Levels of heavy metals in sediments in the vicinity of Chabahar Bay desalination plant

Miri M.[1*]; Nabavi S.M.B.[2]; Doustshenas B.[2]; Safahieh A.R.[2]; Loghmani M.[3]

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Abstract

Desalination plants are potentially capable of having impacts on coastal marine environments due to the production of wastewater with high concentrations of salts (brine discharge) and some heavy metals. The aim of this study was to examine the concentration of accumulated metals (Ni, Cu, Cd, Fe, Zn, Pb) in the sediments near the brine discharge point in the Chabahar Bay. Twenty one sediment samples were collected from seven stations in summer pre-monsoon and post-winter monsoon, in April and October 2011. The results showed that stations closer to brine discharge points had higher concentrations of metals in the sediment than other stations. Metal contamination in sediment samples was below a critical level with the exception of cadmium with higher values than MAFF, ANZECC and FDEP standards at a maximum of 5.76 mg/kg dry weight. There was a clear decreasing gradient in heavy metal concentrations from station 2 to station 7, especially for Cd, Pb, Fe and Zn. The probable reason for this is the water circulation in the Chabahar Bay.

Keywords: Heavy metals, Pre-and post-monsoon, Desalination plant, Chabahar Bay

1-International Center of Hamoon Wetland, University of Zabol, Zabol, Iran

2-Department of Marine Biology, University of Marine Sciences and Technology, Khorramshahr, Iran

3-Department of Marine Biology, University of Chabahar Maritime and Marine Science, Chabahar, Iran

*Corresponding author's email: mirimohadeseh@uoz.ac.ir

Introduction

In recent years, desalination of sea water has become an important industry that has grown due to the scarcity of fresh water resources. There are 14451 desalination plants worldwide and their total world capacity is 59.9 million m^3/day (Mezher *et al*., 2011). The largest number of desalination plants are situated on the coasts of the Persian Gulf countries with the highest production amounts of fresh waters in the United Arab Emirates and Saudi Arabia (Lattemann and Hopner, 2008). The brine discharges may contain heavy metals such as nickel, iron and cadmium which can affect the characteristics of the local marine environment, as well as that of marine life. Desalination brine discharges in the marine environment can alter the nature of water masses at the outlet point in many ways including: oxygen depletion, increasing water temperature and salinity, and excess of heavy metals and toxic chemicals. Desalination brine also may contain many contaminants and hazardous waste including anti-fouling agents, chlorine and acid, which are unavoidably needed in large-scale plants to treat the feed water and pipelines (Dupavillon and Gillanders, 2009).

The aim of the present investigation was to determine the distribution of six trace elements in the Chabahar desalination plant sediments.

Materials and methods

The study was carried out in the coastal zone of the Chabahar Bay. This area is characterized by the homogeneity of sediments that are dominated by silt and clay fraction. Collection of sediment samples took place at discharge point (station 1) and 200m from the brine discharge point (station 2). Station 3 was 200m far from station 2 and stations 4 and 5 were selected 200m far from stations 2 and 3. Control stations (6 and 7) were chosen 1 km away from stations 2 and 4 (Fig.1 and Table1). During pre-summer monsoon and post-winter monsoon, April 2011 and October 2011, respectively 21 sediment samples were collected from seven stations by using Van Veen grab in the Chabahar Bay. The upper most layer of each grab was collected and transferred to acid washed polyethylene bottles. In the laboratory, each sediment sample was oven dried according to MOOPAM (1999) procedures. Dried sediments were then passed through a 63 µm sieve. Nitric acid (65% Merck) and Perchloric acid (60% Merck) at a ratio of 3:1 were added to one gram dried sediment. Digestion of sediments was done using a hotplate digester. After the dilution of samples by double-distilled water, heavy metal concentrations namely Ni, Cd, Cu, Pb, Fe and Zn in sediments were determined using atomic absorption spectrometer model Savanta AA Sigma. Environmental parameters namely pH, dissolved oxygen, temperature and salinity were measured immediately at each station using Horiba UIO analyzer.

In the present study the statistical analysis of data was performed by using

the Statistical Package for Social Science (SPSS) software.

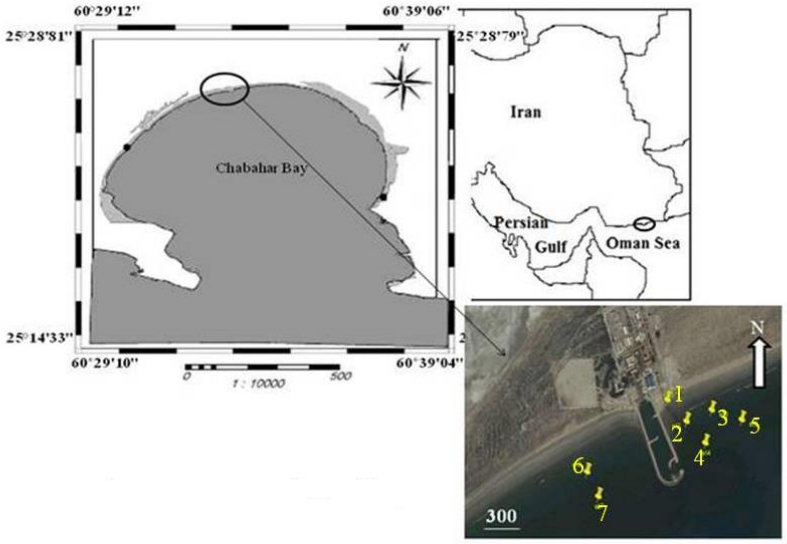

Figure 1: Map showing the locations of sampling stations.

Table 1: Location of the stations.

Stations	Location
Station1	25°26'17.7"N 60°29'18.3"E
Station2	25°29'12.75"N 60°29'23.25"E
Station3	25°26'14.27"N 60°29'30.94"E
Station4	25°26'07.77"N 60°29'28.18"E
Station5	25°26'11.35"N 60°29'39.47"E
Station6	25°26'05.66"N 60°28'52.79"E
Station7	25°26'0.33"N 60° 28' 55.42"E

Results

The results of the environmental parameters are shown in Table 2. According to the results, the maximum values of salinity, temperature and the lowest values of dissolved oxygen and pH were found at the discharge point (station1). Stations away from the brine discharge area had lower values of salinity and temperature and higher values of dissolved oxygen.

Statistical analysis of heavy metal concentrations during pre- and post-monsoon showed significant differences between all stations (p<0.05). The highest values of Cd, Zn, Fe, Pb and Ni concentrations were measured in stations near desalination plant discharges (Fig. 2). In this respect station 2 showed the highest values of 5.76±0.0.6, 34±0.07, 2.9±0.04, 14.86±0.4 and 17.55±0.81 (mg/Kg dry

weight) for Cd, Zn, Fe, Pb and Ni, respectively during pre- monsoon. The exception was Cu with the highest value (5.3±0.07 mg/kg dry weight) in station 1 and the lowest value (0.36±0.06 mg/kg dry weight) recorded in stations 6 and 7.

Table 2: Comparison of environmental parameters at different stations during pre- and post-monsoon (mean±SD) .

	Station1	Station2	Station3	Station4	Station5	Station6	Station7
Pre- monsoon							
Salinity(PSU)	46±0.05^{e}	43±0.05^{d}	40±0.1^{c}	38.5±0/03^{b}	38.2±0/2^{a}	38±0.09^{a}	38±0.1^{a}
Temperature(ºC)	32±0.2^{d}	31.6±0.07^{c}	30.25±0.1^{b}	29.5±0.08^{a}	29.3±0.08^{a}	29.15±0.03^{a}	29±0.03^{a}
pH	7.3±0.05^{a}	8.18±0.1^{b}	8.2±0.01^{b}	8.2±0.05^{b}	8.4±001^{b}	8.5±0.05^{c}	8.5±0.03^{c}
Dissolved Oxygen (ppm)	4.47±0.8^{a}	4.9±0.01^{b}	4.91±0.1^{b}	4.91±0.1^{b}	5±0.01^{b}	5±0.01^{b}	5±0.08^{b}
Post- monsoon							
Salinity(PSU)	45±0.03^{d}	42.3±0/1^{c}	39.23±0.1^{b}	38.1±0.05^{a}	37.7±0.02^{a}	38.25±0.3^{a}	37.8±0.1^{a}
Temperature(ºC)	38.02±0.09^{c}	38±0.04^{c}	37.59±0.09^{b}	37.2±0.09^{b}	37±0.08^{a}	37±0.04^{a}	37±0.07^{a}
pH	7±0.05^{a}	8.2±0.03^{b}	8.35±0.03^{c}	8.48±0.4^{c}	8.54±0.02^{c}	8.6±0.04^{cd}	8.7±0.05^{d}
Dissolved Oxygen(ppm)	3.54±0.2^{a}	3.89±0.01^{b}	3.93±0.01^{b}	4±0.005^{b}	4.2±0.01^{b}	4.03±0.02^{b}	4.06±0.1^{b}

Means with the same letter in the same row are not significantly different (p<0.05).

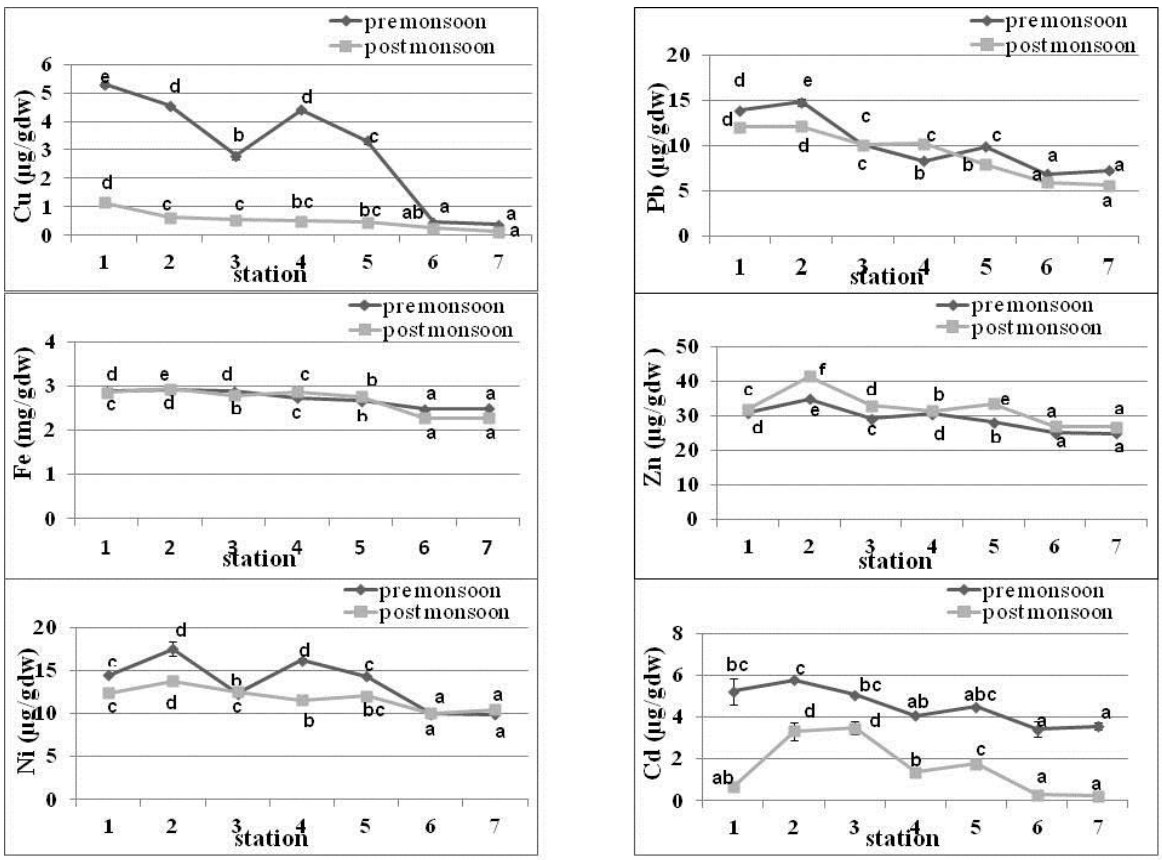

Figure 2: Variations of mean values of heavy metal concentrations in pre- and post- monsoon sediment samples. Means with the same letter are not significantly different (p<0.05).

The results showed that there was no strong correlation and coefficient of determination (R^2) between the heavy metals, especially between Cu and Zn

and between Zn and Cd (Fig. 3). The comparison of heavy metal concentrations in the study area and world standards are shown in Table 3.

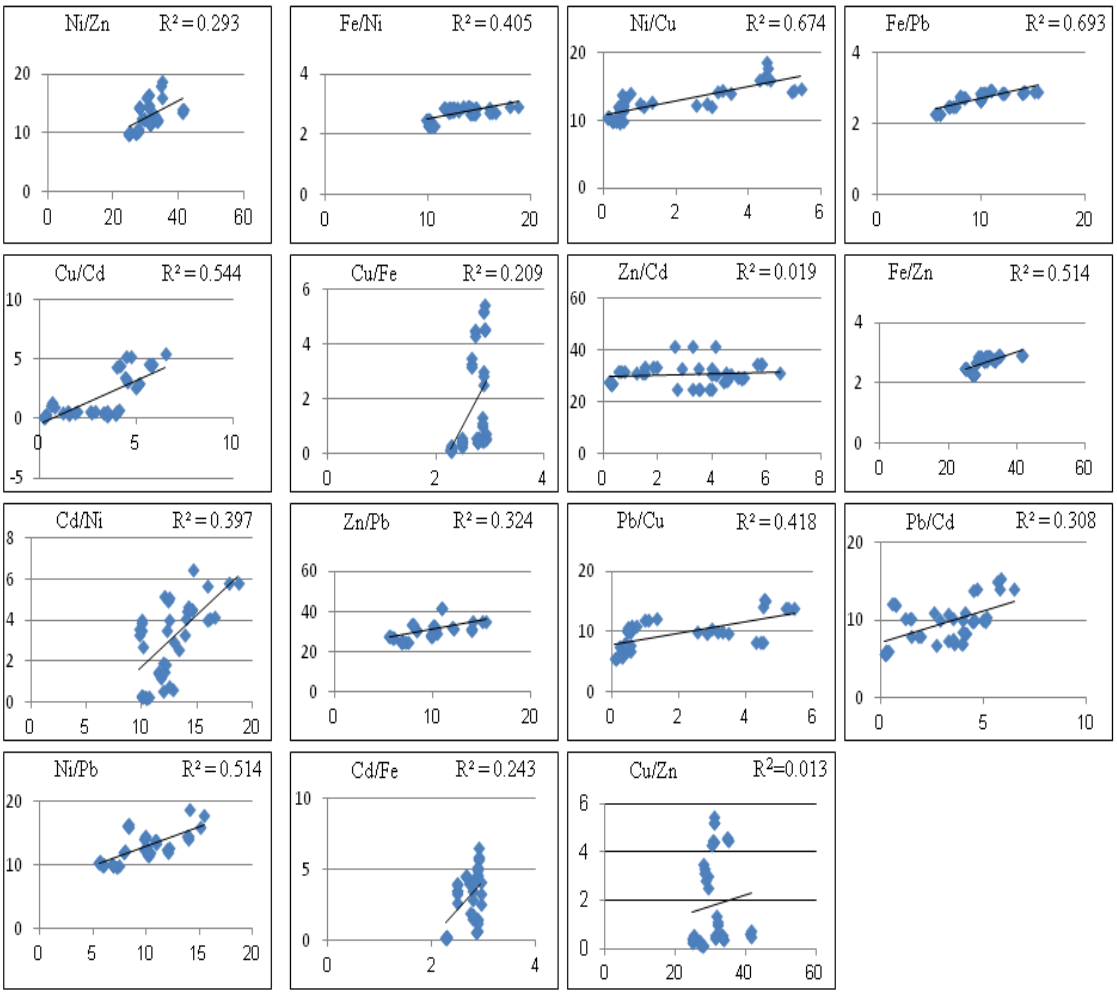

Figure 3: Correlation coefficients of heavy metals in the sediments of the study area.

Discussion

The results indicate that there are significant differences (p<0.05) between heavy metal concentrations in the sediments in different station, during the two seasons of sampling. According to some investigators (Peng *et al.*, 2009; Barua *et al.*, 2011) environmental parameters such as pH, organic compounds in sediments, salinity, temperature, metal species and retention time can affect the distribution of heavy metals in sediments. Among these factors pH and salinity have a key role in controlling heavy metal transfer behavior in sediments. Decreasing pH values and increasing salinity values, often result in some metals being released into the water body. Table 2 shows lower values of pH and dissolved oxygen and higher values of salinity and temperature during both pre- and post- monsoon in station 1.

According to Peng *et al.* (2009) a decrease in pH values and an increase in salinity values can result in

increasing the mobility of heavy metals. In station 1 the decreased pH value and increased salinity value may have been caused by metals being released into the water. The turbulence in station 1 as a result of brine discharges could be another reason for the release of metals into the water at station 1. The samplings show decreased values of Cd, Ni, Pb, Zn and Fe in station 1 (Fig. 2), while Cu showed a different behavior in the sediment, with a higher value occurring at station1. As it stated by some workers (Morillo *et al*., 2004; Stylianou *et al*., 2007), Cu is found at the greatest proportions in the oxidizable fraction (coinciding with organic and sulfur compounds) of sediments. Cu can easily form complexes with organic matter due to the high stability constant of organic Cu compounds (Morillo *et al*., 2004).

This fact indicates that the undesirable solubility and the release of this trace metal in the ecosystem can be avoided under appropriate conditions (Stylianou *et al*., 2007).

Data shown in Fig. 2 indicate higher values of heavy metal concentrations in station 2. There is a clear decreasing gradient of heavy metal concentrations from station 2 to station 7, especially for Cd, Pb, Fe and Zn. For Ni, There were two peaks during pre- monsoon at stations 2 and 4. There were also significant differences (p<0.05) between Cu, Pb, Zn, Ni and Fe concentrations in station3 compared to stations 4 and 5. The probable reason in this respect is water circulation in the Chabahar Bay. The most dominant winds blowing from the southwest towards the southeast caused circulations near the seabed, resulting in the transformation of particulate matter from the northwest and northeast of the Chabahar Bay towards the central parts (PSO, 2008). It seems that at station 3, the brine waters are affected less by heavy metal compounds existing in brine discharges. The results showed that concentrations of heavy metals were higher in sediment samples from the immediate vicinity of the discharge point and decreased progressively away from it. A similar trend was reported by Sadiq (2002) and Abdul-Wahab and Jupp (2009). In the present study the concentrations of heavy metals (Table 3) in the bottom sediments were compared with some international standards such as; ANZECC (Australian and New Zealand Environment and Conservation Council), EPA (Environmental Protection Agency), NOAA (National Oceanic and Atmospheric Administration), FDEP (Florida Department of Environmental Protection) and MAFF (Ministry of Agriculture, Fisheries and Food). According to Table 3, concentrations of Cd were low, compared to EPA and ERM (Effects Range Median) while they were higher than MAFF, ANZECC, ERL (Effects Range Low) and FDEP guidelines. It is a probable concern for the near future and needs to be controlled and managed. Concentrations of Cu and Ni can be seen in Table 3, which are lower than standard values but Ni at its maximum

level (17.55 mg/kg) was higher than the TEL (Threshold Effects Levels) guidelines (Table 3). Pb and Zn concentrations were also lower than standard values. Fe showed a similar trend as other metals with its maximum concentrations in stations near the outfall. Because of corrosion products from alloys used in the process line, the brine discharges contain some metals such a Cd, Cu, Pb, Ni, Zn and Fe. The levels of Fe in the study area were comparable to numbers reported by Abdul- Wahab and Jupp (2009) in Oman coasts.

As there are no human activities around the Chabahar desalination plant, it seems that brine discharge is the main source of heavy metal contamination in the study area. Correlation coefficient data shown in Fig. 3 indicate that there is a moderate relationship between the following sets of variables: Cu and Cd (R^2=0.54), Ni and Zn (R^2=0.29), Cd and Ni (R^2=0.40), Ni and Pb (R^2=0.51), Fe and Ni (R^2=0.41), Ni and Cu (R^2=0.67), Zn and Pb (R^2=0.32), Cu and Fe (R^2=0.21), Fe and Pb (R^2=0.69), Pb and Cu (R^2=0.42), Fe and Zn (R^2=0.51), Cd and Fe (R^2=0.24). There was a weak correlation between Zn and Cd (R^2=0.02) and Cu and Zn (R^2=0.01). As stated before, these metals seem to have originated from corrosion products of the Chabahar desalination plant.

Table 3: Comparison of the heavy metals concentrations (mg/kg) resulting from the present study with the world standards.

Heavy metal	Present study Min	Max	EPA	ANZECC	MAFF	NOAA ERM	ERL	Florida PEL	TEL
Cd	0.22	5.76	31	1.5	2	9.6	1.2	4.21	0.68
Cu	0.12	5.3	136	65	40	270	34	108	18.7
Fe	2280	2940	_	_	_	_	_	_	_
Ni	10.05	17.55	132	21	100	51.6	20.9	42.8	15.9
Pb	5.61	14.86	132	50	40	218	46.7	112	302
Zn	24.92	34	760	200	200	410	150	217	124

ANZECC: Australian and New Zealand Environment and Conservation Council; MAFF: Ministry of Agriculture, Fisheries and Food (UK) ; NOAA : National Oceanic and Atmospheric Administration (USA); ERM : Effects Range Median; ERL: Effects Range Low ; TEL :Threshold Effects Levels; PEL: Probable Effects Levels.

In summary it can be concluded that the higher level of Cu was found in station 1 during pre monsoon season, but it was lower compared to standards namely TEL, PEL (Probable Effects Levels), ANZECC and MAFF. The Cd values were higher than MAFF, ANZECC, ERL and FDEP standards. Ni to a lesser extent showed a relatively higher value compared to TEL during pre- monsoon season in station 2. The rest of the heavy metal concentrations (Cd, Pb, Zn, Fe) showed a similar decreasing trend from stations 2 to 7. Despite the fact

that the results did not show heavily polluted conditions in the study area, monitoring and evaluation of the impact of effluent discharges of desalination plants on water and sediment quality as well as marine flora and fauna is needed, due to the ever increasing desalination activities occurring in the study area.

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