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Determination of the Accumulation of Heavy Metals in Avicennia Marina from Bardestan Estuary, Bushehr Province, with an Emphasis on the Enrichment Coefficient

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Abstract

A. marina from aquatic plants is widely distributed throughout Bardestan estuary (Bushehr, Iran). This study examined the uptake of some metals by *A. marina* and their translocation from the roots to other parts of the plant. For this purpose, samples of sediment, and mangrove roots and leaves were taken from the Bardestan mangrove. Samples were dried in the laboratory and digested in concentrated acids and their metal content was measured using Atomic Absorption Spectrophotometry. The enrichment coefficients in leaves of *A. marina* were smaller than 1.0 for all the studied metals. Similarly, the enrichment coefficients of all the metals (Zn, Ni, Cu, Pb, Cd), in roots of *A. marina* were smaller than 1.0. This study demonstrated that *A. marina* behaves as an excluder plant and could be considered as either a bio-indicator or a bio-accumulator in sediments and waters polluted by heavy metals.

Key words: Accumulation, Heavy metals, *Avicennia marina*, Iran.

تعیین تجمع فلزات سنگین در گیاه حرای خور بردستان استان بوشهر با تاکید بر ضریب غنی شدگی

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چکیده

گیاه حرا (*Avicennia marina*) از گیاهان آبزی مناطق جزر و مدی است که دارای پراکنش وسیعی در خور بردستان (استان بوشهر) می‌باشد. این مطالعه با هدف تعیین میزان تجمع فلزات سنگین در رسوب و بافت های گیاه و نیز توانایی انتقال این عناصر از رسوب به بافت‌های گیاه *A.marina* انجام گردید. بدین منظور پس از هضم نمونه‌ها در آزمایشگاه، غلظت فلزات سنگین با استفاده از دستگاه جذب اتمی اندازه‌گیری شد. بر اساس نتایج حاصل از این پژوهش، ضریب غنی‌شدگی برگ در گیاه مورد مطالعه کمتر از ۱ می باشد. نتایج مشابهی برای بافت ریشه بدست آمد و ضریب غنی‌شدگی ریشه نیز برای فلزات مورد مطالعه(Cd, Pb ,Cu, Ni, Zn) کوچکتر از ۱ بود. با توجه به مقادیر ضریب غنی‌شدگی می‌توان بیان نمود که گیاه *A.marina* یک گیاه دفع کننده فلزات سنگین است. هم‌چنین این گیاه می‌تواند به عنوان بیواندیکاتور عناصر مورد مطالعه در رسوبات و آب‌های آلوده به این فلزات مورد استفاده قرار گیرد.

کلمات کلیدی: تجمع، فلزات سنگین، *Avicennia marina*، ایران.

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1. Introduction

Mangroves are one of the most productive and unique ecosystems in the world. Being located at inter-tidal zones, these ecosystems are highly exposed to pollutants. Mangrove species such as *Avicennia marina* are woody, seed-bearing and highly specialized plants, and are found along sheltered intertidal coastlines of estuaries and lagoons. Because of their unique adaptations, mangroves thrive well in environments where other plants cannot grow. It has been observed that the most important pollutants in mangrove ecosystems are heavy metals originating from urban runoff, sewage treatment plants, industrial effluents, boating activities, domestic garbage dumps, and agricultural fungicides which dramatically increase the heavy metal concentration in intertidal sediments. In addition, specific properties of a non-biodegradable trace metal which has a high affinity towards anoxic sediments due to the presence of fine clay, silt and detrital particles, high pH and sulphate reduction in mangrove ecosystems will lead to the accumulation of metals in the mangrove [1-2]. A number of researchers have found high concentrations of accumulated metals in the tissues of numerous mangrove species in polluted localities including Avicennia spp. [3-5]. In addition, Cheraghi et al. (2013) studied the accumulation of heavy metals in sediment and mangrove plants (Avicennia marina) in Bandar Imam Khomeini. The results of this research showed that metal concentrations in roots were more than in the leaves of plants and also a significant correlation between concentrations of metals in the sediment and plant roots was found, so plant roots can be a good biomonitor for sediment polluted with heavy metals [6].

The Bardestan mangrove forest is the smallest mangrove forest in Bushehr Province with a size of 2 hectares. The *A. marina* is a dominant plant along the Bardestan estuary. Pesticides and fertilizers used in agricultural fields have been affecting the mangrove plant. Knowledge of the heavy metal concentrations in the environment near a Bardestan mangrove forest is of great concern due to their serious effects on the food chain and also on animal and human health. Therefore, knowledge of the heavy metal concentration in this area is very important.

In this study, the objectives are to determine the concentration of some heavy metals in the sediment and plants in the studied area, and to evaluate their mobility according to the transfer factor and the enrichment coefficient in the leaves and root in *A. marina*. The analysed metals were zinc (Zn), nickel (Ni), copper (Cu), lead (Pb) and cadmium (Cd).

2. Materials and Methods

2.1. Sampling Site

This study carried out in September 2010 in Bardestan mangrove forest. The study area is located 208 km to south of Bushehr, Iran and it's drainage area is between 27º 48'- 27º 50' latitudes and 51º 57'- 51º 59' longitudes (Figure 1). Bardestan mangrove forest has a drainage area of 2 hectares.

2.2. Heavy Metal Analysis of Plant Samples

Three samples of the leaves and roots of *A. marina* were collected from each sampling site. The samples of the roots and leaves were dried at 105°C to a constant weight. The plant parts were then ground to a fine powder using a porcelain mortar and pestle. One gram of the powder samples were digested in a mixture of HNO_3 and H_2O_2 (5:1) for 3 h at 140 ºC on a hotplate [4]. The detection of the heavy metals was carried out using an Atomic Absorption Spectrophotometer (GBC SAVANTAA ∑). Blank and laboratory standard samples (DORM-3/ fish protein) were also subjected to the same procedure. The recovery test for the plants was done using a standard analysis and the percentage of the recovery ranged from 92% to 95%.

2.3. Heavy Metal Analysis of Sediment Samples

Triplet sediment samples were collected from around the plant roots. Therefore, the sediment samples were dried in an oven and stone pieces were removed.

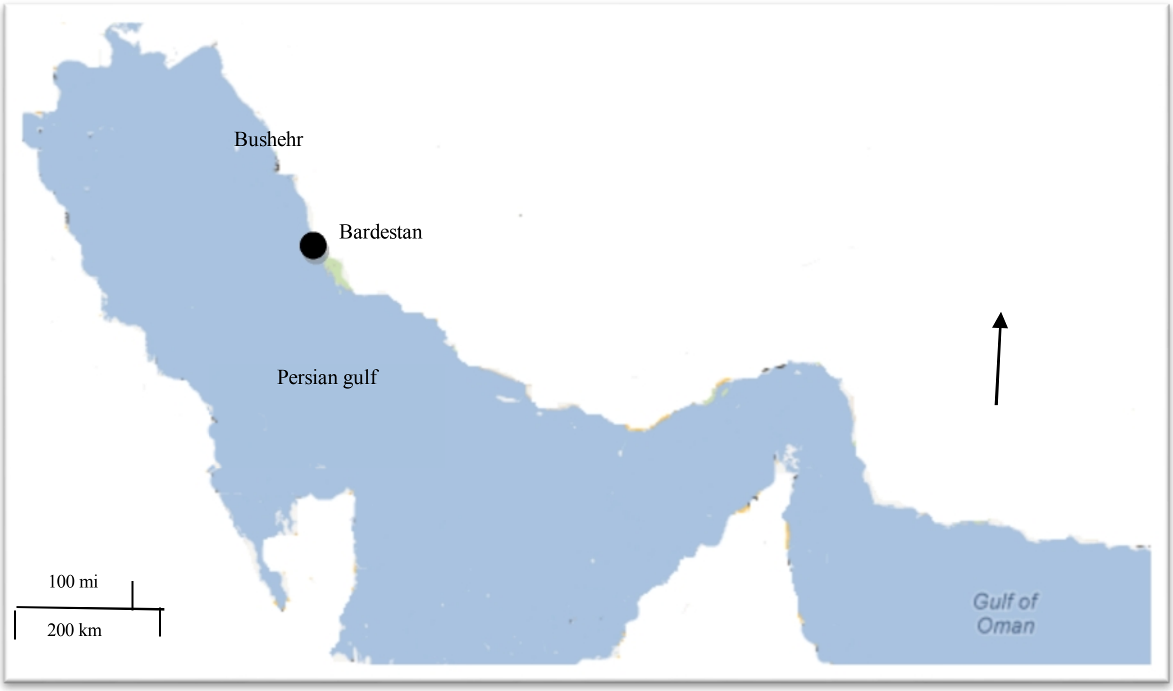

Fig. 1. Location of the study area of the Bardestan Mangrove (stand(•) from where leaves, roots and sediment were collected randomly from *Avicennia marina*

They were ground by using a hand mortar. For the digestion of sediment samples, a mixture of HCl and HNO_3(1:4) was used at 140°C and 3h [7]. The heavy metal detection was carried out in an atomic absorption spectrophotometer (GBC SAVANTAA ∑).

The SPSS statistical program was used to calculate the standard deviations and means.

3. Results and Discussion

3.1. Variations of Heavy Metals in all the Matrixes

Fig. 2-6 show the standard deviation and metal contents of all the studied materials. The organs of *A. marina* included different metal concentrations from each other. The concentrations of Zn, Ni, Cu, Pb and Cd in the roots of *A. marina* were smaller than in the sediment concentrations, but the metal concentrations in the root were significantly higher than in the leaves.

While the mean Zn concentrations were 40.11µg.g^{-1} in the sediment, 29.74µg.g^{-1} in the root, and 21.31µg.g^{-1} in the leaf of *A. marina,* the mean Ni concentrations were 65.24µg.g^{-1} in the sediment, 9.94 µg.g^{-1} in the root, and 2.02 µg.g^{-1} in the leaf. Zn and Ni are essential micronutrients with tissue with a dry weight of 100 and 1.5 µg.g^{-1}, respectively. Pais and Jones (2000) reported that the critical Zn value was 15 µg.g^{-1} for most crops although 10 µg.g^{-1} was sufficient and Zn accumulated in older leaves under some conditions [8]. Kabata-Pendias and Pendias (2001) reported that Ni moved easily from sediment to plant, especially to hyperaccumulator plants such as Alyssum sp. Cu concentrations averaged 12.46 µg.g^{-1} in the sediment, 6.17 µg.g^{-1} in the root, and 4.13 µg.g^{-1} in the leaf. Cu is not only an essential nutrient for plants, but also it is highly phytotoxic at high concentrations [9]. Kabata-Pendias and Pendias (2001) reported Cu levels of various plants from uncontaminated regions in different countries changed between 2.1 and 8.4 µg.g^{-1}. This means Cu can accumulate in the tissues of *A. marina*. Pb has recently received attention as a major chemical pollutant of the environment and as an element that is toxic to plants. Kabata-Pendias and Pendias (2001) reported that the Pb contents of plants grown in unpolluted areas varied between 0.05 and 3.0 µg.g^{-1}. Carranza-Alvarez et al. (2008) also reported Pb concentration ranged from 10 to 25 µg.g^{-1}, and the maximum accumulation of Pb was detected in roots [10]. Concentrations of Pb in the plant were smaller than the average concentrations reported as phytotoxic (<5mgkg−1) by Markert (1992). Pb concentrations were found to be 1.72 $\mu g.g^{-1}$ in the sediment, 1.57 $\mu g.g^{-1}$ in the root, and .94 $\mu g.g^{-1}$ in the leaf [11].

Cd is not an essential element for metabolic processes and collective toxics. Kabata-Pendias and Pendias (2001) reported that both roots and leaves absorbed Cd effectively [9]. Demirezen and Aksoy (2004) reported that Cd accumulated to its lowest level in *Typha angustifolia* in Sultan Marsh. Similarly, we also found that Cd was the lowest metal in *A. marina* due to it having the lowest Cd content of the sediments [12]. Carranza-Alvarez et al. (2008) also reported the root of *T. latifolia* accumulated 25mgkg−1, which means it exceeded 50 times the phytotoxic values (<0.5mgkg−1) reported by Markert (1992). The mean Cd concentrations were 0.62 $\mu g.g^{-1}$ in the sediment, 0.47 $\mu g.g^{-1}$ in the root, and 0.11 $\mu g.g^{-1}$ in the leaf. The roots of *A. marina* adsorbed a significant proportion of cadmium in the sediment and the Cd concentrations in the roots were often smaller than in the sediments. There are positive correlations between the root and sediment, thus the root of *A. marina* could be used as an indicator of the cadmium pollution in the soil.

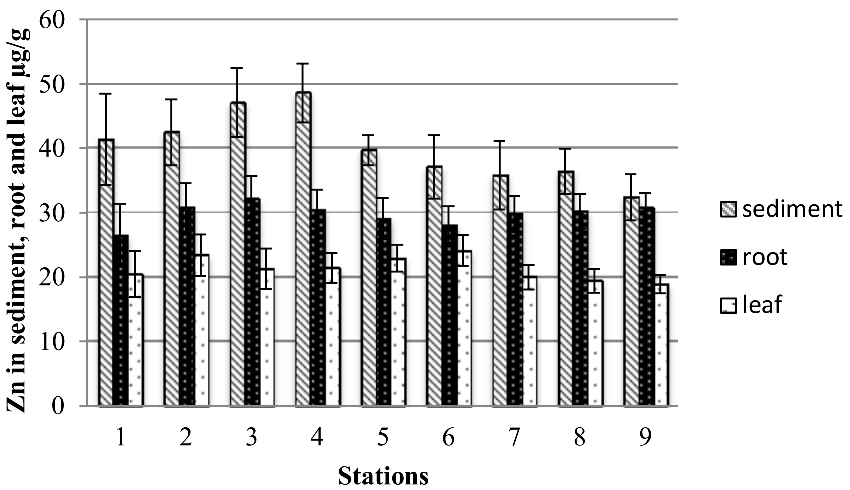

Fig.2. Average Zn concentrations in root and leaf of *Avicennia marina* together with sediment concentrations.

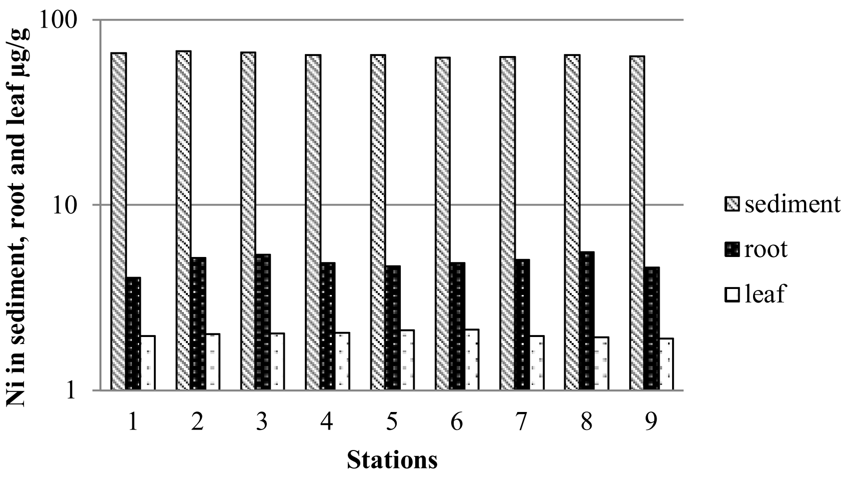

Fig.3. Average Ni concentrations in root and leaf of *Avicennia marina* together with sediment concentrations.

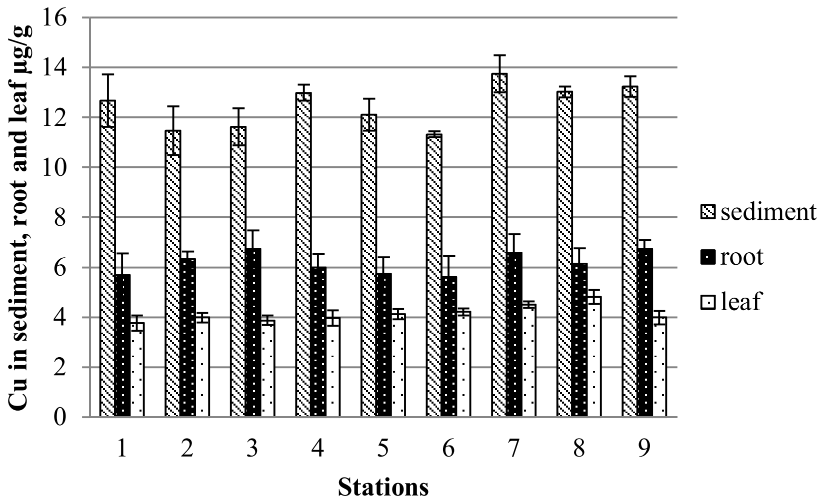

Fig.4. Average Cu concentrations in root and leaf of *Avicennia marina* together with sediment concentrations.

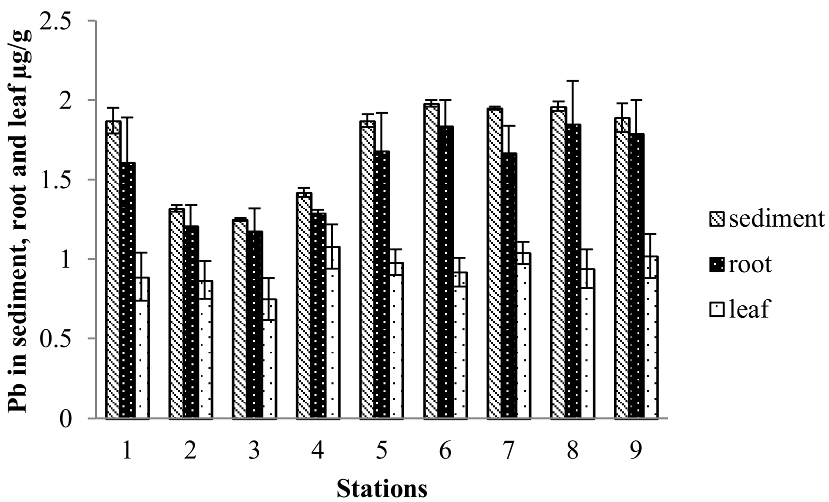

Fig.5. Average Pb concentrations in root and leaf of *Avicennia marina* together with sediment concentrations.

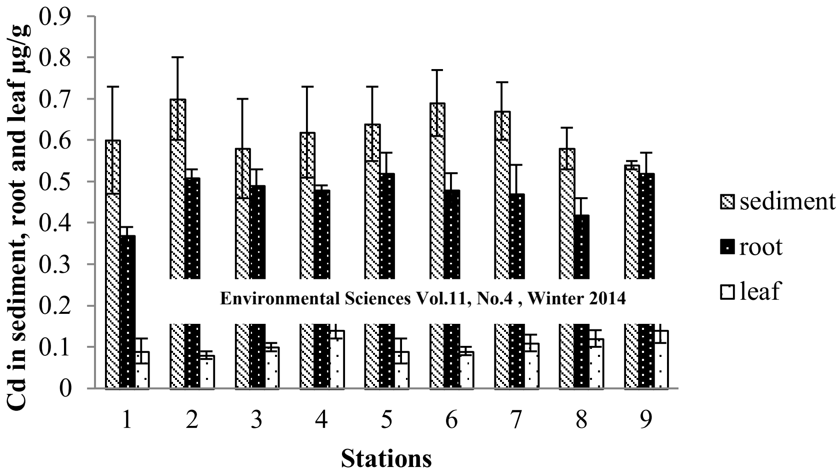

Fig.6. Average Cd concentrations in root and leaf of *Avicennia marina* together with sediment concentrations.

3.2. Transfer Factor (TLF)

Transfer factor can be used to estimate a plant's potential for the purpose of phytoremediation. The transfer factors of the metals in *A. marina* are shown in Table 1.

The mean TLFs for the studied metals were generally lower than 1.0. *A. marina* did not effectively transfer heavy metals from the roots to the body. The excluder ability was in the order of Cd > Ni > Pb >Cu > Zn. The differences in TLFs values indicated that each metal has a different phytotoxic \

3.3. The Enrichment Coefficient for the Leaf of *A. Marina* (ECL)

Enrichment coefficients are a very important factor, which indicate the phytoremediation of a given species [17]. In this study, the enrichment coefficients of all the metals of *A. marina* were generally lower than 1.0. The metal concentrations in the leaf were invariably higher than in the sediment and ECL was also smaller than 1.0. Scientists reported this situation indicated a special ability on the part of the plant to absorb and transport metals from the sediment and then store them in their above-ground part [5, 18].

3.4. Enrichment Coefficient for The Roots of *A. Marina* (ECR)

The enrichment coefficients in the roots of *A. marina* were higher than in the leaves. This situation means that the roots of *A. marina* have an important capacity in the accumulation of heavy metals. However, the bioaccumulation of lead by the root of *A. marina* was high due to its ECR being higher compared to other metals.

4. Conclusion

The Bardestan mangrove forest has various contaminants such as organic, nitrogen, phosphorus, pathogens, and metals, because it has carried some municipal wastewater. In this study, we considered the effect of the heavy metals present in the environment on sediment and plant. All the metals studied in the environment accumulated in the sediments and plants in contact with the estuary. In *A. marina*, the results indicated that roots were appropriate for metal accumulation. This means that the roots of *A. marina* in sediments or soil contaminated by trace metals can be used as biomonitoring for Zn, Ni, Cu, Pb and Cd. The transfer degree of metals from the down-parts to the up-parts was not very efficient according to the TLFs of all the heavy metals. This study verified that the heavy metals accumulated in the area of the Bardestan estuary and its plants, specifically lead. Unfortunately, people in the villages near the estuary use its water for irrigation in agricultural areas and to catch fish. This situation is a threat to public health, and thus a study should be performed on vegetables and fish in the region.

Table1- Transfer factor and enrichment coefficients for leaves, roots and sediments of *Avicennia marina* for heavy metals at all sites

Site	Zn			Ni			Cu			Pb			Cd		
	ECL	ECR	TLF	ECL	ECR	TLF	ECL	ECR	TLF	ECL	ECR	TLF	ECL	ECR	TLF
1	0.49	0.64	0.77	0.03	0.06	0.48	0.30	0.45	0.66	0.48	0.86	0.55	0.15	0.62	0.24
2	0.55	0.72	0.76	0.03	0.08	0.39	0.35	0.55	0.63	0.66	0.92	0.72	0.11	0.73	0.16
3	0.45	0.68	0.66	0.03	0.08	0.38	0.33	0.58	0.57	0.60	0.94	0.64	0.17	0.84	0.20
4	0.44	0.63	0.70	0.03	0.08	0.42	0.31	0.46	0.66	0.76	0.91	0.84	0.23	0.77	0.29
5	0.58	0.73	0.79	0.03	0.07	0.45	0.34	0.47	0.72	0.52	0.90	0.58	0.14	0.81	0.17
6	0.65	0.76	0.86	0.03	0.08	0.44	0.37	0.50	0.75	0.46	0.93	0.50	0.13	0.70	0.19
7	0.56	0.83	0.67	0.03	0.08	0.39	0.33	0.48	0.68	0.53	0.86	0.62	0.16	0.70	0.23
8	0.53	0.83	0.64	0.03	0.09	0.35	0.37	0.47	0.78	0.48	0.94	0.51	0.21	0.72	0.29
9	0.58	0.95	0.62	0.03	0.07	0.42	0.30	0.51	0.59	0.54	0.95	0.57	0.26	0.96	0.27
AVR	**0.54**	**0.75**	**0.72**	**0.03**	**0.08**	**0.41**	**0.33**	**0.50**	**0.67**	**0.56**	**0.91**	**0.61**	**0.17**	**0.76**	**0.23**

ECL: enrichment coefficient for leaf= leaf/sediment, ECR: enrichment coefficient for root= root/sediment, TLF: transfer factor= leaf/root

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