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A Study on Heavy Metal Concentration in Sediment and Mangrove (Avicenia marina) Tissues in Qeshm Island, Persian Gulf

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ABSTRACT: Sediment, Root, stem and leaf of mangrove tree (Avicenia marina) samples were collected from five stations in Qeshm Island in spring 2013. After preparation, the concentration of every metal was measured using the atomic absorption device Konic NOVAA300. Concentration of the heavy metals Cu, Ni, Pb, and Zn in sediments was measured 42.13, 54.12, 47.90, and 43.61 µg per gram dry weight respectively. The concentrations for the plant's root were 25.51, 39.76, 9.43, and 18.94 and for the plant's stem were 24.46, 7.05, 1.17, and 21.65 and for the plant's leaves were 37.73, 2.44, 0.84, and 33.83 µg per g. According to the calculated Bio Concentration Factor (BCF), plant tissues can be a good bio-indicator for Cu in the region. And, the root is a good bio-indicator for Pb and Ni. For Zn, however, leaf and stem tissues were the best bio-indicators. And the Translocation Factor (TF) was only significant for Cu and Zn in stem and leaf tissues which shows the direct relationship between Cu and Zn concentration in roots and following it, in leaves and stems. Comparing the metal concentration results of the sediment with standard concentrations, it was concluded that only the Ni concentration was critical.

***Keywords*:** Heavy metals, Sediment, Mangrove tree, Qeshm Island.

INTRODUCTION

Mangroves are a type of broadleaf evergreen schlorophyll trees which live in the swamps and intertidal shores of tropics and subtropics between latitude 25 degrees north and 25 degrees south at estuaries (where fresh water joins the seas). These trees grow in intertidal places where there is alluvial fine-grained soil which is waterlogged and salty. The trees usually are submerged at ebb time but then come out at tide. About 110 plant types are known as mangroves from which only a few are recognized as real mangroves. The most important types are: Avicennia marina (Hara, Mangrove, white or gray mangroves), Rhizophora mangle (Red mangrove) (Ellison and Farnsworth, 1992). Heavy metals are undegradable compounds which if entered the seas, can increase the heavy metal concentrations in coastal ecosystems including mangrove forests. As the mangrove forest sediments have a high potential for storing heavy metals from the water in tropical and subtropical regions (Kamaruzzaman et al., 2008; Tam and Wong, 1996; Clark et al., 1998). The high capability of mangrove to absorb and store heavy metals in its sediments, is because of the physicochemical properties of these sediments (Qiu et al., 2011; Harbison, 1986). Mangrove sediments are mainly in anaerobic conditions and have high amounts of organic matter. Thus, the mentioned sediments are a good indicator of heavy metal concentration (Tam and Wong, 2000). And these sediments can transfer the abovementioned pollutions to the mangrove trees (Defew et al., 2005). According to this, for environmental monitoring and to make sure that mangrove trees are well protected, it is necessary to measure the heavy metals concentration in the plant tissues and sediments in every region. On the other hand, herbivores do eat the mangrove tissues which necessitates the heavy metal concentration measurement for this tree. Persian Gulf is located at 48 degrees and 56 minutes east and 24 degrees and 30 minutes north and is one of the Northwestern sub-basins of the Indian Ocean. The Persian Gulf has been facing many environmental challenges like biodiversity loss, industrial pollution, and harmful effluents (Sabzalizade and Dehqan Medise, 2010). Since many industrialized cities reside on its shores, Persian Gulf is exposed to several different pollutants. Because of being shallow, limited circulation, salinity, and high temperature, the northern parts of the Persian Gulf are more affected by the pollutants (Saeed et al., 1995). Furthermore, environmental incidents, ship traffic, transportation, oil pollutants, and oil spills can cause different pollutants including heavy metals (Pourang et al., 2005; Tatina et al., 2009).

Mangrove forests which grow at southern coasts of Iran (covering parts of both Persian Gulf and Oman Sea) hold the last borders of mangrove forests in southwestern parts of Asia. The Protected Mangrove Area is the only protected mangrove forest system in Iran and because of its special features, it has universally become known as The Biosphere Reserve. Parts of this area, also, is registered as wetlands in The Ramsar International Convention List. The area is located between Qeshm Island and Khamir Bay and has become a protected area since 1972. Qeshm Island has the largest mangrove forests covered lands (Harji et al., 2008). Therefore, because of its importance, a study on different pollutants that contaminate the area, including heavy metals in mangrove forests of Qeshm Island, seems necessary as these forests are constantly affected by activities that take place in Persian Gulf. The purpose of this study is to measure heavy metal concentrations (Cu, Pb, Ni, and Zn) in sediments and root, stem and leaf tissues of mangrove (A. marina), and also to study the TF and BCF factors in different tissues of the plant.

MATERIALS AND METHODS

Figure 1 shows the area under study. Sampling was done in spring 2013 at tide time from five different locations around the Qeshm Island (table 1 shows the geographical points of sampling). Steel shovel was used to gather sediment samples at every point (3 repetitions). After acid washing them in poly ethylene containers, the samples were put inside an icebox and carried over to the laboratory. The sediments were kept in oven for 3 days at 80˚c to completely dry off. Then, the dried samples were, grinded using a mortar and pestle and sift using a sieve with 63 micron pores and after that, they were kept in plastic bags that were cleaned using acid washed (Nazli and Hashim, 2010). To digest the samples, 1 g of each dried sediment sample was mixed in 10 ml pure concentrated nitric acid (65%) and hydrochloric acid by the proportion 4:1. To digest them, the samples were first kept at 40˚c for 2 hours and then for 3 hours at 140˚c using hot plate. The digested samples were then kept in room temperature. After this, the samples were diluted using double distilled water to the volume of 50 ml and then they were filtered using Whatman 42 micron filter paper (Abdul-Wahab and Jupp, 2009).

Table 1. The position of sampling area in Qeshm Island

Samples stations		Geographical position	
Qeshm Island	St1	26˚ 49´ 43.25˝ N	55˚ 45´ 23.15˝ E
	St2	26˚ 48´ 01.88˝ N	55˚ 45´ 18.41˝ E
	St3	26˚ 50´ 54.53˝ N	55˚ 41´ 40.41˝ E
	St4	26˚ 55´ 32.68˝ N	55˚ 35´ 11.14˝ E
	St5	26˚ 58´ 45.44˝ N	55˚ 38´ 24.45˝ E

To determine the amount of heavy metals in mangrove tissues, root, stem, and leaf samples were picked (3 repetitions). The samples, then, were put inside clean plastic bags and were taken to the laboratory inside an icebox full of ice. Plant tissues were washed with distilled water and kept in oven at 60˚c for 24 hours to dry. The dried tissues, next, were grinded using porcelain mortar and kept in refrigerator until the next steps. 3 repetitions of grinded tissue samples from every station were digested. 1g sample of every tissue from every station was mixed in a 10 ml mixture of concentrated nitric acid and hydrogen peroxide for 2 hours at 90˚c using the Hot plate. The digested samples, then, were cooled and diluted to the volume of 50 ml at laboratory temperature and filtered with 42 micron filter paper (MacFarlane et al., 2003; Macfarlane et al., 2007).

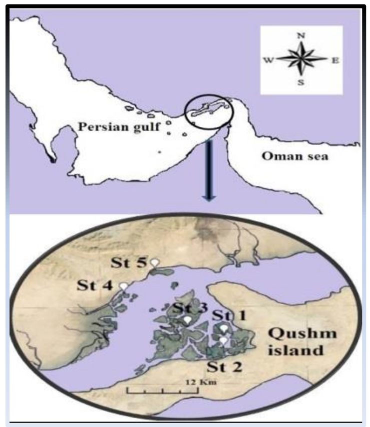

Figure1. Map showing study area

Heavy metal concentrations were measured using atomic absorption spectrometry Konic (FAAS) model Novaa 300 in gram in dry weight gram ($\mu g.g^{-1}$ d.w). To statistically analyze the data, the software SPSS v13 was used. Before going through statistical analysis of the data, the data normality was determined using Klomogrov-Smirnov test. After making sure of data normality, the concentration differences of each metal for every tissue (root, stem, and leaf) and the sediments was measured using the One Way ANOVA and to separate the groups, the Tukey post hoc test was used. And, Microsoft Excel was used to draw the charts.

RESULTS AND DISCUSSION

Results

Tables 2, 3, 4, and 5 show the different Pb, Ni, Cu, and Zn concentrations in the sediments and plant tissues in µg.g. The highest Pb concentration (47.90 $\mu g.g^{-1}$ d.w) was found in the sediment. And the least amount of Pb was seen to be that of the mangrove leaf (0.84 $\mu g.g^{-1}$ d.w) (ANOVA, $P<0.05$). Cu and Ni concentrations in different samples showed significant difference. The highest amounts of these metals was found to be in the sediments. The least concentration of Cu was that of the stem and root while the least concentration of Ni was that of the leaves (ANOVA, 0.05). According to the results, the highest Zn concentration was in the sediments and its least concentration was that of the stem and leaf (ANOVA, $P<0.05$) (figures 2 to 5).

Table 2. Heavy metals content in sediment (µg/g DW)

Station	Cu	Ni	Pb	Zn
1	47.03±0.73	58.09±0.78	47.16±1.91	46.35±19.34
2	47.93±3.40	47.05±0.94	10.18±3.52	26.71±3.77
3	42.42±8.54	57.18±3.78	52.03±1.70	54.24±1.83
4	35.73±2.13	52.11±14.43	50.38±2.91	37.49±11.10
5	37.53±0.50	56.18±0.62	47.06±2.86	42.72±6.29
Total	42.13±6.07	54.12±24.44	47.90±3.77	43.61±12.46

Table 3. Heavy metals content in root of *A. marina* (µg/g DW)

Station	Cu	Ni	Pb	Zn
1	25.27±4.29	39.02±0.87	9.21±1.06	24.88±2.34
2	26.94±3.40	37.42±0.94	10.18±3.52	26.71±3.77
3	23.62±1.29	38.92±1.64	8.10±0.17	7.49±4.44
4	25.27±0.54	39.17±3.37	9.07±0.64	9.64±3.90
5	26.43±1.04	41.68±0.11	10.60±1.18	25.99±0.53
Total	25.51±2.49	39.76±4.20	9.43±1.74	18.94±7.25

Table 4. Heavy metals content in stem of *A. marina* (µg/g DW)

Station	Cu	Ni	Pb	Zn
1	27.10±0.82	7.78±0.87	1.02±0.26	41.76±7.89
2	24.55±0.94	8.75±0.97	1.56±0.06	16.45±1.74
3	23.40±0.75	9.81±0.79	1.24±0.06	14.95±2.11
4	23.15±0.81	5.57±0.72	0.73±0.01	22.32±3.80
5	24.10±1.07	3.34±1.26	1.28±0.32	12.80±2.41
Total	24.46±1.64	7.05±2.57	1.17±0.33	21.65±11.48

Table 5. Heavy metals content in leaf of *A. marina* (µg/g DW)

Station	Cu	Ni	Pb	Zn
1	32.47±7.57	2.50±0.58	0.89±0.14	29.50±4.62
2	38.83±22.91	2.59±0.67	0.87±0.02	19.71±3.97
3	34.94±21.70	2.1788±0.59	0.83±0.02	23.03±4.50
4	59.33±5.91	1.88±0.94	0.81±0.07	49.50±9.34
5	23.08±1.23	3.07±0.58	0.81±0.08	47.43±6.39
Total	37.73±17.59	2.44±0.71	0.84±0.07	33.83±13.80

TF was studied from root to stem and leaf tissues. Formula 1 was used to calculate this factor. For each heavy metal, BCF was measured using the plant tissues (formula 2) (MacFarlane et al., 2007). To study this factor, the concentration ratio of each metal in root, stem, and leaf tissues to the sediment was calculated and the results are shown in table 6 (Machado et al., 2002).

Formula No:1

$$\mathrm{TF} = \frac{\text{concentration in leaf or steam}}{\text{concentreation in root}}$$

Formula No:2

$$\mathrm{BCF} = \frac{\text{concentration in plant tissue}}{\text{concentration in sediment}}$$

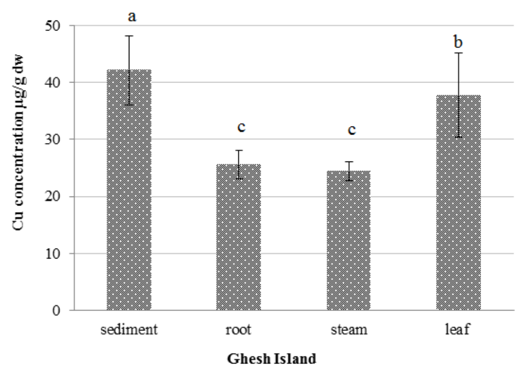

Figure 2. Comparison of Cu content among studied samples

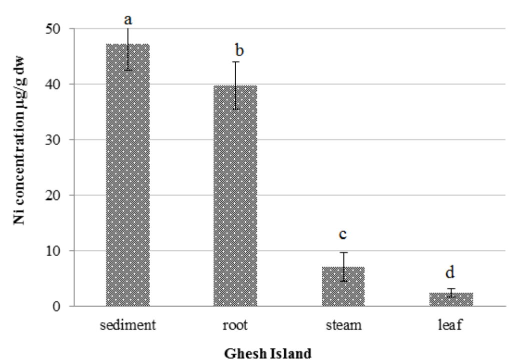

Figure 3. Comparison of Ni content among studied samples

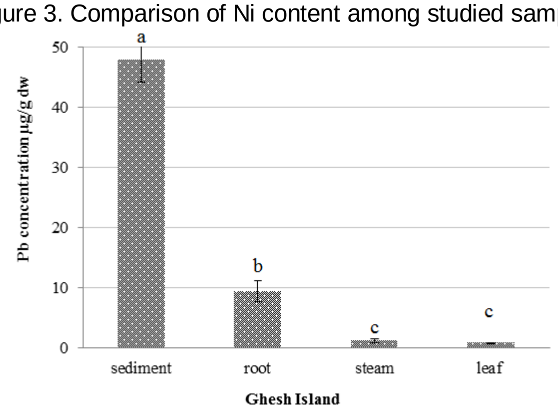

Figure 4. Comparison of Pb content among studied samples

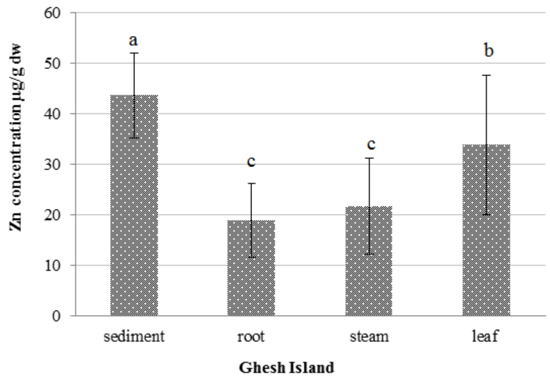

Figure 5. Comparison of Zn content among studied samples

Table 6. BCF and TF factor in each tissue

	Pb	Ni	Cu	Zn
BCF in root	0.60	0.73	0.60	0.43
BCF in steam	0.02	0.13	0.58	0.49
BCF in leaf	0.017	0.04	0.89	0.77
TF in steam	0.12	0.17	0.95	1.14
TF in leaf	0.08	0.06	1.47	1.78

Discussion

According to the statistical analysis of different samples, it became clear that the highest concentrations of all of the studied metals exist in the sediment. Table 7 compares the heavy metal concentration of Qeshm Island sediments with other studies on Persian Gulf and Oman Sea. This comparison showed that the metal concentration trend, a decreasing concentration from essential metals to non-essential metals, is in agreement with other studies. In other words, the rest of the studies also concluded that the essential metals had lower concentrations than non-essentials. Comparing the two, it was also concluded that essential metals had lower concentrations in root tissues while non-essential metals showed higher concentrations in this tissue. These changes may be the results of the plant's defense strategies for concentrating non-essential metals in this tissue and also the plant's physiological need for essential metals like Cu and Zn. Cu is considered to be one of the essential metals for the plant which by itself is an effective factor for its equal concentration in different parts of the plant. The metals Cu and Zn have a part to play in chloroplast processes, protein synthesis, enzyme activities, growth hormones, and carbohydrate metabolisms (Degryse et al., 2006). These results are similar to the findings of Einollahi, (2012), Pakzadtoochaee and Einollahipeer, (2013) who studied heavy metal concentration in the sediment and different tissues of mangrove tree in coastal regions of Gwatr Bay. On the other hand, increase of Pb and Ni concentrations in the root, compared to other tissues, could be an indicator to root's capability for more concentrations of Ni than other tissues. Yim and Tam, (1999) in their study on comparing the heavy metal, including Ni, concentrations in plant tissues found the highest metal concentrations to be in root, stem, and the sediment. They said that higher heavy metal concentration in these tissues is because they have better biological access to the environment.

According to the BCF, plant tissues can be a very good bio-indicator for Cu concentration. The root is a good bio-indicator for both Ni and Pb and leaf and stem tissues are best for Zn. Since the root is in direct contact with the sediment, it can be stated that heavy metal concentration changes in the sediment would directly affect it. Especially according to the results of the present study, this relationship for non-essential metals exists only in the root. Results of Einollahi's study, (2012) on BCF for the heavy metals like Cd, Cu, Zn, and Ni in Gwatr Bay were similar to the findings of this study. In this study too, the root showed the highest metal concentrations compared to other tissues. MacFarlane et al (2007) measured the BCF (metal ratio in root to sediment) for metals like Cu, Pb, and Zn in mangrove (A. marina) and they stated that root tissue is a very good bio-indicator for these metals.

TF index was only significant for Cu and Zn in both stem and leaf tissues which indicates the direct role of the root in transferring them to these tissues. Einollahi (2012), studying the TF index for metals like Cd, Cu, Zn, and Ni in Gwatr Bay, north of Oman Sea, found the highest TF to be those of Cu and Zn. Tam and Wong, (1997), said that mangrove root tissues are a sufficient tool which transfer heavy metals from the environment to the plant's tissues. Macfarlane et al, (2007), found the highest TF index in mangrove plant to be that of the metals Cu and Zn. According to this, it can be stated that because of the plant's need for essential metals, Cu and Zn are directly transferred from the root to other tissues but this process, for Ni and Pb, is in a way that lesser concentrations of these metals are transferred to other tissues from the roots.

Table 7. comparison heavy metals concentrations (in µg/g DW) in surface sediment in present study with other literature data

region	Trace metals				
	Cu	Ni	Pb	Zn	refcrence
Lengeh port, Persian gulf	4.69	---	163.02	31.36	Heidarichaharlang et al., 2011
Surface sediment in Bidkhoon, Basatin, Persian gulf	46.04	64.14	94.80	181.46	Davari et al., 2012
Life Booseif, northwest of Persian gulf	21.80	73.60	23.50	68.60	Sabzalizade and Dehqanmedise, 2010
Northern coast of Oman sea, summer	38.28	26.90	50.37	---	Einollahi Peer and Safahieh, 2011
Gulf of Gwatr, Oman sea	22.09	71.08	---	53.61	Pakzadtoochaee and Einollahipeer, 2013
Qeshm Island	42.13	54.12	47.90	43.61	Current study

Table 8 compares the heavy metal concentrations with China and American standards. According to this table, Pb and Zn concentrations are lower than the standards. Cu was only higher than the primary standard. This comparison also shows that although Cu concentration is higher than this standard, it is still not in the critical range. Ni concentrations were higher than secondary standard of America which indicates that Ni concentration of sediments is in the critical range.

Table 8. Comparison heavy metals concentrations (in µg/g DW) in surface sediment in Qeshm Island with available standards

standards	Cu	Ni	Pb	Zn
Primary standard of China (CSBTS[1]) (Davari et al., 2012)	35	---	60	150
Secondary Standard of China (CSBTS[1]) (Davari et al., 2012)	100	---	130	350
USEPA-Region II[2] (Davari et al., 2012)	108	42.8	112	271
Current study	42.13	51.12	47.90	43.61

1 China State Bureau of Quality and Technical Supervision

2 USEPA-Regions II, USACE-New York District, USDOE-BNL

CONCULSION

Different concentrations of metals in the sediment and tissues of *A. marina* in Qeshm Island can be a result of roles that metals play for the plant. Root, stem, and leaf tissues can be a good bio-indicator for Cu. Only root tissue was a good bio-indicator for Ni and considering Zn, leaf and stem tissues could be used as good bio-indicators. A. marina's root plays an effective role in transferring Cu and Zn to the plant's stem and leaves in Qeshm Island and high concentrations of Ni in the sediments can be a result of transportation activities or perhaps oil compounds spill into the water.

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