

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

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**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 innoxia* 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 HNO<sub>3</sub> and 2 ml HClO<sub>3</sub> 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% HNO<sub>3</sub> 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):

$$BCF = (\text{Conc. Of metal in different tissue}) / (\text{Conc. Of metal in sediment}) \dots (1)$$

$$TF = (\text{Conc. Of metal in one part}) / (\text{Conc. Of metal in former part}) \dots (2)$$

### 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 innoxia 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 innoxia 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.* 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 innoxia 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	<i>Pluchea dioscroides (L.) DC. (Stem)</i>	16.58	4.27	4.18
	A2	<i>Pluchea dioscroides (L.) DC. (leaf)</i>	16.75	6.72	3.70
	B1	<i>Lavandula pubescens Decne. (Stem)</i>	8.52	4.63	0.81
	B2	<i>Lavandula pubescens Decne. (leaf)</i>	17.63	4.52	2.70
Beedah Dam	C1	<i>Pulicaria crispa (Forssk.) Oliv. (Stem)</i>	10.32	5.38	2.33
	C2	<i>Pulicaria crispa (Forssk.) Oliv. (Leaf)</i>	15.15	6.57	2.25
	D1	<i>Argemone ochroleuca Sweet (Stem)</i>	6.53	3.13	0.98
	D2	<i>Argemone ochroleuca Sweet (Leaf)</i>	8.67	4.82	1.60
	E1	<i>Datura innoxia Mill. (Stem)</i>	22.00	12.15	1.50
	E2	<i>Datura innoxia Mill. (Leaf)</i>	45.45	15.55	1.90
Alsadr Dam	F1	<i>Xanthium strumarium L. (Stem)</i>	23.13	5.95	1.72
	F2	<i>Xanthium strumarium L. (Leaf)</i>	24.45	4.80	1.78
	G1	<i>Ricinus communis L. (Stem)</i>	12.63	10.31	1.68
	G2	<i>Ricinus communis L. (Leaf)</i>	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 phytostabilization. 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**

A) BCF values of heavy metals in plants at (Beedah dam) Location						
Element	<i>Pulicaria crispa (Forssk.) Oliv.</i>		<i>Argemone ochroleuca Sweet</i>		<i>Datura innoxia Mill.</i>	
	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
B) BCF values of heavy metals in plants at (Medhas dam) Location						
	<i>Pluchea dioscroides (L.) DC.</i>		<i>Lavandula pubescens Decne.</i>			
	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		
C) BCF values of heavy metals in plants at (Alsadr dam) Location						
	<i>Xanthium strumarium L.</i>		<i>Ricinus communis L.</i>			
	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  $\text{Cu}^{2+}$  ions inhibit  $\text{Ni}^{2+}$  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**

<b>A) TF values of heavy metals in soil-plant system at (Beedah dam) Location</b>						
Element	<i>Pulicaria crispa (Forssk.) Oliv.</i>		<i>Argemone ochroleuca Sweet</i>		<i>Datura inoxia Mill.</i>	
	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
<b>B) TF values of heavy metals in soil-plant system at (Medhas dam) Location</b>						
Element	<i>Pluchea dioscroides (L.) DC.</i>		<i>Lavandula pubescens Decne.</i>			
	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		
<b>C) TF values of heavy metals in soil-plant system at (Alsadr dam) Location</b>						
Element	<i>Xanthium strumarium L.</i>		<i>Ricinus communis L.</i>			
	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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