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Distribution Patterns of Metals Contamination in Sediments Based on Type Regional Development on the Intertidal Coastal Zones of the Persian Gulf, Iran

Ali Kazemi · Alireza Riyahi Bakhtiari · Nabiallah Kheirabadi · Hashm Barani · Behnam Haidari

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Abstract This study was performed to determine the variation of metals concentrations (Pb, Cd, Zn, and Cu) in surface sediments based on type region development from ten sites on the intertidal coastal zone of the Persian Gulf, Iran. The metals concentrations in surface sediments varied from 0.86 to 180.78 μg g^{-1} for Pb, 0.61 to 6.48 μg g^{-1} for Cd, 5.99 to 44.42 μg g^{-1} for Zn, and 3.01 to 43.33 μg g^{-1} for Cu. The quality of the sediments was evaluated based on sediment quality guidelines (effects range-low (ERL) and effects range-medium (ERM) indexes. Biological effects criteria suggest that metals concentrations in sediments were lower than ERM for all sites, but for some sites metals concentrations in sediments were higher than ERL. The present results support the concept that human activities in each region could be a major source of metals pollution input in the aquatic environment.

Keywords Metal(s) · Sediment · Persian Gulf · ERL · ERM

A. Kazemi · A. R. Bakhtiari (✉)
Department of Environmental Sciences, Faculty of Natural Resource and Marine Science, Tarbiat Modares University, P.O. Box 46414-356, Noor, Mazandaran, Iran
e-mail: riahi@modares.ac.ir; ariyahi@gmail.com

N. Kheirabadi · H. Barani
Department of Marine Biology Sciences, Faculty of Natural Resource and Marine Science, Tarbiat Modares University, P.O. Box 46414-356, Noor, Mazandaran, Iran

B. Haidari
Department of Environmental Pollution, Science and Research Branch, Islamic Azad University, Ahvaz, Khouzestan, Iran

The Persian Gulf is a strategic region in the Middle East. Furthermore, it is well known as the most active oil production region in the world (Elhakeem et al. 2007). The Persian Gulf is naturally a highly stressed environment, even before the significant input of anthropogenic sources of pollution. The Gulf is a semi-enclosed sea situated in a semi-arid region, characterized by a shallow average depth of 35 m, high evaporation rates, salinity ranging from 38 to 70 g L^{-1} (parts per thousand), minimal water exchange (3–5 y), and almost land-locked because the only connection to open water is the Strait of Hormuz, which is only 86 km wide (Agah et al. 2009). Due to its shallow depth, limited circulation, high salinity, and temperature, the impacts of pollutants on the marine environment may be significant in the Persian Gulf (Fayad et al. 1996). This Gulf during the last three decades has been affected by two major oil spills. The first occurred in the Iran-Iraq War in 1983, and the second occurred during the 1991 Gulf War (Price 1994; Fayad et al. 1996; Elhakeem et al. 2007). Also, this region has a complex and interesting ecosystem, and is influenced by anthropogenic activities including shipping and transport, the oil and petrochemical industry, fishing, agriculture, harbor, mining, residential and commercial wastewater (de Mora et al. 2004; Karbassi and Bayati 2005). Sediments reflect the history of pollution in the aquatic environment (Karbassi and Bayati 2005; Singh et al. 2005). Sediments play an important role as both carriers and sinks for contaminants including metals transported to aquatic environments (Singh et al. 2005). The metals are considerably dangerous for the aquatic environment. This can be due to their toxicity, wide sources, lack of biodegradable properties, and accumulative behavior (Yu et al. 2008). Sediment contaminated by the metals may have harmful effects on the biota (Long et al. 1995; Santos Bermejo et al. 2003).

The objectives of this study were: (1) to investigate distribution patterns of the metals concentrations in surface sediments; (2) to determine the metal pollution levels in sediments based on human activities in the study area; (3) to assess whether the concentrations of the metals in sediments could have adverse biological impacts.

Materials and Methods

Surface sediments were collected to investigate of metal contents in May 2010 from ten sites on the intertidal coastal zones of Persian Gulf in Iran (Fig. 1). The selection of the stations was based on regional and local criteria of contaminant source input (Table 1). The sediment samples were transferred to plastic zip bags and stored under ice for transport to the laboratory and the samples were kept at −20°C prior to processing and analysis. In the laboratory, sediment samples were defrosted at room temperature, and then the samples were transferred to an oven and dried at a temperature of 105°C for 24 h (Soto-Jiménez and Páez-Osuna 2001). The metal analyses were performed in the 63 µm fraction, because the metals are usually strongly associated with small and fine grain sediments. For the digestion of total Pb, Cd, Cu, and Zn concentrations in the sediment samples, 1 g of each dried sample was put into a PTFE (polytetrafluoroethylene) vessel with a 10 ml mixture of concentrated HNO_3 and $HClO_4$ in a ratio of 4:1 (v:v). The sediment samples were put in a hot-block digester at low temperature of 40°C for 1 h and then fully digested at a temperature of 140°C for 3 h. After digestion and cooling, the completely dissolved samples were then diluted with 25 mL of deionized water to for further analysis. For each digestion program, a blank was prepared with an equal amount of acids (Yap et al. 2006). After filtration, sample solutions and reagent blanks were analyzed for Pb in a graphite furnace atomic absorption spectrophotometer Model 67OG and for Cd, Cu, and Zn in a flame atomic absorption spectrophotometer Model 67OG. NIST standard reference materials (SRM-1646a) were employed to verify the accuracy of the analytical technique. The recoveries obtained with the reference materials in the estuarine sediment were 89.3% Pb, 93.3% Cd, 95% Cu and 92% Zn. The detection limits of Pb, Cd, Cu, and Zn were 0.002, 0.009, 0.010 and 1.0 µg g^{-1}, respectively. The results of trace metals concentrations were determined on a dry weight basis in µg g^{-1}. Analysis of the samples was performed in the laboratories of Tarbiat Modares University, Iran.

Table 2 displays the global baseline values and sediment quality guidelines. Since Iran has no established sediment quality guidelines at this time, the US National Oceanic and Atmospheric Administration (NOAA) guidelines were used as interim measures to assess whether the concentrations of the metals in sediments could have adverse biological impacts. The two guideline values that delineate three concentration ranges that are rarely, occasionally, or frequently associated with adverse biological effects are effects range low (ERL) and effects range medium (ERM). ERL represents concentrations below which adverse effects are expected to occur only rarely. Concentrations equal to and above ERL, but below the ERM, represent a

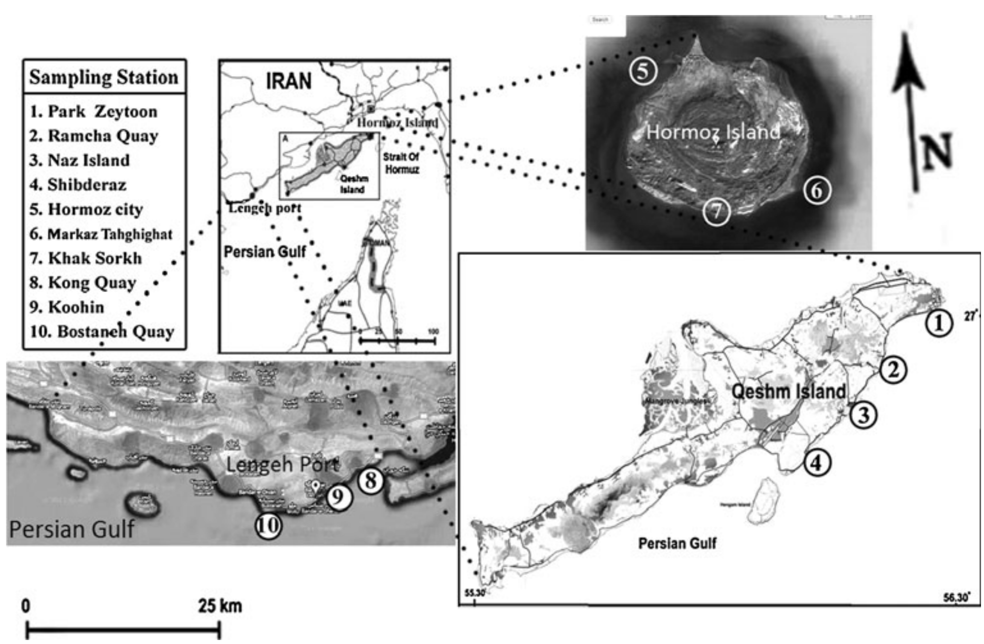

Fig. 1 Location of all sampling sites for sediments on the intertidal Coast of Persian Gulf of Iran

Table 1 Location of sampling sites for sediments samples and distribution type region development

Station	Location	Site description
1	26°55′28″N, 56°16′04″E	Urban area with less development
2	26°53′27″N, 56°09′37″E	Recreational area
3	26°48′49″N, 56°06′56″E	Pristine area
4	26°41′16″N, 55°55′45″E	Pristine area
5	27°04′23″N, 56°49′20″E	Urban area with less development
6	27°04′23″N, 56°43′36″E	Pristine area
7	27°10′25″N, 56°45′30″E	Mining activity
8	26°37′33″N, 54°59′48″E	Urban area, industrial, harbors, and shipbuilding plants
9	26°38′21”N, 55°01′37″E	Urban area, industrial, harbors, and desalination facilities
10	26°30’17″N, 54°39’42″E	Urban area, industrial, shipping and transport, harbors, and agriculture

Table 2 ERL and ERM guideline values for trace metals (μg g^{-1}dry weight), and percent incidence of biological effects in concentration ranges defined by two values

Chemical	Guideline		Percent incidence of effects		
	ERL	ERM	<ERL	ERL-ERM	>ERM
Pb	46.7	218	8.0	35.8	90.2
Cd	1.2	9.6	6.6	36.6	65.7
Zn	150	410	6.1	47.0	69.8
Cu	34	270	9.4	29.1	83.7

ERL effect range-low, *ERM* effect range-medium

probability effects range within which adverse effects would occasionally occur. Finally, concentrations equal to or higher than the ERM value are representative of concentrations for which adverse effects would frequently occur (Long et al. 1995). All statistical analyses were performed using SPSS 17.0 and Excel 2007. Nonparametric comparisons (Kruskal–Wallis test) were applied to test the differences between sediments' metal concentrations in different stations. Significance for all tests was set at 0.05.

Results and Discussion

The concentrations of four metals (Pb, Cd, Cu, and Zn) which were measured in the intertidal surface sediments collected from ten sites in the Persian Gulf of Iran are presented in Table 3. The metals concentrations in the sediments of ten sites based on regional sources were compared. The metals concentrations in sediments ranged between 0.86 and 180.78 μg g^{-1} for Pb, 0.61 and 6.48 μg g^{-1} for Cd, 5.99 and 44.42 μg g^{-1} for Zn, and 3.01 and 43.33 μg g^{-1} for Cu. The results presented in Table 1 showed that Pb concentrations in the stations tended to order 10 > 9> 8 > 7 > 5 > 6 > 1 > 2 > 4 > 3. Different concentrations among stations could be attributed to the variations of contaminant source input. The highest values of Pb were found at sites 8, 9, and 10. These may be related to human activities including shipping and transport, urban and domestic wastewater, agriculture, industrial wastewater at shipbuilding plants and desalination facilities, coastal activities (for example, marinas, jetties, ports and harbors), and fishing boats. On the other hand, low concentrations of Pb in stations 2, 3, and 4 could result from the lack of human activities there. The results of the present study agree with the results obtained by (Price 1993; de Mora et al. 2004; Pak and Farajzadeh 2007). There was significant difference in Zn concentrations between different stations, and high concentrations of Zn were found at sites 9, 7, and 8 (Table 3). These results are consistent with those of other studies and suggest that these stations can be affected by human activities such as industry, urban and domestic activities, economics, and agriculture (Price 1993; Diagomanolin et al. 2004). In addition, there were mining activities in the background of site 7, and the high concentrations of Cd, Cu, Pb, and Zn in this station may be due to mining activity (Price 1994; de Mora et al. 2004). The higher concentrations of Cd were observed in sites which contain more human activities than a pristine area (Price 1994). So human activities could be a major source of metals pollution input in an aquatic environment in each region (Price 1994; Karbassi 1998; Karbassi and Bayati 2005).

The results presented in Table 3 showed sediment chemistry data can be evaluated to identify the adverse biological effect significance on aquatic organisms by using Sediment Quality Guidelines. Based on these results, the measured concentrations of Pb in three sites (10, 9, and 8) exceeded approximately 287%, 227%, and 205% of the ERL guideline, respectively. Sediment results show that Zn concentrations at all sites sampled in Persian Gulf did not

Table 3 Mean ± SE concentrations (μg g^{-1}dry weight) of Pb, Cd, Zn, and Cu in sediments collected from ten sites on the intertidal Coast of the Persian Gulf, Iran, and comparison to sediment quality guidelines

Station	Pb	Cd	Zn	Cu
1	1.47 ± 0.06	0.98 ± 0.04	19.88 ± 9.32	5.13 ± 0.24
2	0.95 ± 0.09	1.06 ± 0.04	5.99 ± 0.71	5.22 ± 0.25
3	0.86 ± 0.11	1.06 ± 0.03	9.87 ± 1.68	3.01 ± 0.57
4	0.91 ± 0.06	0.95 ± 0.05	17.49 ± 7.28	4.81 ± 0.12
5	5.03 ± 0.09	0.93 ± 0.04	11.33 ± 0.33	5.33 ± 0.66
6	1.87 ± 0.07	0.61 ± 0.02	7.66 ± 0.88	4.33 ± 0.66
7	24.93 ± 0.29	6.48* ± 0.16	37.66 ± 1.21	43.33* ± 3.33
8	142.72* ± 11.71	1.12 ± 0.01	36.26 ± 2.62	5.06 ± 0.67
9	153.07* ± 5.53	1.14 ± 0.02	44.42 ± 10.26	5.13 ± 0.54
10	180.78* ± 4.06	1.52* ± 0.01	19.41 ± 2.39	3.86 ± 0.15

SE standard error

*Exceeds effect range-low

exceed the ERL and ERM of NOAA Guidelines. Cd in sites 7 and 10 exceeded the ERL guideline by about 440% and 27%, respectively. Eventually, concentration in site 7 alone exceeded the ERL guideline approximately 27%. This almost indicates that the existing concentrations of metals in these sediments are not sufficiently high to cause adverse biological effects. Previous studies in the Persian Gulf based on variations of contaminant source input agree with the results of the present study (Karbassi 1998; Pourang et al. 2005).

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