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Phytoremediation and Accumulation Characteristics of Heavy Metals by Some Plants in Wadi Alargy-Wetland, Taif-KSA

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Abstract: The present study proved the phytoremediation potentiality and accumulation characteristics of sixteen elements and heavy metals; namely, N, P, K, Ca, Mg, Mn, B, Cu, Fe, Ni, Pd, Co, As, Cr, Cd, Mo, in the different plant organs of four plants; *Amaranthus hybridus, Chenopodium ambrosioides, Mentha longifolia* and *Typha domingensis*. The "translocation factor" (TF) and the "bioconcentration factor" (BCF) for element and metals within the studied species was calculated. Comparing metal contents in different plant organs growing in the contaminated soil showed relatively higher values as compared to those growing in noncontaminated one. As an example, the lead (Pd) concentrations of noncontaminated *A. hybridus* samples were 12.71, 11.34 and 2.53 (mg kg^{-1} DW) for root, stem and leaves; respectively and these values greatly increased to 93.9, 96.76 and 64.11(mg kg^{-1} DW) for the same plant organs but growing in contaminated soil. Accumulation rates of *M.longifolia* toward the measured elements and heavy metals can be arranged in the following order; Pd>Cu>Fe>Mn>K>Ca>B>Cr>As>Mg>P>N>Ni>Mo>Co>Cd. TF recorded maximum value of (5.881) for the translocation of arsenic (As) in *T.domingensis* growing in noncontaminated soil. According to the accumulation rates of the measured element and metals in either contaminated or noncontaminated sites, (TF) and the (BCF), the phytoremediation potentiality of the studied species can arranged in the following order: *T.domingenesis> A.hybridus> M.longifolia> C.ambrosioides*. Comparing different plant organs of the studied species in most cases, nominate the accumulation organs in the following order; stem> root> leaves.

Key words: Phytoremediation · T ranslocation factor · Bioconcentration factor · *Amaranthus hybridus* · *Chenopodium ambrosioides* · *Mentha longifolia* · *Typha domingensis*

INTRODUCTION

Heavy metal contamination of soil and aquatic ecosystem is a major environmental and human-health concern because unlike other contaminants, heavy metals are not biodegradable and tend to accumulate in living systems [1, 2]. Regarding the role of heavy metals in biological systems, there are two groups. The first termed essential heavy metals which are needed by living organisms in minute quantities for the physiological and biochemical purposes. Examples of this category are Fe, Mn, Cu, Zn and Ni. The second group called non-essential heavy metals, which are not needed by living organisms for any biochemical or physiological functions and includes heavy metals like Cd, Pb, As, Hg and Cr [3-5]. Various industrial processes like pharmaceuticals, detergent, chemical factories and textile industries, increase the water and soil input of the heavy metals and that causes major hazards facing our environment [6, 7]. In addition, water and soil pollution with heavy metals have adverse harmful effects on human health even at very low concentrations as it may damage nerves, liver, bones, block functional groups of vital enzymes and are possible carcinogens [8, 9].

Phytoremediation basically refers to the use of plants and associated soil microbes to reduce or remove the high concentrations of heavy metals in the environments [10]. Recent researches have studied the tolerance and accumulation of heavy metals in plants. For instance, [11] studied cadmium in plants growing on polluted soils; [12]

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showed the manganese uptake and accumulation in a woody hyperaccumulator; [13] studied phytoremediation of arsenic using floating macrophytes; [7] proved the phytoremediation potentiality of *Cyperus articulates*; [14] reported the effect of phytoremediation on proteomic analysis of *Scirpus triqueter*.

In Saudi Arabia the phytoremediation researches are scanty and still underworked area especially in the industrial areas at many regions. Thus the aim of the present study was to determine the phytoremediation potentiality and accumulation characteristics of some heavy metals and elements in different plant organs of four plant species; *Amaranthus hybridus* (Amaranthaceae), *Chenopodium ambrosioides* (Chenopodiacea), *Mentha longifolia* (Labiatae) and *Typha domingensis* (Typhaceae), naturally growing in wetlands of two different sites located at Wadi Al-Argy in Taif area. The current work illustrated the potentiality of using these plants as phytoremediators.

MATERIALS AND METHODS

Plant Samples, Water and Soil Preparations: Soil and water samples in addition to biomass of the four plant species; *Amaranthus hybridus, Chenopodium ambrosioides, Mentha longifolia* and *Typha domingensis*, were collected from two different sites at Wadi Al-Arg, Taif province, KSA. One site was a wetland contaminated with industrial wastewater (21^0 19/ N and E 40^0 32/ and altitude of 1591) and the other was noncontaminated wetland near Seesed park (21^0 17/ N and 40^0 29/ E and altitude of 1595m).

Plant samples washed several times by deionized water to remove extraneous and salts then separated to individual organs of leaves, stems (rhizomes in case of *Typha domingensis*) and roots. Plant samples then dried in an oven at 50°C for 48 hrs, chopped and sieved. The particles with an average 0.5 mm were used for obtaining powdered plant material and then ready for measuring heavy metal concentrations.

Plant and Soil Analyses: Plant samples (0.3 g) were digested with a solution of 4/1 (v/v) HNO_3: $HClO_4$. Soil samples were taken from the two sites, air-dried at room temperature for 15 days and then ground to pass through 2mm nylon sieve. Exact one gram of soil samples were digested in 1:2:2 (v:v:v) HNO_3: HCl:$HClO_4$ mixture to obtain the total heavy metal content. Concentration of different heavy metals in plant and soil samples were determined by inductively coupled plasma-atomic emission spectroscopy (ICP-Ultima (Z) VERSION 5 SOFTWARE, IRIS Intrepid II, Thermo Electron Corporation, USA). This analysis was carried out in the Soils, Water and Environment Research Institute (SWERI) which belongs to Agricultural Research Center (ARC), Giza, Egypt. Soil mechanical and chemical analyses were carried out according to the methods described by [15].

Translocation Factor and Bioconcentration Factor: The "translocation factor" (TF) for metals within the studied species was calculated. TF is expressed by the ratio of metal concentration in plant shoots to that in plant roots. The "bioconcentration factor" (BCF) was calculated, which is the ratio of metal concentration in the plant roots to that in the soil sediments [16]. BCF and TF provide two indexes of the ability of the plant to accumulate a particular metal from the soil solution [17].

Analysis of Data: Data were analyzed by ANOVA test to determine the significant differences among the mean values at the $P< 0.05$ probability level using a "general linear model" procedure of the Statistical Analysis System (SAS) program (SAS Institute, 1985).

RESULTS AND DISCUSSION

Water and Soil Analyses: Comparative analyses of the element and heavy metal concentration in the noncontaminated and contaminated water and soil samples showed three categories; the first showed an elevated element level in the contaminated water and soil samples and included (SO_4, K, Ca, Mg, Na, NH_4, Fe, Mn, Zn, Cu, B, Cd, Cr, Ni, Pd, As). Iron for example, recorded 4.53 and 16.54 (mg kg^{-1} D.W.) in the contaminated water and soil; respectively and these values significantly ($p<0.05$) reduced into 0.959 and 7.96 (mg kg^{-1} D.W.) in the noncontaminated water and soil; respectively (Table 1). The second category included (soluble CO_3, NO_3, P) and these elements attained comparatively higher values in case of noncontaminated water and soil samples. The mean values of phosphorus for instance, recorded 0.03 and 5.34 (mg kg^{-1} D.W.) in the contaminated water and soil samples; respectively and these values increased to 0.42 and 6.76 (mg kg^{-1} D.W.) in the noncontaminated water and soil. The third group including (Cl, HCO_3, Mo, Co) and this elements showed relatively higher values in case of noncontaminated water samples than that of contaminated one, while the element attained comparatively lower values in the noncontaminated soil samples than the contaminated one.

Table 1: Selected chemical, metal content and physical parameters (in three sequential extractions) of the investigated noncontaminated (a) and contaminated (b) water and soil samples. (Mean values are given ±SD)

	Water samples		Soil samples	
Variable	a	b	a	b
Total dissolved salts (mmhos/cm)				
EC	0.86[a]±0.009	0.74 [a] ±0.004	1.4[b*]±0.003	2.36[b] ±0.24
pH value	7.35 [a] ±0.080	7.40 [a] ±0.050	7.8 [a] ±0.09	8.00 [a] ±0.05
Dissolved anions (mg kg^{-1} D.W)				
Cl^-	2.09[a b] ±0.021	1.38 [a] ±0.064	8.15 [b] ±0.19	26.72 [b*] ±1.06
SO_4^{--}	2.26 [a] ±0.004	2.28 [a] ±0.098	4.56 [a] ±0.14	57.13 [b*] ±2.71
Soluble CO_3^{--}	0.03 [a] ±0.001	0.00 ±0.00	0.11 [a] ±0.077	0.06 [a] ±0.005
HCO_3^-	3.11 [a] ±0.023	2.00 [a] ±0.077	1.32 [a] ±0.004	1.57 [a] ±0.114
Dissolved cations (mg kg^{-1} D.W)				
Potasium	0.41 [a] ±0.005	0.88 [a] ±0.022	0.63 [a] ±0.001	4.43 [b*]±0.14
Calcium	0.06 [a] ±0.003	0.87 [b] ±0.005	3.05 [b] ±0.032	32.82 [b] ±1.32
Magnesium	0.11 [a] ±0.009	0.54 [a] ±0.006	1.76 [a] ±0.011	6.28 [a*] ±0.22
Sodium	2.26 [a] ±0.014	4.16 [a] ±0.015	8.59 [a b]±0.17	14.33 [b*] ±0.21
Elements (mg kg^{-1} D.W.)				
NH_4^+	1.66 [a] ±0.003	16.54 [a] ±0.032	6.75 [a] ±0.05	23.27 [b*]±1.07
NO_3^-	2.33 [a] ±0.022	0.24 [a] ±0.003	96.3[c]±2.14	5.23 [b**] ±0.24
P	0.42 [a] ±0.001	0.03 [a] ±0.0004	6.76 [a] ±0.18	5.34 [a] ±0.05
Fe	0.95 [a] ±0.06	4.53 [b] ±0.18	7.96 [b] ±1.02	16.54 [b*] ±0.66
Mn	0.074 [a] ±0.004	0.34 [a] ±0.003	0.98 [a] ±0.002	3.25 [a] ±0.21
Zn	0.577 [a] ±0.0003	2.51 [b] ±0.024	2.98 [b] ±0.11	5.23 [b] ±0.47
Cu	0.211 [a] ±0.007	0.492 [a] ±0.003	1.32 [a b] ±0.004	5.64 [c**] ±0.034
B	0.047 [a] ±0.0003	0.185 [a] ±0.011	0.345 [a] ±0.005	0.66 [a] ±0.047
Mo	0.98 [a] ±0.007	0.33 [a] ±0.002	0.138 [a] ±0.004	1.52 [b*] ±0.08
Cd	0.05 [a] ±0.0003	0.22 [a] ±0.004	1.25 [a b] ±0.012	19.53 [b*]±1.08
Co	0.13 [a] ±0.0009	0.09 [a] ±0.001	0.05 [a] ±0.004	0.206 [a] ±0.005
Cr	0.33 [a] ±0.004	2.09 [a] ±0.541	0.198 [a] ±0.002	2.75 [a] ±0.004
Ni	0.69 [a] ±0.02	3.23 [b] ±0.84	5.31 [b] ±0.042	34.28 [c*]±0.88
Pd	0.89 [a] ±0.006	2.824 [a] ±0.015	6.38 [a] ±0.002	18.33 [a] ±0.69
As	0.106 [a] ±0.008	0.529 [a] ±0.004	0.371 [a] ±0.02	2.75 [a] ±0.054
Soil mechanical analysis				
Coarse sand (%)			13.5 [a] ±0.65	22.2 [b*]±0.22
Fine sand (%)			61.5 [a] ±2.14	60.5 [a] ±2.45
Silt (%)			10.1 [a] ±0.24	8.3 [a] ±1.25
Clay (%)			14.9 [b] ±1.03	9.0 [a*]±0.33
Porosity (%)			64.63 [a] ±2.33	56.64 [a] ±3.24
Soil texture			Sandy loam	sandy

* p=0.05, ** p =0.01

In general, heavy metal contents in either contaminated water or soil samples in the study area recorded elevated values than those of noncontaminated samples. This is in accordance with results obtained by many authors like [7, 18].

The presented data in (Table 1) revealed that the water and soil pH varied from 7.35 in the noncontaminated water samples to 8 in the contaminated soil samples. Electric conductivity (EC) ranged between a minimum value of (0.74 mmhos/cm) for the contaminated water samples to a maximum of (2.36 mmhos/cm) for the contaminated soil samples. In addition, the contaminated soil showed sandy soil texture while that of noncontaminated soil was sandy loam. Generally, the contaminated water and soil samples recorded higher EC as compared to those of noncontaminated and this was confirmed by [19].

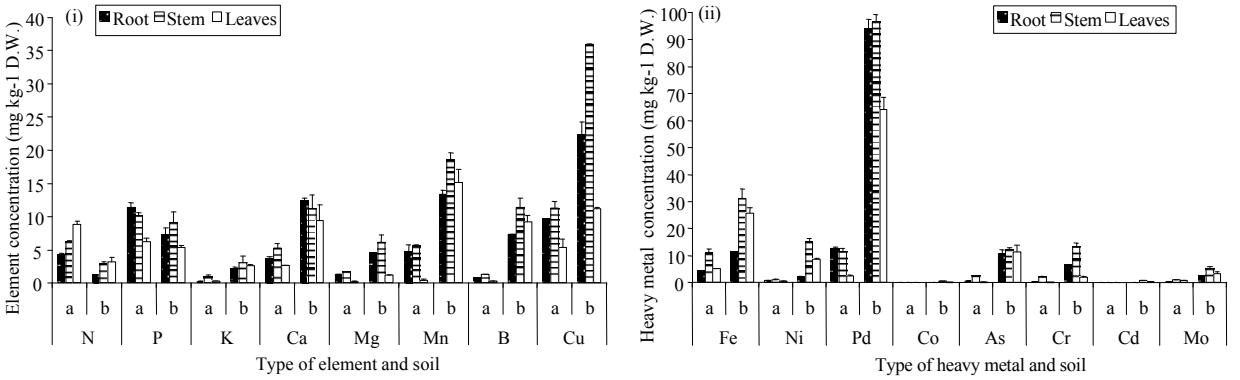

Fig. 1: Element concentration (i) and heavy metal concentration (ii) in root, stem and leaves of *Amaranthus hybridus* naturally growing in noncontaminated (a) and contaminated (b) soil of Wadi Al-Argy wetland. (Values are the mean + SD of three replicates)

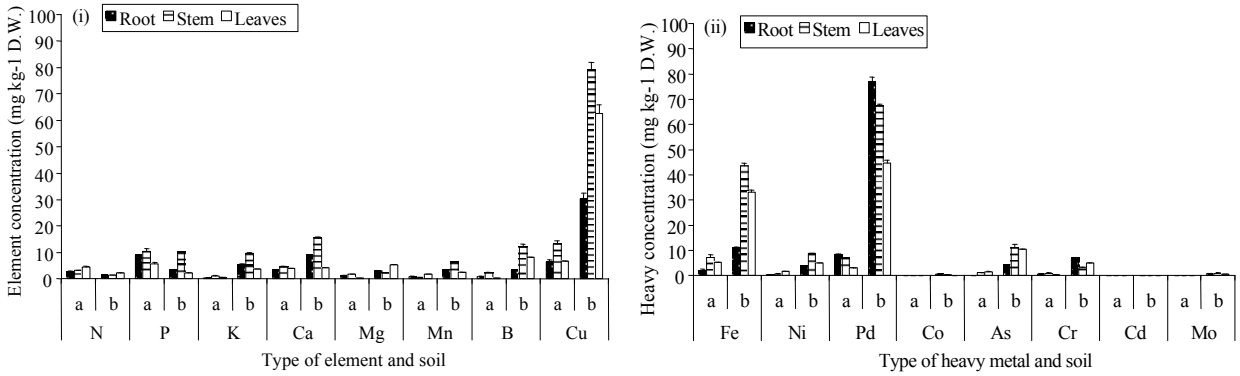

Fig. 2: Element concentration (i) and heavy metal concentration (ii) in root, stem and leaves of *Chenopodium ambrosiodes* naturally growing in noncontaminated (a) and contaminated (b) soil of Wadi Al-Argy wetland. (Values are the mean + SD of three replicates)

Element and Metal Concentrations Through Plant Organs: The first step in the process of phytoremediation is the uptake of metal into root cells then the next step is the translocation of metal from the root to the shoot [20]. Element or heavy metal accumulations in different plant organs of the studied species were illustrated in Figures 1, 2, 3 and 4.

Amaranthus hybridus, commonly called smooth amaranth, smooth pigweed, red amaranth, or slim amaranth, is a species of annual flowering plant. It is believed that many other amaranth species are natural hybrids derived from *A.hybridus*. It is native to North, Central and South America but now it is naturalized in many other places with warm climates and vigorously grows in mining wastelands, tailings, barrens and other disturbed habitats [17]. Thus *A.hybridus,* selected for the current work. The differences in the metal concentrations through different plant organs were illustrated in Figure 1. Comparing metal contents in different plant organs growing in the contaminated area showed relatively higher values as compared to those growing in noncontaminated area. As an example, the lead (Pd) concentrations of noncontaminated *A. hybridus* samples were 12.71, 11.34 and 2.53 (mg kg^{-1} DW) for root, stem and leaves; respectively and these values greatly increased to 93.9, 96.76 and 64.11(mg kg^{-1} DW) for the same plant organs but growing in contaminated area. These findings coincide with many authors e.g. [13, 21, 22].

Moreover, these results proved the phytoremediation potentiality of the studied species [7]. In addition, element and metal concentrations in stems recorded the greatest values among different plant organs of *A. hybridus*. These results were similar with the results by [19, 23]. As illustrated in (Figure 1(i and ii)), element and metal concentrations in the different plant organs of *A.hybridus* were in the order of Pd>Fe>Cu>Mn>As>Ca>Cr>P>B> Ni>Mo>Mg>N>K>Cd>Co. These results confirmed by the pervious findings by [17, 24].

Chenopodium ambrosioides is an annual or short-lived perennial herb that has been used for centuries as condiment, traditional purgative for intestinal worms and many other medicinal purposes [25, 26]. It grows in many disturbed habitats and many wetlands of Taif and first recorded in the study area by [15]. The element and metal concentrations in *C.ambrosioides* was illustrated in (Figure 2) and gave similar results to those obtained by *A.hybridus* as various plants have unique physiologies allowing them to take up elements and/or heavy metals [27]. Maximum element or heavy metal contents were recorded for copper (Cu) by *C.ambrosioides* naturally growing in contaminated soil and amounting to 30.5, 78.92 and 62.59 (mg kg^{-1} DW) in root, stem and leaves; respectively (Figure 2,ii). On the other hand, minimum element and metal contents were recorded for cadmium (Cd) by root, stem and leaves of *C.ambrosioides* naturally growing in noncontaminated soil recording 0.0038, 0.0011 and 0.0027 (mg kg^{-1} DW). Generally, the illustrated data in (Figure 2) arrange the accumulating element and metal by the current plant species in the following order Cu>Pd>Fe>Ca>N>K>As>Ni>B>P>Mg>Cr>Mn>Mo>Co>Cd. These results confirm the minimal values for accumulation of cadmium by different plant organs in either contaminated or noncontaminated soils. This can be explained by [28], who mentioned that "the uptake of Cd in the plant root could be reduced by a competition for transport with Zn and Fe". Thus the higher Fe content in the studied species could be another reason for the reduced Cd content in the plant root (Figure 2, ii). These results coincided with findings of [20].

Mentha longifolia is a species native to Europe, western and central Asia (east to Nepal and the far west of China) and northern and southern (but not tropical) Africa [29]. It grows well in canal banks, ditches, pools and wetlands [30]. For this reason it was chosen for the present work. Regard element and metal contents in the contaminated and noncontaminated sites of the study area, *M.longifolia* obey the same trend. The data was illustrated in (Figure 3). It is to be mentioned here that heavy metal contents in the target species organs naturally growing in contaminated site may have doubled or trebled values if compared to those samples growing in noncontaminated site samples. Iron (Fe) is example for this case, as the root content of *M.longifolia* in contaminated site was 14.56 (mg kg^{-1} DW) and this value reduced to about its half (6.35 mg kg^{-1} DW) for the same plant organ but growing in noncontaminated site. Sometimes the metal content in the plant organs growing in contaminated site gave tenfold values of those growing in noncontaminated site and this case clearly represented by lead (Pd) (Figure 3, ii). These results confirm the hypothesis of using *M.longifolia* as a phytoremediator and that is in accordance with similar studies carried out by many authors for testing phytoremediation potentiality of many species in wetlands; [31-33]. Generally, the accumulation rates of *M.longifolia* toward the measured elements and heavy metals can be arranged in the following order; Pd>Cu>Fe>Mn>K>Ca>B>Cr>As>Mg>P>N>Ni>Mo>Co>Cd. These results confirmed by the previous findings by [34]. Moreover, [35] concluded that wetland species show considerable variations in the metal uptake and accumulation abilities.

Typha domingensis, known commonly as southern cattail or cumbungi, is a perennial herbaceous plant of the genus Typha. It is found throughout temperate and tropical regions worldwide. It is sometimes found as a subdominant associate in mangrove ecosystems and many wetlands and first recorded in Wadi AL-Argy by [15]. In Turkish folk medicine the female inflorescences of this plant are used externally to treat wounds such as burns [36]. In contrast to the above mentioned three species, *T.domingensis* is the only macrophyte species and this may explain the highest recorded values by *T.domingensis* plant organs in either contaminated or noncontaminated sites as compared to those values achieved by *A.hybridus*, *C.ambrosioides* and *M.longifolia*. The metal accumulation rates by *T.domingensis* varied according to the accumulating organ and the type of heavy metal. Accumulation of lead (Pd) recorded maximum values ranged between (96.41 and 98.33 mg kg^{-1} DW) in different plant organs of *T.domingensis* growing in the contaminated soil, while minimum values were obtained for the accumulation of cadmium (Cd) (0.02 to 0.08 mg kg^{-1} DW) for different plant organs growing in noncontaminated site (Figure 3,ii).

T.domingensis accumulated the measured elements and metals in the following order; Pd>Cu>As>Fe>Cr>Mn>Ca>Ni>B>Mo>K>Mg>P>N>Co>Cd. These results were in accordance with similar study carried by [37] but on another species; *Typha latifolia*. In addition, the phytoremediation potentiality of *T.domingensis* was proved by [38] for only six metals; Cd, Pb, Cr, Ni, Zn and Cu.

According to the recorded element and metal concentrations in different plant organs of the studied species it can concluded that the maximum potentiality was acquired by *T.domingensis*, followed by *A.hybridus*, then *M.longifolia* and finally *C.ambrosioides.*

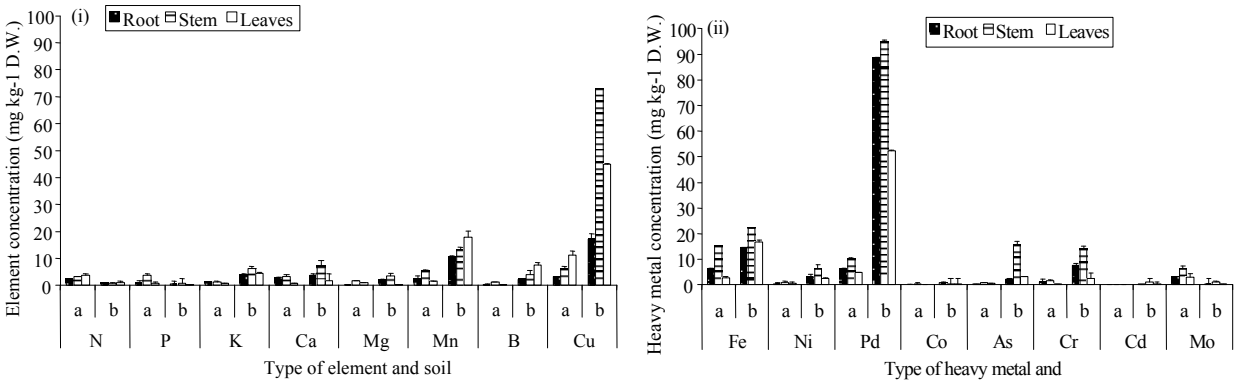

Fig. 3: Element concentration (i) and heavy metal concentration (ii) in root, stem and leaves of *Mentha longifolia* naturally growing in noncontaminated (a) and contaminated (b) soil of Wadi Al-Argy wetland. (Values are the mean + SD of three replicates)

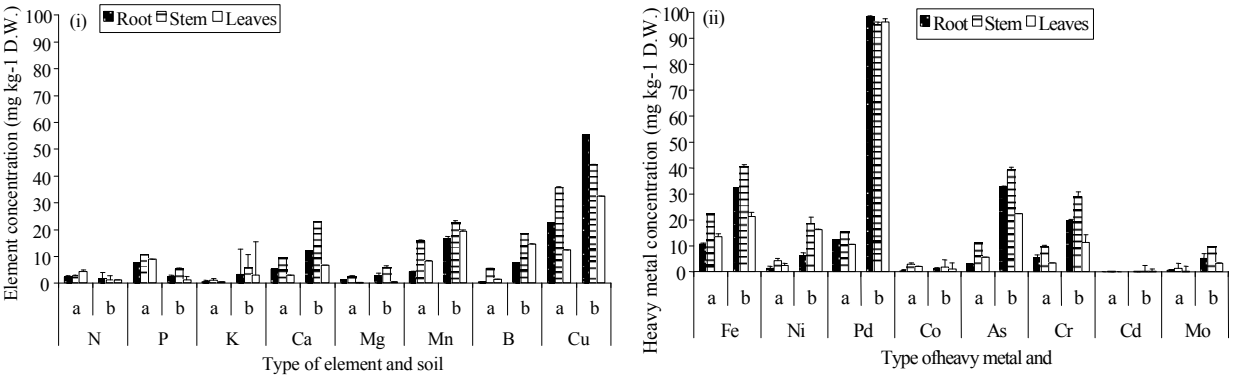

Fig. 4: Element concentration (i) and heavy metal concentration (ii) in root, stem and leaves of *Typha domingensis* naturally growing in noncontaminated (a) and contaminated (b) soil of Wadi Al-Argy wetland. (Values are the mean + SD of three replicates)

The Translocation Factor (TF) and Bioconcentration Factor (BCF): In order to study the metal mobility inside the studied species, the (TF) and (BCF) were calculated and the data was given in (Tables 2, 3, 4 and 5). In all test species, the recorded values of (TF) for the plant samples growing in noncontaminated soil were greater than those growing in contaminated soil. For example the recorded (TF) for cobalt (Co) were 1.091 and 2.926 in *A.hybridus* samples growing in contaminated and noncontaminated soils; respectively (Table 2). These results indicated the phytoremediation potentialities for the studied species and confirmed the significance of below-ground biomass as a heavy metal accumulator and that is in accordance with results obtained by many researchers like [7, 17, 21]. In addition, comparing values of (TF) in the studied four species, one can arrange these values in the following ascending order; *T.domingenesis*> *A.hybridus*> *M.longifolia*> *C.ambrosioides* and these results coincide with the above mentioned one considering element and heavy metals. TF recorded maximum value of (5.881) for the translocation of arsenic (As) in *T.domingensis* growing in noncontaminated soil (Table 5). On the contrary, minimum (TF) value was recorded for cobalt (Co) recording 0.537 in *M.longifolia* growing in noncontaminated soil (Table 4). These results were in accordance with [39].

The bioconcentration factor (BCF), was used to evaluate the metal accumulation efficiency in plants [17]. Most (BCFs) of shoots in the studied species growing in soils were lower than unity. On the contrary most (BCFs) of roots in the studied roots growing in water were more than unity (Tables 2-5). These results were in accordance with [17] and [40].

Table 2: Translocation factor for metals within *Amaranthus hybridus* naturally growing in contaminated soil (TFC) and noncontaminated soil (TFN), bioconcentration factor for the plant shoot growing in contaminated water (BCFW1), contaminated soil (BCFS1) and bioconcentration factor to the plant root growing in contaminated water (BCFW2) and contaminated soil (BCFS2). Mean values are given.

Element or metal	TFC	TFN	BCFW1	BCFS1	BCFW2	BCFS2
N	1.531	2.074	6.254	2.869	1.770	0.812
P	1.429	3.989	54.433	3.058	38.066	2.138
K	2.238	2.625	1.488	0.295	0.238	0.047
Ca	2.227	3.660	9.114	0.241	4.091	0.108
Mg	1.515	2.651	3.537	0.304	2.333	0.200
Mn	1.288	2.507	17.617	1.843	13.676	1.430
B	2.294	2.819	8.432	2.363	3.675	1.030
Cu	1.724	2.117	33.719	2.941	19.552	1.705
Fe	1.745	2.061	3.571	0.980	0.953	0.261
Ni	1.231	2.187	0.479	0.046	0.214	0.020
Pd	1.091	2.926	4.918	0.756	4.507	0.693
Co	1.533	3.423	0.051	0.022	0.033	0.014
As	2.357	2.210	4.692	0.887	1.076	0.203
Cr	2.423	2.355	1.047	0.796	0.124	0.094
Cd	1.055	2.522	0.004	0.608	0.004	0.0006
Mo	1.764	2.817	5.939	1.289	1.030	0.223

Table 3: Translocation factor for metals within *Chenopodium ambrosioides* naturally growing in contaminated soil (TFC) and noncontaminated soil (TFN), bioconcentration factor for the plant shoot growing in contaminated water (BCFW1), contaminated soil (BCFS1) and bioconcentration factor to the plant root growing in contaminated water (BCFW2) and contaminated soil (BCFS2). Mean values are given.

Element or metal	TFC	TFN	BCFW1	BCFS1	BCFW2	BCFS2
N	11.50	2.588	3.254	1.493	1.066	0.489
P	1.782	2.697	53.233	2.990	29.866	1.677
K	1.434	2.395	1.9431	0.386	0.261	0.051
Ca	1.641	2.194	9.862	0.261	3.735	0.099
Mg	1.591	2.551	3.537	0.304	2.222	0.191
Mn	2.662	2.457	6.735	0.704	2.529	0.264
B	1.909	2.401	13.884	3.878	4.756	1.333
Cu	1.019	2.639	40.386	3.523	13.371	1.166
Fe	0.639	1.918	2.726	0.748	0.483	0.132
Ni	1.820	1.521	0.801	0.077	0.117	0.011
Pd	1.207	1.449	3.524	0.542	2.918	0.448
Co	0.833	0.605	0.555	0.242	0.666	0.291
As	2.057	2.963	5.461	1.032	1.346	0.254
Cr	2.303	1.169	0.727	0.552	0.315	0.243
Cd	2.333	2.431	0.006	0.007	0.002	0.003
Mo	0.853	2..022	0.020	0.004	0.024	0.005

Table 4: Translocation factor for metals within *Mentha longifolia* naturally growing in contaminated soil (TFC) and noncontaminated soil (TFN), bioconcentration factor for the plant shoot growing in contaminated water (BCFW1), contaminated soil (BCFS1) and bioconcentration factor to the plant root growing in contaminated water (BCFW2) and contaminated soil (BCFS2). Mean values are given.

Element or metal	TFC	TFN	BCFW1	BCFS1	BCFW2	BCFS2
N	1.243	2.083	0.733	0.336	0.367	0.168
P	1.702	2.288	5.333	0.299	3.133	0.176
K	1.660	2.598	2.170	0.431	1.306	0.259
Ca	1.462	2.251	4.505	0.119	3.080	0.081
Mg	2.044	1.803	5.074	0.436	1.667	0.143
Mn	2.184	2.961	20.551	2.150	7.382	0.772
B	2.257	2.991	8.054	2.257	1.891	0.530
Cu	2.264	2.892	34.776	3.033	6.605	0.576
Fe	2.824	2.684	3.924	1.077	1.401	0.384
Ni	1.616	2.889	0.507	0.049	0.090	0.008
Pd	2.351	1.660	5.361	0.824	2.280	0.350
Co	1.333	0.537	1.778	0.776	0.333	0.145
As	1.272	2.253	2.653	0.501	0.423	0.082
Cr	1.721	2.146	1.004	0.763	0.583	0.443
Cd	2.165	2.483	0.044	0.001	0.002	0.002
Mo	2.600	2.946	3.909	0.848	0.454	0.098

Table 5: Translocation factor for metals within *Typha domingensis* naturally growing in contaminated soil (TFC) and noncontaminated soil (TFN), bioconcentration factor for the plant shoot growing in contaminated water (BCFW1), contaminated soil (BCFS1) and bioconcentration factor to the plant root growing in contaminated water (BCFW2) and contaminated soil (BCFS2). Mean values are given.

Metal or element	TFC	TFN	BCFW1	BCFS1	BCFW2	BCFS2
N	2.952	1.572	2.879	1.321	0.975	0.447
P	2.564	2.968	65.233	3.664	25.433	1.428
K	2.824	2.685	1.829	0.363	0.647	0.128
Ca	2.397	2.499	14.413	0.382	6.011	0.159
Mg	2.370	2.181	5.092	0.437	2.148	0.184
Mn	5.458	2.561	70.323	7.356	12.882	1.347
B	12.660	4.210	38.324	10.742	3.027	0.848
Cu	2.129	2.617	98.008	8.549	46.016	4.014
Fe	3.262	1.909	7.894	2.167	2.419	0.664
Ni	5.083	5.580	2.021	0.195	0.397	0.038
Pd	2.113	2.008	9.120	1.403	4.315	0.663
Co	1.804	2.085	53.777	23.495	4.555	1.990
As	1.891	5.881	32.519	6.149	5.519	1.043
Cr	2.340	2.043	6.114	4.647	2.612	1.985
Cd	2.500	3.166	0.454	0.005	0.181	0.002
Mo	3.045	2.487	4.060	0.881	1.333	0.289

CONCLUSION

In conclusion, the current work proved the phytoremediation potentiality for the studied species. According to the accumulation rates of the measured element and metals in either contaminated or noncontaminated sites and the (TF), the phytoremediation potentiality of the studied species can arranged in the following order: *T.domingenesis*> *A.hybridus*> *M.longifolia*> *C.ambrosioides*. Comparing different plant organs of the studied species in most cases, nominate the accumulation organs in the following order; stem> root> leaves.

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