**Accumulation of Cu, Ni and Pb in Selected Native Plants Growing Naturally in Sediments of Water Reservoir Dams, Albaha Region, KSA**

Sami A. Zabin 1\* and Saad M. Howladar 2

1\* Chemistry Department, Faculty of Science- Albaha University, Al-Baha, KSA

2 Biology Department, Faculty of Science- Albaha University, Al-Baha, KSA

[samizabin@gmail.com](mailto:samizabin@gmail.com) or [szabin@bu.edu.sa](mailto:szabin@bu.edu.sa)

**Abstract:** The main purpose of this investigation was to evaluate the levels of Cu, Ni and Pb in aboveground tissues of selected seven native plants growing naturally in sediments of three water reservoir dams at Albaha province, KSA. The elements level was different among plant species at the same site. Variation in concentration was greater in the leaves compared to the stem tissue. The selected plant species accumulate much higher Cu in their aboveground tissues than Ni and Pb. Biological concentration factor (BCF) and translocation factor (TF) were calculated and results generally indicate that the BCFs <1 for Cu, Ni, and Pb in most plants studied. Only for Pb the BCFs >1 in *Pluchea Dioscroides (L.) DC*. at Medhas dam location. TF (leaf/stem) values > 1 in most of the plant species studied, indicating the ability to take up and translocate the studied heavy metals from the stem to the leaves with a slight variation in efficiency. The highest TF values found for *Lavandula Pubescens Decne*. were 3.346 for Pb and 2.069 for Cu. *Datura inoxia Mill.* (TF=2.066) was efficient in translocation of Cu metal and *Pulicaria Crispa (Forssk.) Oliv.* (TF=2.296) was efficient in translocation of Pb from the stem to leaves.

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**1. Introduction**

The main water supply people use in Albaha region, KSA comes from water reservoir dams. These dams are designed to hold water for some time, and during the retention time, many particles and silts eventually settle down in the bottom of reservoirs as sediments. Sediments represent the ultimate repository of most of the heavy metal contaminants from both natural and anthropogenic components that enter water ways (Ghrefat and Yusuf, 2006; Cevik et al. 2009; Wu et al. 2011; Adeleye and Shelle, 2011).

Heavy metals have ecological significance and increased the attention and focus due to their adverse effect on the environment and human health and become a serious major environmental problem worldwide (Zabin et al. 2008, Golia et al. 2008; Khan et al. 2008; Guala et al. 2010; Kaoud and El-Dahshan, 2010; Bandita et.al., 2011).

From a contamination perspective, sediments being a growing media for plants serve as the largest pool of heavy metal contaminants for bioaccumulation. (Friesl et al. 2006; Çevik et al. 2009; Banu et al. 2013; Zahra et al. 2014). Plants living in metal contaminated sediments can have exceptional properties which make them interesting for phytoremediation (Parizanganeh et al., 2010). There is evidence that many plant species have enormous ability to uptake and accumulate heavy metals and plays an important role in sequestering large quantities of metals from the environment by storing them in various tissues (Deng et al. 2004; Malik et al. 2010; Adams and Happines, 2010). Some tolerating and accumulating plants can adsorb heavy metals, and then transferring and storing them at the aboveground parts (phytoextraction) (Lasat 2002; Rafati et al. 2011; Ali et al. 2013). In the last few decades, phytoextraction have attracted attention and focus, and extensive research has been conducted to investigate the biology of metal phytoextraction (Lasat 2000). This technique can be used successfully for phytoremediation of soils and sediments polluted with heavy metals (Pilon-Smith, 2005; Milic et al. 2012). The success of phytoextraction is dependent on a plant's ability to accumulate sufficient metal concentration that is able to reduce the metal concentration in soils to regulatory levels with relatively few repeated cropping (McGrath et al. 2001; Clemens et al. 2002).

The efficiency of phytoextraction depends on several factors including the extent of sediment contamination, metal bioavailability, speciation of heavy metals and plant ability to intercept, absorb, and accumulate metals in aboveground tissues (Lasat 2000, sakakibara et al. 2011; Shabani and Sayadi 2012; Al-Qahtani, 2012).

Many studies showed that there is difference in metal accumulation between different plant species, and even though the same plant species have different uptake and translocation properties to heavy metals in plant parts (Stoltz and Greger 2002; Baldantoni et al. 2004; Yang et al. 2008; Guala et al. 2010). Most of the hyperaccumulators known so far are slow growing, low biomass yielding or unable to accumulate various metals combined (McGrath et al. 2001; Clemens et al. 2002).

Natural occurrence of native plant species capable of accumulating extraordinarily high metal levels makes the investigation of this process particularly interesting and the best and most cost-effective technique for reclaiming contaminated sediments. To our knowledge there are no studies were conducted to evaluate the ability of naturally grown plant species in the sediments of water reservoir dams at Albaha region, to tolerate and accumulate heavy metals in their different parts.

Therefore, this study was conducted to (1) determine the heavy metals (Cu, Ni and Pb) content of stems and leaves in selected plants growing naturally in sediments of water reservoir dams at Albaha region, KSA, (2) to evaluate the potential and ability of the selected plant species grown naturally in these sediments to accumulate and translocate heavy metals within their aboveground tissues, and (3) to determine the heavy metal selectivity and the difference in heavy metal concentration in each selected plant.

**2. Material and Methods**

***2.1 Study Site***

This investigation was conducted at Albaha province located in the southwestern part of Saudi Arabia. Albaha region falls in the semi-arid zone (El Atta et al. 2013). Three water reservoir dams locations namely: *Alsadr, Beedah and Midhas* are chosen in this study. These dams are built for irrigation and household water supplies.

***2.2 Plant and Sediment Sampling and Analysis***

Seven plant species grown naturally in the water reservoir dams' sediments were selected in the present study: *Pluchea dioscroides, Lavandula pubescens Decne, Pulicaria crispa (Forssk.) Oliv.* (medicinal plant), *Argemone ochroleuca Sweet, Xanthium strumarium L.* (toxic plant), *Ricinus communis* (Caster oil Plant) and *Datura inoxia Mill* (thorn-apple).Plant species collected were the most common/dominant species at these sites. During the full growing season (June – July 2014) plants and sediments were collected. Triplicate plant samples of different species were collected from different points in the sites. All plants were mature and appeared healthy and did not show any presence of parasites.

The plant samples were washed with tap water and rinsed with deionized water to remove any sediment particles attached to the plant surfaces. The aboveground tissues (stem and leaves) were separated and naturally dried in open air for 5 days and then dried in oven at 60°C for 24 hrs. to constant weight. The dried tissues were ground into powder and 0.5 gm dry weight sample was digested using 8 ml concentrated HNO3 and 2 ml HClO3 and kept for 5 hrs. (Deng et al. 2004). The extract was filtered and diluted up to 50 ml and used for metal concentration analysis.

Plant samples were sent for analysis to the Central Laboratory for Soil, Water & Plant Analysis (CLSWPA), Faculty of Agriculture - Fayoum University, Egypt. The plant samples were analyzed for heavy metals using Inductive Coupled Plasma Emission Spectroscopy (ICP-ES). Each sample was repeated twice and averaged. Data were presented as mean standard error and difference test was made using SPSS 20.

At the same time rhizosphere sediment samples (n = 6 from each site) were collected within rooting depth of about (20-30cm) from the base of each uprooted plant using regular auger sampler. The sediment sampling spots were cleared before sampling. The sediment samples (about 500 mg) at each site were taken in plastic bags and transferred to the laboratory for treatment and analysis. Sediment samples were air dried for 5 days on open trays. The samples were grounded and sieved through a 2mm mesh and then oven dried for two days at 50°C. Sediment samples were digested using 11466 ISO standard methods -the aqua regia digestion method (Parizanganeh et al. 2010). 0.3gm of each sample was treated with a solution mixture of 15 ml 35%HCl and 5ml 65% HNO3 and kept overnight and then heated for 2 hours and filtered. The sediment samples were analyzed for metal content at King Abdulaziz University using Perkin Elmer-3100 model Atomic Absorption Spectrophotometer. All the analysis were carried out twice and averaged for each sample.

***2.3 Calculation of Biological Concentration Factor (BCF) and Translocation Factor (TF)***

To study the accumulation ability characteristics of heavy metals in the aboveground tissues of the plants and transportation characteristics of the selected heavy metals, biological concentration factor (BCF) and translocation factor (TF) within a plant were calculated in the sediment-plant system (Deng et al. 2004; Yang et al. 2008; Malik et al. 2010; Usman et al. 2013). BCF and TF were calculated using the following equations (Usman et al. 2013):

***BCF*** *= (Conc. Of metal in different tissue) / (Conc. Of metal in sediment)… (1)*

***TF*** *= (Conc. Of metal in one part) / (Conc. Of metal in former part) … (2)*

***2.4 Statistical Analysis***

A statistical comparison of means was examined with one-way ANOVA at a significant level of p < 0.05 using SPSS statistics 20 software followed by Tukey-HSD test.

**3. Results and Discussion**

The plants collected from different three locations of selected water reservoir dams have different metal concentrations in different aerial parts. The Cu, Ni and Pb concentration for stems and leaves of the seven selected plants at the three sites are shown in table 1. All the three metals were observed in each and every plant. However, the plants selected were dominant plants growing naturally in the sediments.

***3.1 Distribution of heavy metals in plants***

Mean heavy metal (Cu, Ni and Pb) concentrations in aerial plant parts (stem and leaves) collected from the three dams sites (*Medhas Beedah and Alsadr*) are presented in table 1. The data show that the metal contents in the plant tissues varied among dams sites, which reflected the edaphic metal conditions in the sediments. Results show that the highest Cu concentration averaging (6.53-45.45) mg/kg in the aboveground tissues (stems and leaves) was measured in the different species. While, the concentration of Ni was in the average of (3.13-15.55) mg/kg and Pb in the average of (0.81-4.18) mg/kg. The selected plant species accumulate much higher Cu in their aboveground tissues than Ni and Pb. This may be attributed to the difference in concentration of these metals in the sediments and their bioavailability for the plants.

Variation in elements concentration have been observed and were greater in the leaves compared to the stem tissue. and also differed among elements. Metal concentrations in plant tissues also differed among species at the same site (table 1) indicating their different capacities for metal uptake. For instance, *Datura inoxia Mill* accumulated significantly higher Cu (45.45 mg/kg) and Ni (15.55 mg/kg) in its leaves than the other species at the Beedah dam site. Also the stem tissue of *Datura inoxia Mill* accumulate 22.0 mg/kg Cu and 12.15 mg/kg Ni. At the Alsadr dam site, *Xanthium Strumarium L*. attained an average concentration of 24.45 mg/kg Cu in the leaves and 23.13 mg/kg in the stem, which was much higher than the other species. *Ricinus communis L*. accumulated significantly higher Ni in its aboveground tissues (14.78 mg/kg in leaves and 10.31 mg/kg in stem) than the other species at Alsadr dam site. Our results for concentration of heavy metals in the aboveground tissues of two plant species (i.e. *Ricinus communis L*. *Ricinus communis L*. and *Xanthium Strumarium L*.) nearly similar to that obtained by Malik et al. (2010).

At the Medhas dam, *Pluchea dioscroides (L.) DC*. stem accumulated significantly higher Pb (4.18 mg/kg) than other species. While accumulate Cu (16.58 mg/kg) and Ni (4.27 mg/kg in its stem tissue.

Copper is an essential trace metal for plants and animals, and may become toxic to plants at tissue concentrations higher than 20 mg/kg (of dry weight) in the edible parts of plants (Prakash et al. 2007). In the present investigation the mean Cu concentration was found to be less in aboveground tissues in most of the studied plant species. An exception was observed in *Datura inoxia Mill*. stems and leaves (22.0 mg/kg and 45.45 mg/kg respectively) and in *Xanthium Strumarium L*. stems and leaves (23.13 and 24.45 mg/kg respectively) the concentration of Cu has exceeded the normal level (20 mg/kg) which may be toxic to plants and animals feeding on them (Prakash et al. 2007; Malik et al. 2010).

Lead toxicity in humans has been well documented and has chronic effect due to long exposure to low levels of lead (Flora et al., 2012). It is not reported to be essential for plants or animals. The normal range found in plants varied between 0.1 to 10 mg/kg dry weight (Prakash et al., 2007). According to Malik et al. (2010) the normal concentration is considered 5 mg/kg dry weight. In our study, the results showed that concentration of Pb in the aboveground tissues (stems and leaves) in all studied plant species were below the normal level.

Nickel recently has been recognized as an essential element for plants. It is involved in the enzyme urease and is a part of several other enzymes involved in plant metabolism. Ni concentration in majority of plant species is very low (0.05-10mg/kg dry weight) (Chen et al., 2009). The normal tissue concentration of Ni is reported to be 1 mg/kg dry weight and toxicity to plants (such as inhibition of mitotic activities, reduction in plant growth and adverse effects on fruit yield and quality) occurs at metal concentration beyond 50 mg/kg (Prakash et al. 2007; Chen et al. 2009). In the present investigation the level of Ni in the aboveground tissues of the studied plant species was found to accumulate higher than the normal concentration limit (i.e. 1 mg/kg) but, less than the toxic level of 50 mg/kg dry weight.

***3.2 Heavy metals in sediments***

According to the results presented in table 2 for average concentration of Ni, Cu and Pb in the sediments at *Alsadr, Beedah* and *Medhas* dams shows moderately high concentration for Ni and Cu while, low for Pb in all the three sites. The highest concentrations for Ni and Cu were at *Alsadr* dam followed by *Beedah* site. The variation in concentration of metals from one dam location to another could be attributed to the volume of anthropogenic activities near these sites and the geological distribution of minerals.Moreover, the variance in concentration is probably related to differences in sedimentary and particle size characteristics (Desmond et al. 2000)**.**

**Table 1. Average heavy metal content in aboveground tissues (mg/kg dry weight plant)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Location** | **Sample No.** | **Plant Name** | **Cu** | **Ni** | **Pb** |
| **Medhas Dam** | A1 | *Pluchea dioscroides (L.) DC. (Stem)* | 16.58 | 4.27 | 4.18 |
| A2 | *Pluchea dioscroides (L.) DC. (leaf)* | 16.75 | 6.72 | 3.70 |
| B1 | *Lavandula pubescens Decne. (Stem)* | 8.52 | 4.63 | 0.81 |
| B2 | *Lavandula pubescens Decne. (leaf)* | 17.63 | 4.52 | 2.70 |
| **Beedah Dam** | C1 | *Pulicaria crispa (Forssk.) Oliv. (Stem)* | 10.32 | 5.38 | 2.33 |
| C2 | *Pulicaria crispa (Forssk.) Oliv. (Leaf)* | 15.15 | 6.57 | 2.25 |
| D1 | *Argemone ochroleuca Sweet (Stem)* | 6.53 | 3.13 | 0.98 |
| D2 | *Argemone ochroleuca Sweet (Leaf)* | 8.67 | 4.82 | 1.60 |
| E1 | *Datura inoxia Mill. (Stem)* | 22.00 | 12.15 | 1.50 |
| E2 | *Datura inoxia Mill. (Leaf)* | 45.45 | 15.55 | 1.90 |
|  | F1 | *Xanthium strumarium L. (Stem)* | 23.13 | 5.95 | 1.72 |
| **Alsadr Dam** | F2 | *Xanthium strumarium L. (Leaf)* | 24.45 | 4.80 | 1.78 |
|  | G1 | *Ricinus communis L. (Stem)* | 12.63 | 10.31 | 1.68 |
|  | G2 | *Ricinus communis L. (Leaf)* | 12.73 | 14.78 | 2.32 |

**Table 2: Average concentration (mg/kg) of heavy metals in the sediments of the selected water reservoir dams**

|  |  |  |  |
| --- | --- | --- | --- |
| **Metals** | **Alsadr Dam** | **Beedah Dam** | **Medhas Dam** |
| Ni | 78.8 | 39.85 | 51.91 |
| Cu | 71.56 | 70.50 | 53.73 |
| Pb | 3.51 | 6.46 | 3.40 |

***3.3 Accumulation and translocation of heavy metals in Plants***

To study the accumulation ability characteristics of these metals in the aboveground tissues of the plants and transportation characteristics of the selected heavy metals, biological concentration factor (BCF) and translocation factor (TF) were calculated in the soil-plant system (Deng et al. 2004; Yang et al. 2008; Malik et al. 2010). In addition, BCF and TF can be used to evaluate the potential of the selected plant species for Phytoextraction and phtostabilization. Whereby, values of BCF greater than 1 are an indication of plant potential to phytoextract (Li et al. 2007; Juarez-Santillan et al. 2010).

Table 3 shows the BCFs of each tissue in different plant species collected. The results generally indicate that the BCFs of Cu, Ni, and Pb in all plants studied is higher for leaf than stem, but the difference is not significant. The results indicated that accumulation ability of Cu and Ni in stem and leaf of most plant species studied was weak as the BCFs values do not exceed 1. While, in case of Pb value of BCFs exceeded 1 only in *Pluchea Dioscroides (L.) DC.* in both tissues the stem and leaf at Medhas dam location.

**Table 3: Biological concentration factor (BCF) values of heavy metals in plants**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **BCF values of heavy metals in plants at (Beedah dam) Location** | | | | | | |
| Element | *Pulicaria crispa (Forssk.) Oliv.* | | *Argemone ochroleuca Sweet* | | *Datura inoxia Mill.* | |
| Stem | Leaf | Stem | Leaf | Stem | leaf |
| Cu | 0.146 | 0.215 | 0.093 | 0.123 | 0.312 | 0.645 |
| Ni | 0.135 | 0.165 | 0.079 | 0.121 | 0.305 | 0.390 |
| Pb | 0.361 | 0.348 | 0.151 | 0.248 | 0.232 | 0.294 |
| 1. **BCF values of heavy metals in plants at (Medhas dam) Location** | | | | | | |
|  | *Pluchea dioscroides (L.) DC.* | | *Lavandula pubescens Decne.* | |  | |
|  | Stem | Leaf | Stem | Leaf |  |  |
| Cu | 0.309 | 0.312 | 0.159 | 0.328 |  |  |
| Ni | 0.082 | 0.129 | 0.089 | 0.087 |  |  |
| Pb | 1.229 | 1.088 | 0.238 | 0.794 |  |  |
| 1. **BCF values of heavy metals in plants at (Alsadr dam) Locatio**n | | | | | | |
|  | *Xanthium strumarium L.* | | *Ricinus communis L.* | |  | |
|  | Stem | Leaf | Stem | Leaf |  |  |
| Cu | 0.323 | 0.342 | 0.176 | 0.178 |  |  |
| Ni | 0.076 | 0.061 | 0.131 | 0.188 |  |  |
| Pb | 0.490 | 0.507 | 0.479 | 0.661 |  |  |

Table 4 shows the TF values in the soil-plant system which indicate that TF > 1 in case of (leaf/stem) in most of the plant species studied in all locations. This indicate that the plant species screened has the ability to take up and translocate the studied heavy metals from the stem to the leaves. There was a slight variation in the efficiency of taking up and translocation of heavy metals from the stem to the leaves as shown in table 4. The highest TF value was found for *Lavandula Pubescens Decne.* At *Medhas dam* site were 3.333 for Pb and 2.069 for Cu. Also, *Datura inoxia Mill.* at *Beedah dam* site (TF = 2.066) was efficient in translocation of Cu metal from the stem to leaves. According to the present results it seems to be *Pluchea dioscroides (L.) DC.* plant species has good capacity for phytoextraction of lead, while *Lavandula pubescens Decne.* Plant species has the best ability to translocate Pb and Cu from stem to leaves and are suitable as phytostabilizers. Similarly, *Datura inoxia Mill.*, *Argemone ochroleuca Sweet and Ricinus communis L.* are good phytostabilizers for all metals studied. *Pluchea dioscroides (L.) DC. and Pulicaria crispa (Forssk.) Oliv.* Has the ability to translocate Ni from stem to leaves.

Accumulation of the selected metals varied slightly among plants species and uptake of the metal elements is primarily dependent on the plant species and its inherent controls, sediment quality and the sediment pH (Malik et al. 2010). Structure of the sediments has been considered very important that affect the extent of the metals taken up by the plants. The alkaline nature of the sediment (pH ranges 7.5 – 8.5) result in greater retention of metals and their lower solubility in the sediment of the study sites reduced the availability of metal ions to the plants. In addition, Cu, Ni, and Pb ions are carried out mainly via passive diffusion and active transport which is varied with plant species and metal form and concentration. Since Cu2+ ions inhibit Ni2+ ions influx and uptake competitively as they are absorbed by the same transport system (Chen et al. 2009). This is why the uptake of Cu was much more than that of Ni in all plant species studied in this work (table 1). Also, it is reported that over 50% of the Ni absorbed is retained in the roots because of sequestration in the cation exchange sites and immobilization in the vacuoles of roots (Sergin and Kozhevnikova 2006).

**4. Conclusion**

The analyses of the total concentration of the studied metals show slightly different in all sediment samples collected the three sites. It may be due to geological strata or volume of pollution at the studied sites. The selected plants uptake metals with difference and accumulate more levels in leaves than stem part. The studied plants accumulate more Cu metal than Ni and Pb in the aboveground tissues. The values of the BCF (< 1) indicate low accumulation characteristics of metals in these plant species with no significant difference, except in *Pluchea Dioscroides (L.) DC*. the BCF value for Pb was greater than one in both tissues (stem and leaf) at *Medhas* dam location. TF calculations in the soil-plant system, results show that TF (leaf/stem) values > 1 in most of the plant species studied, indicating the ability to take up and translocate the studied heavy metals from the stem to the leaves. There was a slight variation in the efficiency of taking up and translocation of heavy metals from the stem to the leaves. The highest TF value was found for *Lavandula Pubescens Decne.* were 3.346 for Pb and 2.069 for Cu; *Datura inoxia Mill.* (TF = 2.066) was efficient in translocation of Cu metal and *Pulicaria Crispa (Forssk.) Oliv.* (TF = 2.296) was efficient in translocation of Pb from the stem to leaves.

**Table 4: Translocation factor (TF) values of heavy metals in soil-plant system**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 1. **TF values of heavy metals in soil-plant system at (Beedah dam) Location** | | | | | | |
| Element | *Pulicaria crispa (Forssk.) Oliv.* | | *Argemone ochroleuca Sweet* | | *Datura inoxia Mill.* | |
| Stem/soil | Leaf/stem | Stem/soil | Leaf/stem | Stem/soil | Leaf/stem |
| Cu | 0.146 | 1.468 | 0.093 | 1.330 | 0.312 | 2.066 |
| Ni | 0.135 | 1.221 | 0.079 | 1.540 | 0.305 | 1.280 |
| Pb | 0.361 | 0.966 | 0.151 | 1.633 | 0.232 | 1.266 |
| 1. **TF values of heavy metals in soil-plant system at (Medhas dam) Location** | | | | | | |
|  | *Pluchea dioscroides (L.) DC.* | | *Lavandula pubescens Decne.* | |  | |
|  | Stem/soil | Leaf/stem | Stem/soil | Leaf/stem |  |  |
| Cu | 0.309 | 1.010 | 0.159 | 2.069 |  |  |
| Ni | 0.082 | 1.574 | 0.089 | 0.976 |  |  |
| Pb | 1.229 | 0.885 | 0.238 | 3.333 |  |  |
| 1. **TF values of heavy metals in soil-plant system at (Alsadr dam) Location** | | | | | | |
|  | *Xanthium strumarium L.* | | *Ricinus communis L.* | |  | |
|  | Stem/soil | Leaf/stem | Stem/soil | Leaf/stem |  |  |
| Cu | 0.323 | 1.057 | 0.176 | 1.008 |  |  |
| Ni | 0.076 | 0.807 | 0.131 | 1.433 |  |  |
| Pb | 0.490 | 1.035 | 0.479 | 1.381 |  |  |

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**Corresponding Author:**

Dr. Sami A. Zabin

Department of Chemistry

Faculty of Science

Albaha University

Al-Baha, Saudi Arabia

E-mail: [samizabin@gmail.com](mailto:geetakh@gmail.com) or [szabin@bu.edu.sa](mailto:szabin@bu.edu.sa)

**References**

1. Adams I.V. and Happines I.V. (2010). Quantitative specification of potentially toxic metals in expired canned tomatoes found in village markets. Nature and Science, 8(4): 54-59.
2. Adeleye A.O., Shelle R.O.D., Akinnigbagbe A.E. (2011). Pollutant dynamics and distribution in sediments north of Lagos Lagoon ecosystem. Nature and Science, 9(5): 13-16.
3. Ali H. (2013): Phytoremediation of heavy metals- Concepts and applications. Chemosphere, 91: 869-881.
4. Al-Qahtani K.M. (2012). Assessment of heavy metals accumulation in native plant species from soil contaminated in Riyadh city, Saudi Arabia. Lif. Sci. J., 9(2): 384-392.
5. Baldantoni D., Alfani A., Di Tommasi P., Bartoli G., De Santo A.V. (2004): Assessment of macro and microelement accumulation capability of two aquatic plants. Environ. Pollut. 130: 149-156.
6. Bandita Deo, Gayatri Nahak, and Sahu R.K. (2011). Studies on the uptake of heavy metals by selected plant species growing on coal mine spoils in sub-tropical regions of India. Journal of American Science, 7(1): 26-34.
7. Banu Z., Chowdhury M., Hussain M., Nakagami K. (2013): Contamination and Ecological Risk Assessment of Heavy Metal in the Sediment of Turag River, Bangladesh: An Index Analysis Approach. Journal of Water Resource and Protection 5(2): 239-248.
8. Cevik F., Goksu M.Z.L., Derici O.B., Findik O. (2009): An assessment of metal pollution in surface sediments of sehan dam by using enrichment factor, geoaccumulation index and statistical analyses. Envirn. Monit. Assess. 152: 309-317.
9. Chen C., Huang D., Liu J. (2009): Functions and toxicity of nickel in plants: recent advances and future prospects. Clean. 37 (4-5): 305-313.
10. Chojnacka K., Chojnacki A., Go´recka H., Go´recki H., 2005. Bioavailability of heavy metals from polluted soils to plants. Sci Total Environ. 337, 175–182.
11. Clemens S., Palmgren M.G., Kramer U. (2002). A long way ahead: Understanding and engineering plant metal accumulation. Trends Plant Sci. 7: 309-315.
12. Dan T., Hale B., Johnson D., Conard B., Stiebel B., Veska E. (2008): Toxicity thresholds for oat (Avena sativa L.) grown in Ni-impacted agricultural soils near Port Colborne, Ontario, Canada. Canadian Journal of Soil Science. 88: 389-398.
13. Deng H., Ye Z.H., Wong M.H. (2004): Accumulation of Lead, Zinc, Copper and Cadmium by 12 wetland plant species thriving in metal-contaminated sites in China. Environmental pollution. 132: 29-40.
14. Desmond E., Walling P.N., Owens B.D., Waterfall, Graham J.L.L, Paul D.W. (2000): The particle size characteristics of ﬂuvial suspended sediment in the Humber and Tweed catchments, UK. The Science of the Total Environment. 251/252: 205-222.
15. El Atta H, Aref I., Ahmed A. (2013): Effect of acacia spp. on soil properties in the highlands of Saudi Arabia. Life Science Journal. 10(4): 100-105.
16. Flora G., Gupta D., Tiwari A. (2012): Toxicity of lead: a review with recent updates. Interdisciplinary Toxicology. 5(2):47–58.
17. Friesl, W., Friedl, J., Platzer, K., Horak, O., Gerzabek, M.H. (2006): Remediation of contaminated agricultural soils near a former Pb/Zn smelter in Austria: batch, pot and field experiments. Environmental Pollution. 144: 40-50.
18. Ghrefat H., Yusuf N. (2006): Assessing Mn, Fe, Cu, Zn, and Cd pollution in bottom sediments of Wadi Al-Arab Dam, Jordan. Chemosphere. 65: 2114–2121.
19. Golia E. E., Dimirkou A., Mitsios I. K. (2008): Levels of heavy metals pollution in different types of soil of central Greece. Bull Environ Contam Toxicol. 80: 206–210.
20. Guala S.D., Vega F.A., Covelo E.F. (2010): Heavy metal concentrations in plants and different harvestable parts: A soile plant equilibrium model. Environmental Pollution. 158: 2659-2663.
21. Juarez-Santillan L.F., Lucho-Constantino C.A., Vazquez-Rodriguez G.A., Ceron-Ubilla N.M., Beltran-Hernandez R.I. (2010): Manganese accumulation in plants of the mining zone of Hidalgo, Mexico. Bioresource Technology 101: 5836–5841.
22. Kaoud H.A. and El-Dahshan A.R. (2010). Bioaccumulation and histopathological alterations of the heavy metals in *Oreochromis niloticus* fish. Nature and Science, 8(4): 147-156.
23. Khan S., Cao Q., Zheng Y.M., Huang Y.Z., Zhu Y.G. (2008): Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environmental Pollution, 152: 686-692.
24. Lasat M.M. (2000): Phytoextraction Of Metals From Contaminated Soil: A Review Of Plant/Soil/Metal Interaction And Assessment Of Pertinent Agronomic Issues. Journal of Hazardous Substance Research, vol 2: (5-1)-(5-25).
25. Lasat M.M. (2002): Phytoextraction of Toxic Metals: A Review of Biological Mechanisms. J. Environ. Qual. 31: 109–120 (2002).
26. Li M.S., Luo Y.P., Su Z.Y. (2007): Heavy metal concentration in soils and plant accumulation in a restored manganese mine land in Guangxi, South China. Envirnmental Pollution. 147: 168-175.
27. Malik R.N., Husain S.Z., Nazir I. (2010): Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. Pak. J. Biol. 42(1): 291-301.
28. McGrath, S.P., Zhao F.J., Lombi E. (2001): Plant and rhizosphere processes involved in phytoremediation of metal-contaminated soils. Plant Soil. 232: 201-214.
29. Milic, D., Lukovic, J., Ninkov, J., Zeremski-Skoric, T., Zoric, L., Vasin, J., Milic, S. (2012): Heavy metal content in halophytic plants from inland and maritime saline areas. Cent. Eur. J. Biol. 7: 307–317.
30. Parizanganeh A., Hajisoltani P., Zamani A. (2010): Concentration, distribution and comparison of total and bioavailable Mmetals in top soils and plants accumulation in Zanjan Zinc Industrial Town-Iran. Procedia Envirnmental Sciences. 2: 167-174.
31. Pilon-Smits, E. (2005): Phytoremediation. Annual Revisions in Plant Biology. 56: 15–39.
32. Prakash V.H.B., Manjula M.N., Bhargavi M.V., Parama V.R.R. (2007): Heavy metal and Micronutrient levels in vegetables, fruits, and other crops grown using sewage in Peri Urban Bangalore, In: International Conference on 21st Century Challenges to Sustainable Agri-Food Systems: Biotechnology, Environment, Nutrition, Trade and Policy, (15-17 March, 2007). P240-249.
33. Rafati, M., Khorasani, N., Moattar, F., Shirvany, A., Moraghebi, F., Hosseinzadeh, S. (2011): Phytoremediation potential of Populus alba and Morus alba for cadmium, chromium and nickel absorption from polluted soil. Int. J. Environ. Res. 5: 961–970.
34. Sakakibara, M., Ohmori, Y., Ha, N.T.H., Sano, S., Sera, K. (2011): Phytoremediation of heavy metal contaminated water and sediment by Eleocharis acicularis. Clean: Soil, Air, Water 39: 735–741.
35. Seregin I.V., Kozhevnikova A.D. (2006): Physiological role of nickel and its toxic effects in higher plants. Russ. J. plant Physiol. 53: 257-277.
36. Shabani, N., Sayadi, M.H. (2012): Evaluation of heavy metals accumulation by two emergent macrophytes from the polluted soil: an experimental study. Environmentalist 32: 91–98.
37. Stoltz E., Greger M. (2002): Accumulation properties of As, Cd, Cu, Pb, and Zn by four wetland plant species growing on submerged mine tailings. Environ. Exp. Bot. 47: 271-280.
38. Usman A.R.A., Alkredaa R.S., Al-Wabel M.I. (2013): Heavy metal contamination in sediments and mangroves from the coast of RedSea: Avicennia marina as potential metal bioaccumulator. Ecotoxicology and Environmental Safety, 97: 263–270.
39. Wu G.H., Shan S.C., Shui R.C., Fang T.C. (2011): Accumulation and remobilization of metals in superficial sediments in Tianjin, China. Environ Monit Assess. 173: 917–928.
40. Yang H., Shen Z., ZhoS., Wang W. (2008): Heavy metals in wetland plants and Ssoil of Lake Taihu, Chaina. Environmental Toxicology and Chemistry. 27 (1): 38-42.
41. Zabin, Sami A., Foaad M.A., Al-Ghamdi, A.Y. (2008): Non-carcinogenic risk assessment of heavy metals and fluoride in some water wells in the Al-Baha region, Saudi Arabia', Human and Ecological Risk Assessment: An International Journal. 14(6): 1306-1317.
42. Zahra A., Hashmi M. Z. Malik R. N., Ahmed Z. (2014): Enrichment and geo-accumulation of heavy metals and risk assessment of sediments of the Kurang Nallah—Feeding tributary of the Rawal Lake Reservoir, Pakistan. Science of the Total Environment, 470–471: 925–933.
43. Zhitong Yao, Jinhui Li, Henghua Xie, Conghai Yu. (2012): Review on remediation technologies of soil contaminated by heavy metals. Procedia Environmental Sciences. 16: 722 – 729.

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