Bioaccumulation and Translocation of Heavy Metals from Coastal Soil by Wild Halophytes

Yasser A. El-Amier[1,*], Suliman M. Alghanem[2], Fahad M. Alzuaibr[2]

[1]Botany Department, Faculty of Science, Mansoura University, Mansoura, Egypt
[2]Biology Department, Faculty of Science, Tabuk University, Tabuk, KSA
*Corresponding author: yasran@mans.edu.eg

Abstract In the present study, six native halophytes were collected from soil of northern Nile Delta to evaluate their phytoremediation potential of heavy metals. For this purpose, soil, the aboveground parts and roots of the samples were analyzed for total concentrations of Fe, Pb, Ni, Co and Cd using atomic absorption spectrometer. The concentrations of different heavy metals in soils have the sequence of Fe>Ni>Pb>Co>Cd. The pollution quantification for each metal in the study area indicated that, the extremely high enrichment value for Cd; very high enrichment values for Pb and Co and low enrichment values for Ni and Fe; The contamination factor has very high for Cd; moderate for Pb and Co and low for Ni and Fe, while the contamination degree (CD) indicates that the study area is considered to be coast with low to moderate contamination degree (2.74 and 10.29). In the study area, the concentrations of heavy metals in plant species have the order of Fe>Pb>Ni>Cd>Co. Most plant species had a TF<1 for Fe, Ni, Co and Cd except Pb>1, while the BAF values for Fe, Pb, Ni, Co and Cd were <1, except BAF root of *A. halimus, L. pruinosum* and *S. pruinosa* were >1. The highest BAF shoot and root values was observed in *Atriplex halimus*, while the lowest was for *Suaeda maritima*. Similarly, the highest TF values were observed for *Z. aegyptium, S. pruinosa* and *L. monopetalum*, while the lowest was for *S. pruinosa*. Results suggest that these plants could be suitable for use in the phytoremediation of contaminated soil sites.

Keywords: coastal desert, iron, lead, nickle, cadmium, cobalt, phytoremediation, soil indices

1. Introduction

In recent years, the problem of environmental contamination by a wide variety of chemical pollutants including heavy metals been observed throughout the world because of toxicity and potential risk for human health [1]. Contamination with heavy metals are one of the main pollutants which affect the plants and animals throughout globe. Food and fodder crops raised on metal contaminated soils have the tendency to accumulate excessive amounts of heavy metals, which poses severe risk to human and animal health [2,3]. Heavy metal contents in plants are dependent on soil, climatic factors, agrochemical application, irrigation water quality, plant growth rates and plant parts [4,5]. Although heavy metals like Cu, Cr and Co are vital for plant and animal metabolism, at levels above maximum permissible limits they disrupts the normal functioning of organisms [6,7]. Cd and Pb are known to be highly toxic and carcinogenic for animals and humans [8].

Bioavailability, bio-accumulation and translocation of metallic components in ecosystem are attaining great importance of study throughout the world [9]. Phytoremediation is a green technology and bioremediation by plants can be better option to remove toxicants from the polluted environment because plants have the ability to detoxify poisonous elements and to grow in degraded ecosystem. Plants can bio-accumulate metallic ions and dissolved chemicals by either root, leaf or stem and are arrested and sequestered into their tissues at least impermanently [10,11]. These chemicals arise from increasing levels of anthropogenic activities such as industrialization and urbanization, coal and metals ore mining, chemical manufacturing, petroleum mining and refining, electric power generation, melting and metal refining, metal plating and to some extent domestic sewage [12,13].

Previous studies showed that some plants are able to grow in these extreme environments and often are able to evolve into metal-tolerant ecotypes [14,15,16]. Halophytes are of important attention since these plants are naturally present in environments with an excess of toxic ions and research findings suggest that these plants also tolerate other environmental stresses, especially heavy metals as their tolerance to salt and to heavy metals may, at least partly, rely on common physiological mechanisms. Therefore, halophytic plants have been suggested to be naturally better adapted to overcome the heavy metals compared to glycophytic plants commonly chosen for phytoremediation research [17]. The present work aimed to study various native plant species in northern Nile Delta to evaluate their bioaccumulation and translocation of heavy metals.

2. Materials and Methods

2.1. Description of the Study Area

The area chosen for the present study is located in the northern part of the Nile Delta region of Egypt (Figure 1). The Deltaic coast (middle section of the Mediterranean coast) extends from Abu-Quir (in the west, Long. 32°19' E) to Port-Said (in the east Long. 31°19' E) with a length of about 180km, and with a width in a N-S direction for about 15km from the coast, which covers the north borders of three Governorates namely: Damietta, El-Dakahlia and Kafr El-Sheikh. Ecologically, the study area comprises four habitats: salt marshes, sand formations, reed swamps and fertile non-cultivated lands habitat [18].

Geologically, the Nile Delta, as a part of northern Egypt, has been subjected to the same geologic events that affected the whole region during its geological history. The formation of the Nile Delta started in the late Pliocene with its main development in the Pleistocene and Holocene associated with progradation of large volumes of coastal Delta sands and the accumulation of turbidities off shore (Nile cone) [19].

The soils of the Nile Delta are heavy in texture, rather compact at the surface and rich in humus [20]. According to the map of the world distribution of the arid regions [21], soil of the study area are man-made variants of Gley soils and Fluvisoils that belong to the Pliocene and Pleistocene [22]. Deposits covering the Delta reach about 10.9 m in thickness. These deposits are composed mainly of silt, clay, sandy clay with biotite, magnetite and limestone formations, these deposits are considered as the basis of Egypt's fertility [23].

2.2. Plant Sampling and Analyses

In the study area, wild plant species (n=6) were collected at full maturity stage during March to June 2017, marked properly and packed in polyethylene bags. Nomenclature and identification of plant species were carried out according to Tackholm [24] and Boulos [25] (Table 1). All plants were washed and cleaned with tape water, separated into roots and shoots, oven dried at 50 ℃, and ground into powder with electric grinder. For metal analyses, 0.1 g (dry weight) of plant samples was added to Teflon beakers and digested with HNO_3/H_2O_2 (3:1, v/v) at 70 to_90°C during which temperatures were raised to approximately 95°C until evolution of nitrous gas had stopped and the digest became quite clear. The digests were diluted with distilled water up to a known volume [26]. Fe, Cd, Co, Ni and Pb were estimated using Atomic Absorption Spectrometer (A Perkin-Elemer, Model 2380, USA).

Figure 1. A map showing study area and the sampling sites

Table 1. List of native plant species and their respective families

Scientific name	Vernacular name	Family	Duration	Site collection
Atriplex halimus L.	Qataf	Chenopodiaceae	Perennial	4, 5, 6 & 7
Limoniastrum monopetalum (L.) Boiss.	Zeita	Plumbaginaceae	Perennial	4, 5, 6 & 7
Limonium pruinosum (L.) Chaz.	Molleih	Plumbaginaceae	Perennial	4, 5, 6 & 7
Suaeda maritima (L.) Dumort	Sowweid	Chenopodiaceae	Annual	1, 2 & 3
Suaeda pruinosa Lange	Sowweid	Chenopodiaceae	Perennial	1, 2 & 3
Zygophyllum aegyptium Hosny	Rotreit	Zygophyllaceae	Perennial	4, 5, 6 & 7

2.3. Soil Sampling and Analyses

Surface soil samples (0–20cm depth; n=6) were collected from each site (triplicates) using a Van-Veen grab coated with polyethylene. Soil texture and amount of organic matter were determined according to Piper [27], while calcium carbonate content was determined according to Jackson [28]. The soil solution (1:5) was prepared and electrical conductivity and pH values were determined by portable meter (Model Corning, NY 14831 USA) [28]. To detect the heavy metal contamination in the sediment samples. The samples were deep-frozen until analysis. The samples were dried in the oven at 70°C and sieved using 0.75 mm plastic sieve and digested for about two hours in a mixture of 3:2:1 HNO_3, $HCLO_4$ and HF acids, respectively as described by Oregioni and Astone [29].

2.4. Pollution Quantification

The pollution quantification for each metal were calculated by determination of Contamination Factor (CF), Enrichment Factor (EF) and Pollution Load Index (PLI) using the following equations according to Shah et al. [30] and Muhammad et al. [31]:

$$\text{Contamination factor}(CF) = \frac{C_{m\ sample}}{C_{m\ background}} \qquad (1)$$

Where C_m represents the concentrations of metals in contaminated and background sites.

Enrichment Factor is considered as an effective tool to evaluate the magnitude of contaminants in the environment. Iron (Fe) was chosen as the controlling element [32].

$$(\text{Enrichment factor})EF = \frac{C_{trace\ metal}}{C_{background}} \qquad (2)$$

Where, C is the concentration of metal.

$$(\text{Pollution load index})PLI$$
$$= n\sqrt{CF1 \times CF2 \times CF3 \ldots \ldots \ldots CFn} \qquad (3)$$

Where n is the number of metals (five in the present study) and CF is the contamination factor value.

2.5. Phytoremediation Efficiency

The translocation factor (TF) and bioaccumulation factor (BAF) were calculated for heavy metals. TF is the translocation of a metal from the roots to shoots. However, BAF determines the ability of a plant to uptake a metal from soils. In this study, the TF and BAF values for heavy metals are calculated with the following equations:

$$TF = \frac{C_{shoot}}{C_{root}} \qquad (4)$$

$$BAF_{shoot} = \frac{C_{shoot}}{C_{soil}} \qquad (5)$$

$$BAF_{root} = \frac{C_{root}}{C_{soil}} \qquad (6)$$

Where C_{shoot}, C_{root}, and C_{soil} represent the metal concentrations in the shoots, roots, and soil, respectively [33,34].

2.6. Statistical Analyses

The analysis of soil samples and heavy metal of plant were done in triplicates and the data is presented as mean ±standard deviation. Pearson correlation coefficients were calculated to analyze the correlation between heavy metals in plant and soil.

3. Results and Discussion

3.1. Soil

3.1.1. Physiochemical Parameters

The heavy metal contents in soil are also dependent on soil physico-chemical properties, which affect the mobility, availability and ecotoxicological risks of heavy metals [35]. Table 2 summarizes the physico-chemical properties of the soil. Soil pH mean values were found highest in site 1 (9.86), while they were lowest in site 4 (7.81) of the study area. Soil conductivity which indicates the salinity was maximum at site 3 (4.73 ms.cm^{-1}) and minimum at site 6 (0.47 ms.cm^{-1}). The pH changed among the studied sites as a result of different drainage waters and soil organic matter, highest EC values were recorded at site 1, 2, 3 and 7 due to nearby lakes and sea water intrusion from the Mediterranean Sea [36].

The observed soils were found to be sandy in texture with sand contents ranging from 77.4 (Site 2) to 96.8 % (Site 6). Similarly, SOM was found highest in site 2 (1.97%), while it was lowest in site 6 (0.43%) (Table 2). The soil organic matter (SOM) associated with different soil textures (sand, silt, and clay) and will differ in susceptibility to decomposition, which is one of the most important indicators of soil health (Rattan et al. 2005). The main reason for such low levels of SOM is the poor silt and clay contents of soils [37]. The carbonate content (CaCO$_3$) ranged from 1.89 to 5.95 % revealing the nature

of the studied soils, which play role in soil structure, colour and neutralize soil acidity. The levels of soil physico-chemical parameters in the present study were similar to the levels observed in other study [38,39,40].

Table 2. Soil analysis collected from the Deltaic Mediterranean coast during winter (2017)

Soil parameters	Sites no.							Mean
	1	2	3	4	5	6	7	
pH	9.86±0.93	9.12±0.85	8.05±0.75	7.81±0.72	8.3±0.77	8.54±0.80	8.01±0.74	8.53±0.80
EC ms.cm^{-1}	1.79±0.12	3.79±0.32	4.73±0.42	0.84±0.03	0.48±0.05	0.47±0.05	1.09±0.04	1.88±0.13
Sand %	90.2±8.96	77.4±7.68	83.3±8.27	92.6±9.60	94.7±9.61	96.8±9.59	91.2±9.62	89.46±7.05
Silt %	6.7±0.61	12.4±1.18	9.4±0.88	2.3±0.17	2.6±0.020	1.6±0.10	1.2±0.06	5.17±0.64
Clay %	3.1±0.25	10.2±0.96	7.3±0.67	1.1±0.05	0.7±0.01	1.9±0.13	2±0.14	3.76±0.32
CaCO3 %	5.89±0.53	5.95±0.54	5.24±0.47	3.29±0.27	3.12±0.25	1.89±0.13	3.18±0.26	4.08±0.31
SOM %	1.79±0.05	1.97±0.06	1.72±0.04	0.46±0.03	0.48±0.03	0.43±0.02	0.45±0.02	1.04±0.04

EC: Electrical conductivity; SOM: Soil organic matter.

Table 3. Total metals concentration (μgg^{-1} dry weight) in soil from the Deltaic Mediterranean coast during winter (2017)

Sites no.	Metals (μgg^{-1} dry weight)				
	Fe	Pb	Ni	Co	Cd
1	2002.36±20.0	18.4±1.8	62.25±6.2	20.54±2.1	2±0.2
2	1940.96±19.4	20.2±2.0	42.4±4.2	17.4±1.7	1.8±0.1
3	2043.96±20.6	22.8±2.3	49.21±4.9	13.64±1.4	2.3±0.2
4	760.96±7.6	5.41±0.5	3.65±0.4	0.53±0.1	0.9±0.2
5	789.56±7.9	8.47±0.8	7.45±0.7	1.54±0.2	1.1±0.2
6	1079.56±10.8	3.24±0.3	4.65±0.5	2.98±0.3	0.7±0.1
7	1811.76±18.1	9.48±0.9	25.64±2.6	7.54±0.8	1.2±0.1
Mean	1489.87±14.9	12.57±1.3	27.89±2.8	9.17±0.9	1.43±0.1
Average shale	47200	20	68	19	0.3
EPA, 2002	15	10	-	-	6
EU, 2002	-	300	75	11.6	3

Average shale, after Turekian and Wedepohl [41]
EPA: Environmental Protection Agency for sediment samples in (μg/g).
EU: European Union Standard in (μg/g).

3.1.2. Heavy Metal Contents in Soil

Heavy metals concentration in soil samples from the seven sampling sites along are presented in Table 3. The concentrations of different heavy metals displayed remarkable site to site variations, with the highest concentration recorded at the site 3 for most metals. Fe (760.96 – 2043.96 μgg^{-1} dry weight) maintain relatively the highest concentration followed by Ni (3.65 – 62.25 μgg^{-1} dry weight), Pb (3.24 – 22.8 μgg^{-1} dry weight), Co (0.53 – 20.54 mgl-1) and Cd (0.7 – 2.3 μgg−1 dry weight). The concentrations of metals were observed in the order of Fe>Ni> Pb> Co >Cd.

The main sources of heavy metals in the soil samples are parent rock material, polluted irrigation water, sea water intrusion and various agrochemicals (fertilizers, pesticides, weedicides etc.) [42,43]. Site 1, 2 and 3 demonstrated the highest level of heavy metal contamination recorded during the present study. This can be explained by the increasing industrial activities at these sites and sea water intrusion [44]. These results are in agreement with those obtained by El-Sikaily et al. [45] at

other Egyptian coastal areas on the Mediterranean and Red Sea and El-Serehy et al. [44] at Deltaic Mediterranean coast. However, these concentrations were found higher than those reported by Beheary and El-Matary [46] in soil of northern Nile Delta. The heavy metal contents in soil samples in the present analysis are high the maximum permissible limits set by EPA [47] but within the limit of EU [48].

3.1.3. Metal Enrichment Factor (EF)

The Enrichment Factor (EF) in metals is indicator used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil [49]. Figure 2 summarizes the soil EF values at studied sites in Deltaic Mediterranean coast. Cd (102.02-219.19) maintain relatively the highest concentration followed by Pb (7.08-26.33), Co (1.73-25.48) and Ni (2.99-21.58). Values of 0.5≤EF≤1.5 suggest that the trace metal concentration may come entirely from natural weathering processes [50]. However, an EF>1.5 indicates that a significant portion of the trace metals was delivered from non- crustal materials so, these

trace metals were delivered by other sources, like point and non-point pollution and biota [51,50]. According to categories proposed by Sutherland et al. [51] the deltaic coast has extremely high enrichment values for Cd; very high enrichment for Pb and Co and low enrichment values for Ni and Fe.

3.1.4. Contamination Factor (CF) and Contamination Degree (CD)

The contamination factor of different heavy metals displayed remarkable site to site variations, with the highest concentration recorded at the site 3 for all metals (Figure 3). Cd (2.33-7.67) maintain relatively the highest concentration followed by Pb (0.16-1.14), Co (0.03-1.08), Ni (0.05-0.92) and Fe (0.02-0.04). According to Hakanson classification [52], CF < 1 (low contamination factor); $1 \leq$ CF < 3 (moderate contamination factors); $3 \leq CF < 6$ (considerable contamination factors) and $CF \geq 6$ (very high contamination factor). On this basis, the deltaic coast has very high CF values for Cd; moderate CF for Pb and Co; low CF for Ni and Fe. Calculation of the contamination degree (CD) indicates that the deltaic coast is considered to be coast with low to moderate contamination degree [52], vary between 2.74 and 10.29 with mean value of 6.31 (Figure 4), indicating serious anthropogenic pollution.
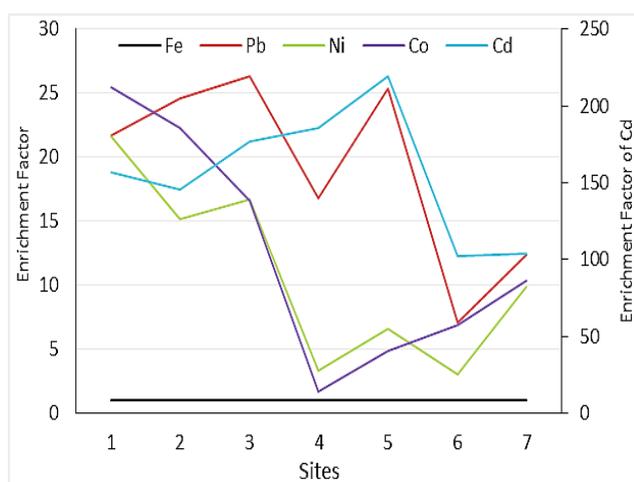

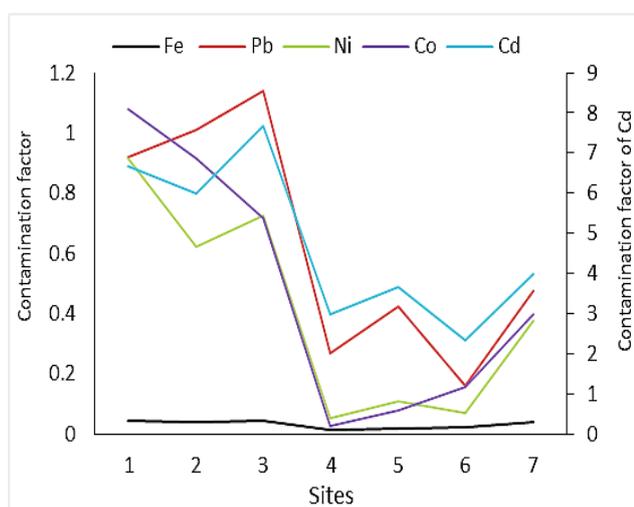**Figure 2.** Enrichment factor value of soil in the study area

Figure 3. Contamination factor value of soil in the study area
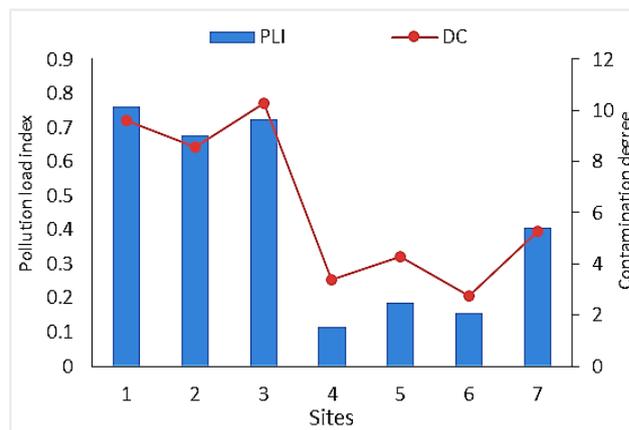

Figure 4. Contamination degree and pollution load index values of soil in the study area.

3.1.5. Pollution Load Index (PLI)

The PLI is aimed at providing a measure of the degree of overall contamination at a sampling site. Figure 4 shows results of the PLI for the five metals studied at deltaic coast, vary between 0.11 and 0.76 with the mean value of 0.43. This values (PLI < 1) showed that there is no appreciable pollution in deltaic coast with those metals [47].

3.2. Plants

3.2.1. Heavy Metal Concentrations in Plants

Plant helps a good tool for phytoremediation. Hyper-accumulation refers to the natural ability of certain plants to clean up soil, air, and water contaminated with hazardous chemicals [53]. The heavy metal concentration in the different tissues of various plant species growing naturally along the Deltaic Mediterranean coast was recorded during the study periods (Table 4). Iron concentrations ranged from 90.98 to 695.3 $\mu g.g^{-1}$ in root with a highest concentration in *S. maritima* and lowest in *Z. aegyptium*, while ranged from 186.89 to 360.4 $\mu g.g^{-1}$ in shoot of *S. pruinosa* and *L. pruinosum*, respectively (Table 4). Fe as an essential nutrient plays an important role in plant cell wall, photosynthesis process and protein [54]. Plants uptake Fe through their roots at high concentrations and the produced free radicals permanently impair cellular structure and damage the membranes, DNA, and proteins [55].

The highest Pb concentration (5.76 and 5.11 $\mu g.g^{-1}$) was observed in root of *Z. aegyptium* and in shoot of *Suaeda pruinosa*, respectively, while the lowest (root: 1.56 and shoot: 2.22 $\mu g.g^{-1}$) was observed in *S. maritima* (Table 4). Generally, the Pb concentrations ranging from 1.56 to 5.11 $\mu g.g^{-1}$, while safe agriculture limit is 10 $\mu g.g^{-1}$ [56]. Pb is non-essential and toxic metal which causing phytotoxicity when exceeded the limits [57,58].

The highest Ni concentration ranged from 2.21 to 3.58 $\mu g.g^{-1}$ in root of *Z. aegyptium* and *S. pruinosa*, while ranged from 0.74 to 1.9 $\mu g.g^{-1}$ in shoot of *S. maritia* and *L. pruinosum*, respectively. Nickel is an essential micronutrient that occurs in the environment at very small amounts as reported by Wood et al. [59]. Excess accumulation of Ni reduced the water content in plant species. This decrease in water uptake is used as an indicator of Ni toxicity in plants [60]. Similarity, cobalt concentration (1.11 - 1.9 $\mu g.g^{-1}$)

was observed in root of *Z. aegyptium* and *S. pruinosa*, while in shoot (0.5 - 1.0 µg.g^{-1}) was observed in *S. maritia* and *L. pruinosum*, respectively (Table 4). Plants can uptake only small amount of Co from the soil and its consequent distribution in plants is reliant on species mechanisms [61].

The highest concentrations of Cd (root: 0.13 to 2.4 µg.g^{-1}; shoot: 0.08-1.8 µg.g^{-1}) was observed in *Atriplex halimus* and *Zygophyllum aegyptium*, respectively. Cadmium is present as an impurity in some products, including phosphate fertilizers, detergents and refined petroleum products [62]. In plants, Cd accumulation causes growth inhibition, browning of root tips, chlorosis, water and nutrient uptake, reduction in photosynthesis and finally death [63].

3.2.2. Metal Bioaccumulation Factor (BAF)

Table 5 represents the bioaccumulation of roots, shoots, and transfer factor values in selected plant species collected from deltaic coast. The BAF was used to assess the capacity of studied plants to uptake metals from the surrounding environment. Plant species show TF and BAF greater than one are suitable for phytoextraction of heavy metals [64]. Among the plant species, the highest BAF shoot and root values (1.85 and 2.46) was observed in *Atriplex halimus*, while the lowest (0.01 and 0.05) was for *Suaeda maritima*, respectively. Similarly, the highest TF values (2.62, 1.73 and 1.58) were observed for *Z. aegyptium, S. pruinosa* and *L. monopetalum*, respectively, while the lowest (0.26) was for *S. pruinosa* (Table 5).

Table 4. Mean concentration (µg.g^{-1} dry weight) of total heavy metals ± standard deviation in tissues of studied halophytes during winter (2017)

Plant species	Plant part	Metals (µg.g^{-1} dry weight)				
		Fe	Pb	Ni	Co	Cd
Atriplex halimus	Shoot	283.5±28.4	4.35±0.4	1.5±0.2	0.8±0.1	1.8±0.2
	Root	458.69±45.9	3.2±0.3	2.67±0.3	1.48±0.1	2.4±0.2
Limoniastrum monopetalum	Shoot	290.1±29.1	4.3±0.4	1.7±0.2	0.9±0.1	0.6±0.1
	Root	311.45±31.1	2.48±0.2	2.89±0.3	1.24±0.1	0.9±0.1
Limonium pruinosum	Shoot	360.4±36.0	5.0±0.5	1.9±0.2	1.0±0.1	0.8±0.1
	Root	476.2±47.6	3.15±0.3	3.42±0.3	1.56±0.2	1.78±0.2
Suaeda maritima	Shoot	234.36±23.4	2.22±0.2	0.74±0.1	0.5±0.1	0.81±0.1
	Root	695.3±69.5	1.56±0.2	2.59±0.3	1.12±0.2	1.41±0.1
Suaeda pruinosa	Shoot	186.89±18.7	5.11±0.5	1.59±0.2	0.8±0.1	0.82±0.1
	Root	636.14±63.6	3.23±0.3	3.58±0.4	1.9±0.1	2.34±0.2
Zygophyllum aegyptium	Shoot	238.45±23.8	4.09±0.4	1.54±0.2	0.85±0.1	0.08±0.0
	Root	90.98±9.1	5.76±0.6	2.21±0.2	1.11±0.1	0.13±0.0

Table 5. Bioaccumulation of metals in roots, shoots, and their transfer factors in contaminated sites

Plant species	Plant part	Metals				
		Fe	Pb	Ni	Co	Cd
Atriplex halimus	BAF$_{Root}$	0.41	0.48	0.26	0.47	2.46
	BAF$_{Shoot}$	0.26	0.65	0.14	0.25	1.85
	TF	0.62	1.36	0.56	0.54	0.75
Limoniastrum monopetalum	BAF$_{Root}$	0.28	0.37	0.28	0.39	0.92
	BAF$_{Shoot}$	0.26	0.65	0.16	0.29	0.62
	TF	0.93	1.73	0.59	0.73	0.67
Limonium pruinosum	BAF$_{Root}$	0.43	0.47	0.33	0.50	1.83
	BAF$_{Shoot}$	0.32	0.75	0.18	0.32	0.82
	TF	0.76	1.59	0.56	0.64	0.45
Suaeda maritima	BAF$_{Root}$	0.35	0.08	0.05	0.11	0.69
	BAF$_{Shoot}$	0.12	0.11	0.01	0.03	0.40
	TF	0.34	1.42	0.29	0.26	0.57
Suaeda pruinosa	BAF$_{Root}$	0.32	0.16	0.07	0.07	1.15
	BAF$_{Shoot}$	0.09	0.25	0.03	0.05	0.40
	TF	0.29	1.58	0.44	0.71	0.35
Zygophyllum aegyptium	BAF$_{Root}$	0.08	0.87	0.21	0.35	0.14
	BAF$_{Shoot}$	0.21	0.62	0.15	0.27	0.08
	TF	2.62	0.71	0.69	0.76	0.59

In the study area, most plant species had a TF<1 for Fe, Ni, Co and Cd except Pb greater than one, while the BAF values for Fe, Pb, Ni, Co and Cd were <1, except BAF root of *A. halimus, L. pruinosum* and *S. pruinosa* were >1. Phytoextraction usually involves the uptake of toxic heavy metals from contaminated soils and their accumulation in harvestable parts of plant species. Plants being considered as hyperaccumulators must have the potential to tolerate the metals and transfer them from roots to above-ground parts of the plant species [65]. On the basis of the BAF values, only *A. halimus* could be considered as a Cd hyperaccumulator as this species had a BAF shoot and root values >1. On the basis of TF, *Z. aegyptium* for Fe and all plant species could be considered as hyperaccumulators for Pb except *Z. aegyptium*. Generally, different plant species showed a variation in metal accumulation and uptake. This may be due to different concentrations of the metals in soil, pH, soil organic matter [9], age of plant, and plant physiology.

The uptake of metals by halophytic plants depends upon their mobility and availability in sediments. In the view of the above-mentioned data, metals in halophytes are mainly accumulated in the roots with small quantities translocated to the stems and leaves, except in the case of more mobile elements such as Mn, Cd and Zn [17].

Table 6. Inter-correlations between the heavy metals in soil, roots, and shoots of the plant species

	Fe	Pb	Ni	Co	Cd
Soil					
Fe	1.000	0.842*	0.916**	0.903**	0.838*
Pb		1.000	0.912**	0.880**	0.984**
Ni			1.000	0.971**	0.933**
Co				1.000	0.868*
Cd					1.000
Shoots					
Fe	1.000	0.239	0.494	0.588	0.184
Pb		1.000	0.930**	0.866*	0.072
Ni			1.000	0.988**	-0.064
Co				1.000	-0.12
Cd					1.000
Roots					
Fe	1.000	-0.789	0.541	0.596	0.749
Pb		1.000	-0.344	-0.684	-0.475
Ni			1.000	-0.099	0.652
Co				1.000	0.245
Cd					1.000

*: Values are significant at P<0.05;
**: Values are significant at P<0.01.

3.2.3. Inter-Metals Correlations in Plants and Soil

The simple linear correlation coefficient showed a strong significant correlation between pairs of heavy metals in all soil samples (P<0.05 and P<0.01) (Table 6). Similarly, a correlation was also observed in shoots for Pb–Ni (r=0.930), Ni–Co (r=0.988) and Co–Pb (r=0.866), while in roots negative or no correlations between the pairs of heavy metals (Table 6). A correlation gives us knowledge about heavy metal sources and pathways. These results showed that the selected metals derived from the same polluting source in the study area (Deltaic Mediterranean coast) were both anthropogenic and geogenic (weathering of bed rocks) [66].

4. Conclusion

In the present study, we have concluded that:
1) The heavy metal contents in soil are also dependent on soil physico-chemical properties, the concentrations of different heavy metals in soils have the sequence of Fe>Ni> Pb> Co >Cd.
2) The pollution quantification for each metal in the study area indicated that, the extremely high enrichment value for Cd; very high enrichment values for Pb and Co and low enrichment values for Ni and Fe; The contamination factor has very high for Cd; moderate for Pb and Co and low for Ni and Fe, while the contamination degree (CD) indicates that the study area is considered to be coast with low to moderate contamination degree (2.74 and 10.29).
3) In the study area, the concentrations of heavy metals in plant species have the order of Fe>Pb> Ni > Cd >Co. most plant species had a TF<1 for Fe, Ni, Co and Cd except Pb >1, while the BAF values for Fe, Pb, Ni, Co and Cd were <1, except BAF root of *A. halimus, L. pruinosum* and *S. pruinosa* were >1.
4) The highest BAF shoot and root values was observed in *Atriplex halimus*, while the lowest was for *Suaeda maritima*. Similarly, the highest TF values were observed for *Z. aegyptium, S. pruinosa* and *L. monopetalum*, while the lowest was for *S. pruinosa*.
5) The Potential environmental dangers are related with large amounts of heavy metals in soils and plant species. The current research demonstrated that some plant species could be appropriate for remediation of contaminated sites.

Acknowledgments

List of Abbreviations

EC: Electrical Conductivity
SOM: Soil Organic Matter
EPA: Environmental Protection Agency for sediment samples in (µg/g)
EU: European Union Standard in (µg/g)
BAF: Bioaccumulation Factor
TF: Translocation Factor
EF: Enrichment Factor
CF: Contamination factor
CD: Contamination Degree
PLI: Pollution Load Index.

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