of shoot metal concentration to total soil metal concentrations can also partially reflect the ability of plants to absorb soil heavy metals and transport them to shoots [34-35].



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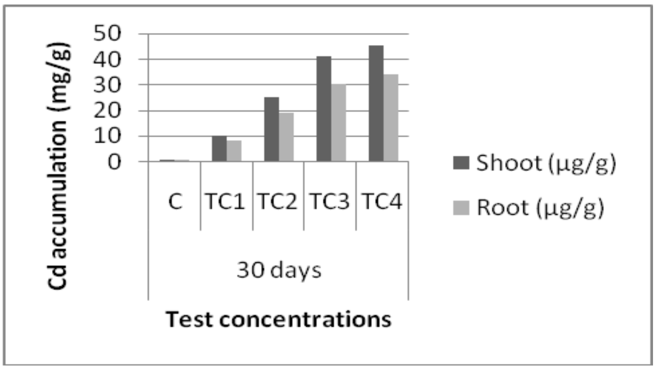

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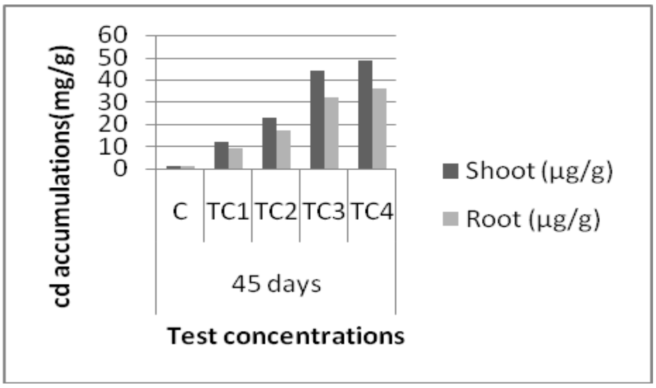

2c

Figure 2: a-c accumulations of cadmium(II) in shoot and root in different concentrations on day 15 – 45 in *Datura inoxia*

Table 4: Cadmium(II) accumulations in soils, shoot and root, Bioconcentration factor (BCF) and Translocation factor (TF) in different test concentrations on different harvest days

Cadmium(II) Accumulation	Harvest Days														
	15 days					30 days					45 days				
	C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4	C	TC1	TC2	TC3	TC4
Shoot (µg/g)	0.80 ±0.05	7.995 ±0.05	19.43 ±0.04	37.8 ±0.34	41.0 ±0.36	1.14 ±0.04	10.5 ±0.05	25.0 ±0.36	41.25 ±0.05	45.5 ±0.04	1 ±0.03	12.1 ±0.05	22.8 ±0.36	43.9 ±0.03	28.5 ±0.36
Root (µg/g)	0.68 ±0.08	6.56 ±0.014	15.37 ±0.03	24.1 ±0.35	28.9 ±0.08	0.93 ±0.014	8.25 ±0.30	19.0 ±0.20	30.5 ±0.014	34.1 ±0.03	1.12 ±0.08	9.35 ±0.36	17.1 ±0.014	32.14	30.0 ±0.08
BCF of Shoot	1.40	1.56	1.72	1.88	1.92	1.52	1.68	1.84	2.00	2.08	1.60	1.76	1.92	2.08	2.15
BCF of Root	1.20	1.28	1.36	1.20	1.36	1.24	1.32	1.40	1.48	1.56	1.28	1.36	1.44	1.52	1.60
TF	1.17	1.22	1.26	1.57	1.42	1.23	1.27	1.31	1.35	1.33	1.25	1.29	1.33	1.37	1.34

Results are means ±SD(n=5)

As shown in **Table 4** the maximum BCF of shoot and root were 2.15 and 1.60 in TC4 on day 45 respectively in cadmium(II) contaminated soils. The BCF values in experiment increased with increase the dosage of cadmium(II) concentrations and all of them higher than 1.0.

Translocation values in the experiment were 1.25 - 1.37 respectively. Plants must have the ability to translocate the metals from roots to above ground parts. As shown in **Table 2** the maximum BCF of shoot and root were 1.45 & 1.14 observed in TC4 on day 45 respectively in chromium(VI) contaminated soils. Maximum translocation values in the experiment were 1.19 observed in TC4 on day 45.

4. Conclusion

A significant increase shoots and root concentrations of the heavy metals cadmium(II) and chromium(VI) with increase in all test concentrations. In this pot study experiment the test plant species *Datura inoxia* shown positive response for its accumulation. The plant tolerance for cadmium(II) and chromium(VI) was evident in form of increase in shoot height and shoot dry matter of the plant. However root biomass was significantly reduced in soils with increase cadmium(II) and chromium(VI). Accumulation of metals cadmium(II) and chromium(VI) in *Datura inoxia* induces stress and causes growth reduction.. As shown in **Table 2 and 4** the maximum uptake was observed in TC4 on day 45 in both shoot and root (48.6 mg/g & 36.2 mg/g) in cadmium contaminated soils. Results of chemical analysis proved that both BCF and TF values are greater than 1.0. The maximum accumulation by roots and shoots were 34.8 mg/kg & 23.5 mg/kg in TC4 soils on day 45 in chromium(VI) contaminated soils. Results of chemical analysis proved that BCF values were greater than 1.0 whereas, TF values are less than 1.0. It can be concluded that selected test plant species, *Datura inoxia* could be good hyper accumulator for cadmium(II) rather than chromium(VI) However, being BCF values greater than 1.0 it can be considered as good for phytostabilizaton of chromium(VI). *Datura inoxia* is widely distributed, reproduced easily by its seed and have strong ecological adaptability. Hence *Datura inoxia* has great potential for remediation and could be considered as hyper accumulator for cadmium(II) & chromium(VI) contaminated soils.

References

[1] Yoon J, CaoX, Zhou Q, Ma LQ Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Sci. Total Environ. 368(2-3):456-464 2006.
[2] **Duffus, J. H.,**. Heavy metals- A meaningless term (IUPAC Technical Report). Pure and Applied Chemistry, **31**: 74-80 2002.
[3] USEPA Method 3051a: Microwave assisted acid dissolution of sediments, sludges, soils, and oils.2nd ed. U.S. Environmental Protection Agency, U.S. Government Printing Office, Washington, DC1997.
[4] Lasat MM. Phytoextraction of toxic metals: A review of biological mechanisms. J. Environ. Qual. 31: 109-120 2002 .
[5] Ruiz JM, Blasco B, Ríos JJ, Cervilla LM, Rosales MA, Rubio-Wilhelmi M M, Sánchez-Rodríguez E, Castellano R, Romero L. Distribution and efficiency of the phytoextraction of cadmium by different organic chelates. Terra LatinoAmericana 27(4):296-3012009.
[6] Shukla, O.P., S. Dubey and U.N. Rai.. Preferential accumulation of cadmium and chromium toxicity in *Bacopa monnieri* L., under mixed metal mreatments. *Bull. Environ. Contam Toxicol*., 78: 252-257 2007.
[7] WHO. Cadmium. In: *Air quality guidelines for Europe*, 2nd ed. Copenhagen, World Health Organization Regional Office for Europe 2000 (http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf)
[8] V.,Venkateshwar, P., Biosorption: An eco-friendly alternative for heavy metal removal. Afr. J. Biotechnol. **6**, 11,2924-2931 2007.
[9] Huang, X., Penrose, A., Glick, D. and Greenberg, B., "A multiprocess phytoremediation system for removal of poly aromatic hydrocarbons from contaminated soil." Environmental Pollution, 130.154-162.2004.
[10] A. N. Matthew, ―Phytoremediation of heavy metal contaminated soil, MSc dissertation, Graduate College, Oklahoma State Univ., Tulsa, Ok, 2005.
[11] Raskin, I., P.B.A.N. Kumar, S. Dushenkov- and D.E. Salt: Bioconcentration of heavy metals by plants.Curr. Opin. Biotechnol., 5, 285-290 1994.
[12] Salt, D.E., R.D. Smith and I. Raskin: Phytoremediation. Annu. Rev. Plant Physiol.Plant Mol. Biol., 49, 643-668 1998.
[13] Amaya-Chavez, A., L. Martinez-Tabche, E. Lopez-Lopez, M. Galar-Martinez. Methyl parathion toxicity to and removal efficiency by *Typha latifolia* in water and artificial sediments. Chemosphere 63: 1124-1129 2006.
[14] Tian, D., W. Xiang, W. Yan, W. Kang, X. Deng, Z. Fan.. Biological cycles of mineral elements in a young mixed stand in abandoned mining soils. Journal of Integrative Plant Biology 49: 1284-1293 2007.
[15] Garbisu C, Alkorta I Phytoextraction: A cost-effective plant-based technology for the removal of metals from the environment. Bioresour. Technol. 77(3):229-236 2001.
[16] Robinson B, Schulin R, Nowack B, Roulier S, Menon M, Clothier B, Green S, Mills T (Phytoremediation for the management of metal flux in contaminated sites. Forest, Snow Landscape Res. 80(2):221-234 2006.
[17] Alkorta I, Hernández-Allica J, Becerril J, Amezaga I, Albizu I, Garbisu C Recent findings on the phytoremediation of soils contaminated with environmentally toxic heavy metals and metalloids such as zinc, cadmium, lead, and arsenic. Rev. Environ. Sci. Biotechnol. 3(1):71-90 2004.
[18] Rajakaruna N, Tompkins KM, Pavicevic PG Phytoremediation: An affordable green technology for the clean-up of metal-contaminated sites in Sri Lanka. Ceylon J. Sci. (Biological Sciences) 35:25-392006
[19] Blaylock, M.J.-and J.W. Huang: Phytoextraction of metals. In: Phytoremediation of toxic metals using plants to clean up the environment (Eds: I. Raskin and B.D. Ensley). Wiley, New York. pp. 53-70 (2000).
[20] Cluis C (Junk-greedy Greens: phytoremediation as a new option for soil decontamination. BioTech J. 2:61-67 2004.
[21] Li JT, Liao B, Dai Z, Zhu R, Shu WS Phytoextraction of Cd-contaminated soil by carambola (*Averrhoa carambola*) in field trials. Chemosphere 76(9):1233-1239. 2009.
[22] Sun Y, Zhou Q, Diao C Effects of cadmium and arsenic on growth and metal accumulation of Cd-hyperaccumulator *Solanum nigrum* L. Bioresour. Technol. 99(5):1103-1110 2008.
[23] Sun Q, Ye ZH, Wang XR, Wong MH Cadmium hyperaccumulation leads to an increase of glutathione rather than phytochelatins in the cadmium hyperaccumulator Sedum alfredii. J. Plant Physiol. 164(11):1489-1498 2007.

[24] Saraswat S, Rai JPN (Phytoextraction potential of six plant species grown in multimetal contaminatedsoil. Chem. Ecol. 25(1):1-11 2009.
[25] Westerman. R.L. Sampling. Handling and Analyzing Plant Tissue Samples. In: *Soil Testing and Plant Analysis*. 3rd ed. Soil Science Society of America. *Inc. Madison*. Wisconsin. USA 1990.
[26] Anonymous. United State Environmental Protection Agency (USEPA), EPA Method 3051: Microwave assisted acid digestion of sediments, sludge, soils, and oils, In: Test Methods for Evaluating Solid Waste, third ed. Washington, DC 1995.
[27] Yoon, J., X. Cao, Q. Zhou and L.Q. Ma.. Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. *Science of the Total Environment*, 368: 456-464 2006.
[28] Cui, S., Q. Zhou and L. Chao. Potential hyperaccumulation of Pb, Zn, Cu and Cd in endurant plants distributed in an old smeltery, northeast China. *Environmental Geology*, 51: 1043-1048 2007.
[29] Li, M.S., Y.P. Luo and Z.Y. Su. Heavy metal concentrations in soils and plant accumulation in a restored manganese mineland in Guangxi, South China. *Environmental Pollution*, 147: 168-175 2007.
[30] Shanker, A.K., C. Cervantes, H. Loza-Tavera and S. Avudainayagam..Chromium toxicity inplants. *Environ. Int*., 31: 739-753 2005.
[31] Calabrese, E.J.. Defining hormesis. *Hum. Exp. Toxicol.*, 21: 91-97 2002.
[32] Peralta-Videa, J.R., J.L. Gardea-Torresdey, K.J. Tiemann, E. Gomez, S. Arteaga, E. Rascon and J.G. Parsons.. Uptake and effects of five heavy metals on seed germination and plant growth in Alfalfa (*Medicago sativa* L.). *Bull. Environ. Contam. Toxicol.*, 66: 727-734 2001.
[33] Shah, F.R., N. Ahmad, K.R. Masood and D.M. Zahid. The influence of Cd and Cr on the biomass production of Shisham (*Dalbergia sissoo* Roxb.) seedlings. *Pak. J. Bot*., 40(4): 1341-1348 2008.
[34] Baker, A.J.M., McGrath, S. P., Sidoli, C.M.D., Reeves, R.D., The possibility of in-situ heavy-metal decontamination of polluted soils using crops of metal-accumulating plants. Res. Conserv. Recycl. 11**,** 41-49 1994.
[35] Dahmani-Muller, H., van Oort, Balabane, M., Metal extraction by Arabidopsis halleri grown on an unpolluted soil amended with various metal-bearing solids: a pot experiment.Environ. Pollut. 114, 77-84 2001.