Distribution, Partition and Ecotoxicological Impact Assessment of Heavy Metals in Surface Sediment of the North Persian Gulf, Iran

*Shirin Rahmanpour, Seyede Masoumeh Lotfi Ashtiyani
Iranian national institute for oceanography (INIO), Tehran, Iran.

Abstract

The concentration of heavy metals was determined in surface sediment of sole four stations along the Persian Gulf. The concentration order of heavy metals in sediment were Ni > V > Co > Pb > Hg=Cd. Concentration of heavy metals varied depending on different sampling sites. Generally, the highest concentration of the studied metals was found in S2. The results of linear regression analysis indicated that there were positive significant relationships between the level of Ni, V and Co and silt fractions of the sediment. The results also showed that there were negative relationships between the concentrations of Pb and V and sand fraction of the sediments.

Keywords: Heavy metals, Sediment, Grain Size, Persian Gulf

Introduction

Recently, significant quantities of heavy metals have been discharged to the marine environment in industrial regions of the world. These have come from a variety of sources, including mining agricultural activities; industries such as petrochemical manufacture and refineries; and the corrosion of underground pipes (de Mora et al., 2005; Safahieh et al., 2011; Abdolahpur Monikh et al., 2012). Heavy metals most often remain only to a minor extent as dissolved ions in the water. These contaminants can be adsorbed to particulate matter that settles on sediments and can be adsorbed directly by the sediments (Adamo et al., 2005; Alagarsamy, 2006). According to previous studies, sediment represents the main sink for heavy metals in coastal areas that are impacted by anthropogenic activities (Zhang et al., 2007; Abdolahpur Monikh et al., 2012). In addition, most contaminants such as heavy metals tend to be trapped in sediments (Adamo et al., 2005). Fine-grained sediments (< 63 um) represent the major repository for heavy metals because of their large adsorption capabilities (Zhang et al., 2007; Abdolahpur Monikh et al., 2013). Therefore, it is confirmed that in order to evaluate the potential heavy metal pollution in an aquatic ecosystem, the sediments of the ecosystem represent the present and past metal contamination in the area (de Mora et al., 2005).

The Persian Gulf, a part of ROPME sea area (Abdolahpur Monikh et al., 2012), is contaminated by different anthropogenic activities such as tanker traffic, industrial, and agriculture activities (Al-Saleh and Shinwari, 2002). National Research Council in 1985 estimated that oil pollution in the Persian Gulf is 4.7% of the whole oil pollution in the world (Al-Saleh and Shinwari, 2002). Because of geographical geological characteristics, shallow depth, limited circulation of water (Saeed et al., 1995), high turbidity in some seasons (Sheppard et al., 2010), the north part of the Persian Gulf tends to accumulate large

Correspond author: Email: saraloshirin@yahoo.com, tel: 09126074498, Tehran

amount of heavy metals relative to other parts of the sea. On the other hand, fresh water and mud sediments that are transported into this area by some temporal rivers make it special and proper for various marine organisms and vary the concentration of heavy metals in the region.

Therefore, the chief purposes of the present investigation were (a) to determine heavy metal concentrations in sediment from the north Persian Gulf in order to measure the load of these contaminants in the area and (b) to evaluate the level of heavy metals bound to different phases of sediment. In addition, because SQGs (sediment quality guidelines) can predict the potential toxicity of contaminated sediment and recognize the aquatic sediment area, numerical SQGs for marine ecosystems have been developed (Macdonald et al., 2000). In this study, some of SQGs have been used to assess sediment contamination in the region.

Materials and Method

Surface sediment samples were collected from 4 different sampling sites distributed along the north Persian Gulf in summer 2012 (Fig. 1). The sampling sites were at Kohe Mobarak (S1), south of Qeshm (S2), Faror (S3) and the Strait of Hormuz (S4). The upper 5 cm depth of sediment was taken with a Van Veen grab and were placed into polyethylene. Sediment samples were collected and kept in freezer until analysis, as described by Abdolahpur Monikh et al. (2013).

In order to analysis the grain size of sediments, the sample were dried performed using a 2 m high settling tube for the > 50 μm fraction and a 5000D Sedigraph for the fine fraction following the method described by Giro and Maldonado (1985). To determine metals level, sediment were digested with a mixture of nitric acid and perchloric acid in the ratio of 3:1. The digests were diluted with double distilled water and filtered by 42-μm filter paper (Safahieh et al., 2011). All reagents used were of analytical grade. All the glassware were soaked in 10% nitric acid for 24 h and rinsed three times with double distilled water before use. Concentrated stock solution of 1000 mg/l (Merck, Germany) of each metal was diluted by double distilled water for instrument calibration. The accuracy of method was measured using certified reference material SRM 1645 (National Bureau of Standards). The agreement was satisfactory with the recovery. The recovery rates of metals were between 91.2% and 115% for sediment. An atomic absorption spectrometer of GBC Scientific Equipment Pty. Ltd. (Dandenong, Vic. 3175, Australia) with hyper pulse deuterium background corrector in flame air-acetylene was used to measure the concentration of heavy metals.

Statistical analysis was carried out with the SPSS program. All data were tested for normal distribution with Shapiro-wilk normality test. One-way analysis of variance and Duncan multiple comparison test were used to compare the concentration of heavy metals between stations. Pearson correlation coefficients were applied to examine the relationship between heavy metals concentrations and the size of the sediments. The significance level was set at $\alpha = 0.05$.

Results and Discussion

The mean concentrations and standard deviation of the metals Ni, Pb, Hg, Cd, V and Co measured in the surface sediment of the four stations in the north Persian Gulf are given in Table 1. Following the results of one-way ANOVA no significant differences could be observed among the sampling stations in Hg and Cd concentrations. The results indicated that the highest concentrations of Ni, V and Co were observed in S2, while the samples from S1, S2 and S3 showed the maximum levels of Pb. The high Ni, Pb, V and Co levels in the sediments from S2 sampling site can be explained by the located Qeshm port an a lot of

aquaculture farms and manufactories. On the other hand, S3 and S4 sampling sites are close to the Strait of Hormuz, where considerable numbers of oil tankers enter the sea from other countries (Abdolahpur Monikh et al., 2013). Enrichment in Ni and V, observed in the four stations, may be brought about by oil pollution in the Persian Gulf. About 800 offshore platforms and 25 major oil terminals as well as oil supertankers traffic exert tremendous stress by oil pollution in the Persian Gulf (Sheppard et al., 2010).

Most previous studies on heavy metals in the sediments of the Persian Gulf have reported severe contamination in the areas (pouring et al., 2005; Safahieh et al., 2011; Abdolahpur Monikh et al., 2012). They also highlighted the primary role of the industrial zone as a source of pollutants, with estimated peaks of release and accumulation in sediments during the period of its greatest expansion, from the Gulf War (Al-Saleh and Shinwari, 2002; Sheppard et al., 2010). The concentrations of Ni, Pb and Co obtained in this study are generally higher than those reported in Jebel Ali (UAE), Abu Dhabi (UAE) and Ras Laffan (Qatar) along the south Persian Gulf (de Mora et al., 2004). On the other hand, the concentration of V in BAPCO refinery and Ni in Mina Al Fahal (Oman) (de Mora et al., 2004) was extremely higher than that recorded in this study. The concentration of V, Pb and Ni in the northern part of the Persian Gulf (Pourang et al., 2005) was considerably greater than that observed in this study. The concentration of heavy metal in the current study was also lower than that reported by Abdolahpur Monikh et al. (2013) for the northwest of the Persian Gulf.

ISQG (interim marine sediment quality guideline) have been widely used to evaluate sediment pollution by comparing sediment contaminant levels with the corresponding guidelines in the aquatic environment (MacDonald et al., 2000). Generally, the concentrations of heavy metals measured in current study for the surface sediments of the north Persian Gulf do not exceed ERL, ISQG, ERM and PEL. Apart from these, in the case of Cd, Pb and Ni the results of the present study are approximately within the range of those in the guideline that was established by ROPME sea area for the Persian Gulf.

Grain size analysis showed that muddy sediments (Silt) are more abundant in S2, while S1, S3 and S4 (near the Strait of Hormuz) had significant amount of sand sized sediments (Table 2). Significant positive relationships were observed between silt and nickel ($p < 0.05$, $r= 0.974$) concentration, vanadium ($p < 0.001$, $r= 0.98$) and cobalt ($p < 0.05$, $r= 0.91$) concentration in sediment. Significant negative relationships were found between sandy sediment and lead ($p < 0.05$, $r= -0.78$) and vanadium ($p < 0.05$, $r= -0.92$) concentrations in the sediments. In most cases, however, there were no significant correlations the size of sediment grain and some heavy metals. Previous studies show that the geochemical properties and grain size of sediment are critical in affecting the metal concentration (Luoma and Campbell, 1987; Culshaw et al., 2002). The highest levels of heavy metals were often associated with the finest sediments such as silt fraction (Table 2). The fact that metals bind preferentially to finest particulates has been indicated previously in the sea for Cu, Co, Cd, Ni, Pb and Zn (Abdolahpur Monikh et al., 2012). The characteristics of small sediments such as large surface area, higher organic content, high binding capacity of silt particles, largely describe the binding capacity of fine sediments, however other physico-chemical properties, especially dissolved oxygen, temperature and salinity are also important (Little and Smith, 1994; Abdolahpur Monikh et al., 2013). In addition, it is well known that granulometry and organic matter contents play a considerable role in controlling the abundance of heavy metals in sediment (Zhang et al., 2007). Organic matter on particles is predominant in fine-grained sediments (Chen et al., 1992).Zhang et al. (2007) studied concentrations of heavy metals (Cu, Pb, Zn, Cd, Cr, Ni and Fe) in surface sediments from nine sites in western Xiamen Bay. They found significant relationships between the levels of heavy metals and the size of sediment grain.

Conclusion

This study provides new information on the distribution and partition of heavy metals in sediment from the north Persian Gulf. The sediment from S2 showed greater concentration of the metals than those from the other areas. The high concentration of metals in sediment at the S2 sampling site could result from anthropogenic influence. The concentrations of Ni and V were the highest among the studied metals and these findings could be attributed to oil pollution in the Persian Gulf. Metals concentrations in sediment were well below sediment quality guideline provided by ISQG and ROPME. The results of regression analyses showed that silty and to some extent clay mineral have the greatest ability to accumulate heavy metal in comparison to large size grain.

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Table 1: Heavy metal concentration (µg/g dw) and standard deviation in samples of surface sediment (number of samples n=15 for each station) taken from the north Persian Gulf and compared to guidelines

Stations	Nickel	Lead	Mercury	Cadmium	Vanadium	Cobalt
Kohe Mobarak (S1)	16.26 ± 0.06[a]	2.60 ± 0.13[b]	< 0.05	< 0.05	7.58 ± 0.08[a]	2.02 ± 0.04[a]
South of Qeshm (S2)	26.44 ± 0.04[c]	2.82 ± 0.03[b]	< 0.05	< 0.05	12.62 ± 0.28[b]	3.29 ± 0.04[c]
Faror (S3)	16.38 ± 0.08[a]	2.31 ± 0.02[b]	< 0.05	< 0.05	7.25 ± 0.05[a]	2.02 ± 0.01[a]
The Strait of Hormuz (S4)	19.86 ± 0.78[b]	1.86 ± 0.05[a]	< 0.05	< 0.05	7.89 ± 0.10[a]	2.50 ± 0.07[b]
ROPME (1999)[d]	70-80	15-30		1.2-2		
ISQG[dt]	15.9	30.2	0.1	0.7		
ERL (NOAA)[dt]	21	47	0.2	1.2		
PEL (NOAA)[dt]	42.8	112.2	0.7	4.21		
ERM (NOAA)[dt]	52	218	0.7	9.6		

ISQG: interim marine sediment quality guideline; PEL: probable effect levels; ERL: effect range low; ERM: effect range medium; NOAA: national oceanic and atmospheric administration; ROPME: Regional Organization for the Protection of the Marine Environment. a,b,c Significant differences in metal concentration between stations.

[d]Abdolahpur Monikh et al. (2013)

[f]Mooraki et al. (2009)

Table 2: The relationships between heavy metal levels and sediment grain size in the north Persian Gulf

Metal	Silt		Clay		Sand	
	r	*p*	r	*p*	r	*p*
Nickel	0.974	< 0.05	0.463	NS	0.524	NS
Lead	0.70	NS	0.36	NS	-0.78	< 0.05
Mercury	-	-	-	-	-	-
Cadmium	-	-	-	-	-	-
Vanadium	0.98	< 0.001	0.67	NS	-0.92	< 0.05
Cobalt	0.91	< 0.05	0.631	NS	0.63	NS

NS. Not Significant, P > 0.05

Fig. 1. A map showing the Persian Gulf and the stations

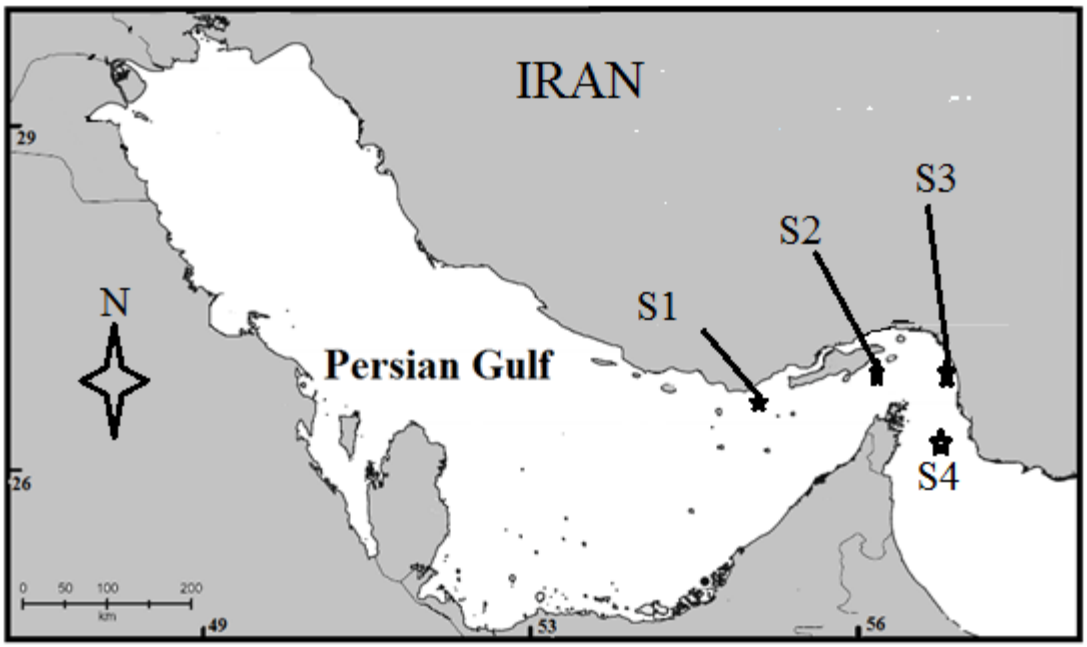


Fig. 1