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Metal Concentrations in the Sediments from the Arabian Gulf Coast of Saudi Arabia

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Pollution of costal marine environments by trace metal contamination is a major concern since it may lead to deterioration of natural habitats by depleting ecologically sensitive species or by eliminating or tainting commercial species. Acute metal pollution may also pose a serious public health hazard such that which developed in the well documented and often cited "Minamata" disease case in which more than 700 people died or were disabled through eating fish or shellfish contaminated with methyl mercury (Saha, 1972).

In saudi Arabia, trace metal enrichment of marine environment may result from a number of anthropogenic activities, especially from petroleum and petrochemical industry wastes. Only limited trace element pollution research has previously been conducted in Saudi Arabia (RIUPM, 1982). The objective of this study was to determine metal concentrations in the sediments from the Arabian Gulf cost of Saudi Arabia. This study may serve as baseline information for future evaluation of metal pollution in this region.

MATERIALS AND METHODS

Five sampling stations, representing different activities in the study area, were selected. These are namely: Abu Ali and Manifa (oil fields), Jana Island (relatively less exposed to drilling activities) and Tarut Bay and Ju'amyah (related to oil transportation) and are shown on Figure 1.

Five sampling locations in an area of approximately 1 sq kilometer were selected at each sampling station. Divers descended with plastic sampling tubes filled with seawater. After removing the lids, the tubes were pressed down into the sediment. The lids were placed on the top and the samplers were pulled out slowly and carefully. The bottom of the sampler was capped before transporting it to the boat.

A total of 20 sediment samples from each sampling station were collected. The excess water above the sediment core was decanted. The sediment cores, obtained from the Manifa area, were divided

into three segments: 0-5, 5-10 and 10-20 cm depth intervals (sediments in other areas were not deep enough to be vertically sampled). All the sediment samples were dried at room temperature and crushed gently to pass through a 425 um sieve. Twenty grams of each crushed sample was used to determine moisture content at 60 C. Concentrations of all the metals analyzed in this study are expressed on sediment basis dried at 60 C.

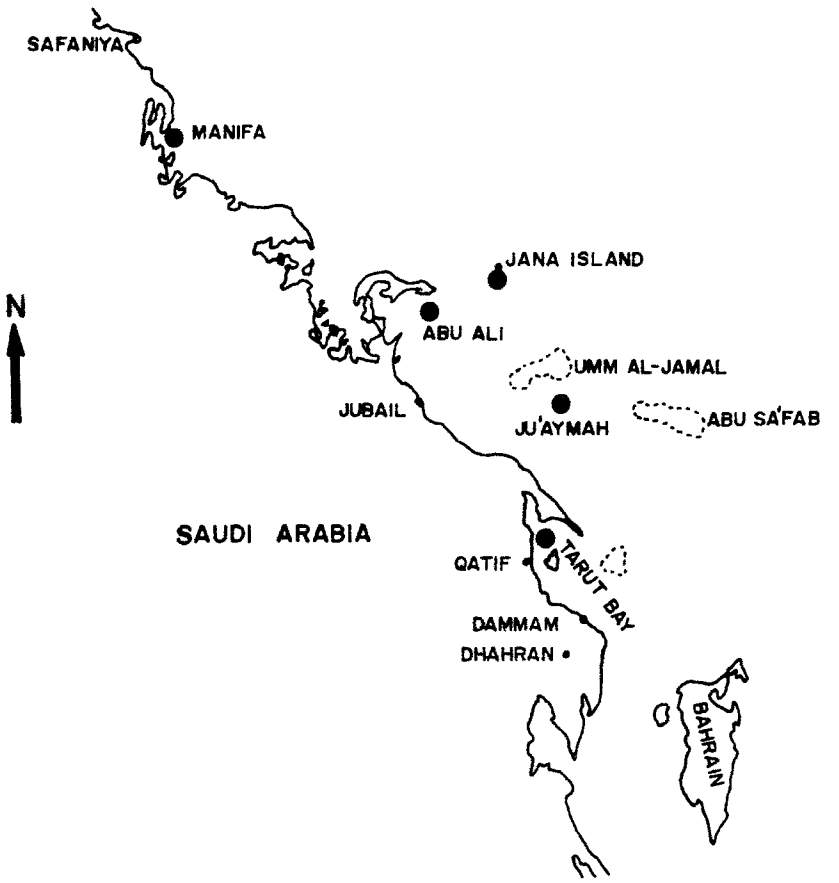

Figure 1: Sampling areas (●)

In order to determine metal concentrations in the sediments, 2 g of each sample was digested in 15 ml HNO3 at 150 C to near dryness. After cooling, the residue was dissolved in 5 ml of 50 percent HNO3. An aliquot was filtered through regular 0.45 um filter paper and the volume was made upto 100 ml. The filtrate was used for determining arsenic(As), cadmium(Cd), copper(Cu), molybdenum(Mo), chromium(Cr), nickel(Ni), lead(Pb), zinc(Zn), manganese(Mn) and vanadium(V) using atomic absorption spectrophotometer. Digestion of the sediment samples for mercury(Hg) determinations was carried out accoding to the procedure given by Agemian and Chau (1976a, 1976b). Mercury

concentration in the aliquot samples was determined using cold vapor technique (USEPA, 1979).

RESULTS AND DISCUSSION

The concentrations of As, Cd, Cr, Cu, Hg, Mn, Mo, Ni, Pb, V and Zn found in the sediments from the Saudi Arabian coastal areas of the Arabian Gulf are given in Table 1. The maximum mean concentrations of As was found in the sediments from the Manifa area followed by the Abu Ali area. Arsenic in the sediments from Jana Island was the lowest. However, the concentrations of Cd in the sediments from the Jana Island were the highest. The reason for the highest content of Cd at Jana Island is unknown. The second highest mean concentration of Cd was found in the sediments from Ju'aymah area which is about 1.5 kilometer from the oil tanker route. The concentrations of Cd in the sediments from Tarut Bay were not significantly different from those of Ju'aymah ($P < 0.05$). The Manifa and Abu Ali areas are oil fields and contained the minimum levels of Cd in the sediments. The observations of this study suggest that Cd enrichment may be related to oil transportation activities but further studies are needed to verify this hypothesis.

The concentrations of Cr, Cu, Hg, Mn, Ni, V and Zn in the sediments from the Manifa area were significantly higher than any other area studied ($P < 0.05$). However, the concentrations of Mo and Pb were also higher in the sediments from the Manifa area but were not significantly different from other areas. Although the Manifa area is an oil field but the data obtained in this study are inconclusive in relating the higher concentrations of metals in the sediments from the Manifa area to drilling activities. It may be pointed out that the sediments from the Manifa area were mostly silt (finer) as compared with the sediments from other areas which were mostly sand. The textural differences among the sediments from different areas may account partially for metal enrichment in the sediments from the Manifa area. It may further be noted that, in general the concentrations of metals in the sediments from all the other areas were statistically similar ($P < 0.05$) if the data for the Manifa area are excluded. Therefore, the metal concentrations in the sediments, other than the Manifa area, may represent background concentrations. More elaborated studies are needed to explain the higher metal concentrations in the Manifa area.

The vertical metal distribution in the sediments from the Manifa area is depicted on Figure 2. Except for Cd, the concentration of all the metals were higher in the upper 5 cm layer as compared with the deeper sediments. The differences in the concentrations of Cr, Ni Pb, Zn, Mn and V between the 0-5 cm layer and 5-10 cm layer were wider than As concentrations in these sediments. Cadmium was uniformly distributed in the sediments. The observations presented in Figure 2 indicate that there was a recent enrichment of metals in the sediments of the Manifa area.

TABLE 1: Metal concentrations (ug/g; Hg as ng/g) in the top sediments from the Arabian Gulf coast of Saudi Arabia

Metal Analyzed	Sampling Locations 1	2	3	4	5	mean
			Abu Ali			
arsenic	1.0	1.3	1.2	1.1	1.1	1.1
cadmium	4.2	3.7	3.5	3.9	3.9	3.8
chromium	7.8	6.5	8.6	7.5	8.1	7.7
copper	7.8	9.3	9.1	9.9	5.8	8.4
lead	1.8	1.8	1.9	1.5	1.4	1.7
manganese	11.8	12.4	12.3	11.1	11.1	11.6
mercury**	3.0	3.2	2.9	3.6	3.1	3.2
molybdenum	1.0	1.0	1.1	1.0	1.0	1.0
nickel	22.8	25.0	28.5	24.6	20.3	24.2
vanadium	1.2	0.8	0.9	0.6	0.8	0.9
zinc	5.4	6.3	6.7	5.3	4.6	5.7
			Manifa			
arsenic	2.5	2.2	2.7	3.3	3.1	2.7
cadmium	2.7	3.4	3.2	3.2	3.6	3.2
chromium	35.0	28.8	45.1	51.3	42.0	40.4
copper	11.8	9.2	15.0	16.6	16.3	13.8
lead	2.4	1.9	3.4	3.9	3.4	3.0
manganese	106.4	70.8	147.8	177.0	142.3	128.9
mercury**	24.9	25.5	37.2	34.4	24.6	29.2
molybdenum	2.0	1.4	1.3	1.9	1.0	1.5
nickel	44.5	37.6	54.0	60.4	55.5	50.4
vanadium	21.0	18.3	29.3	28.7	22.7	24.0
zinc	14.0	10.2	18.2	20.6	18.8	16.4
			Jana Island			
arsenic	0.3	0.3	0.2	0.3	0.2	0.3
cadmium	5.0	4.8	4.8	4.8	5.2	4.9
chromium	7.4	7.2	8.8	7.8	5.4	7.3
copper	7.5	6.8	6.8	7.3	5.4	6.8
lead	0.7	0.7	0.7	0.8	0.8	0.7
manganese	10.1	12.3	8.8	8.6	10.8	10.1
mercury**	6.8	7.4	5.9	6.2	5.5	6.4
molybdenum	0.7	0.6	0.7	1.2	1.1	0.9
nickel	28.1	26.9	28.9	28.6	28.7	28.2
vanadium	4.6	3.4	5.8	5.2	3.9	4.6
zinc	5.3	5.6	5.9	5.9	5.5	5.6
			Tarut Bay			
arsenic	0.6	0.7	0.6	0.5	0.5	0.6
cadmium	4.4	4.3	4.5	4.5	3.9	4.3
chromium	8.8	8.2	16.0	13.0	11.0	11.4
copper	5.6	6.1	8.5	9.8	9.9	8.0
lead	1.4	1.2	1.2	1.5	1.1	1.3
manganese	12.5	10.7	23.3	17.4	10.1	14.7
mercury**	5.3	7.0	4.5	4.0	3.0	4.8
molybdenum	0.7	0.8	0.9	0.6	0.6	0.7
nickel	25.3	27.5	31.9	28.4	28.5	28.3
vanadium	7.7	7.3	9.8	9.5	6.3	8.1
zinc	5.7	5.6	15.0	7.2	10.0	8.7

	Ju'aymah					
arsenic	0.5	0.8	0.9	0.5	0.5	0.7
cadmium	4.4	4.2	4.2	4.7	4.9	4.5
chromium	9.6	10.9	11.6	9.6	10.7	10.5
copper	9.2	8.8	8.1	7.7	7.1	8.3
lead	0.8	1.0	1.0	1.0	1.0	1.0
manganese	11.2	16.0	13.5	14.0	13.1	13.6
mercury**	4.1	4.8	4.4	3.8	4.0	4.2
molybdenum	0.7	0.7	0.7	0.6	0.6	0.7
nickel	29.6	31.4	32.1	29.5	32.5	31.0
vanadium	2.2	2.9	1.4	2.4	2.1	2.2
zinc	9.1	8.4	8.6	7.6	6.0	7.9

TABLE 2: Metal concentrations (ug/g dry sediment) in the sediments from various parts of the world

Areas	Cd	Pb	Zn	Ni	Cr	Reference
Arabian Gulf Saudi Arabia	2.5-5.0	0.6-4.2	4.2-22.6	20.5-64.6	3.4-53.0	Present work
Arabian Gulf Kuwait Bay	1.2-3.9	17-48	12-123	15-139	17-121	Anderlini et al (1982)
Lebanon Coast	0.8-3.8	0.5-104.6	12.8-154.6	18.3-38.4	5.9-13.0	Shiber (1979)
Mediterranean Sea, Israel	0.3-2.2	3.9-19.7	2.1-18.2	18.2-29.0	1.7-12.4	Roth & Hornung (1977)
Torbay English Coast	0.2-0.7	21.3-65.7	17.2-42.0	4.2-15.0	5.0-17.0	Taylor (1974)
Harbor Island Gulf of Mexico	0.4-1.1	3.4-9.0	14.0-28.0	5.0-10.9	-	Roth & Hornung (1977)
Portsmouth Harbor, UK	0.5-3.3	4.9-114.0	68-210	19-30	8-25	Soulsby et al (1978)
New South Wales, UK	0.2-2.5	4-53	2-144	1-24	5-125	Shiber (1979)
North Sea UK	0.1-0.8	17-238	19.7-197.5	6.5-22.0	4-41	--do--
Koahsiung Harbor, Taiwan	0.3-1.8	26-576	103-3514	42-285	42-285	--do--
Narragansett Bay, USA	0.1-2.5	17-81	53-168	6-34	13-81	Eisler et al (1977)

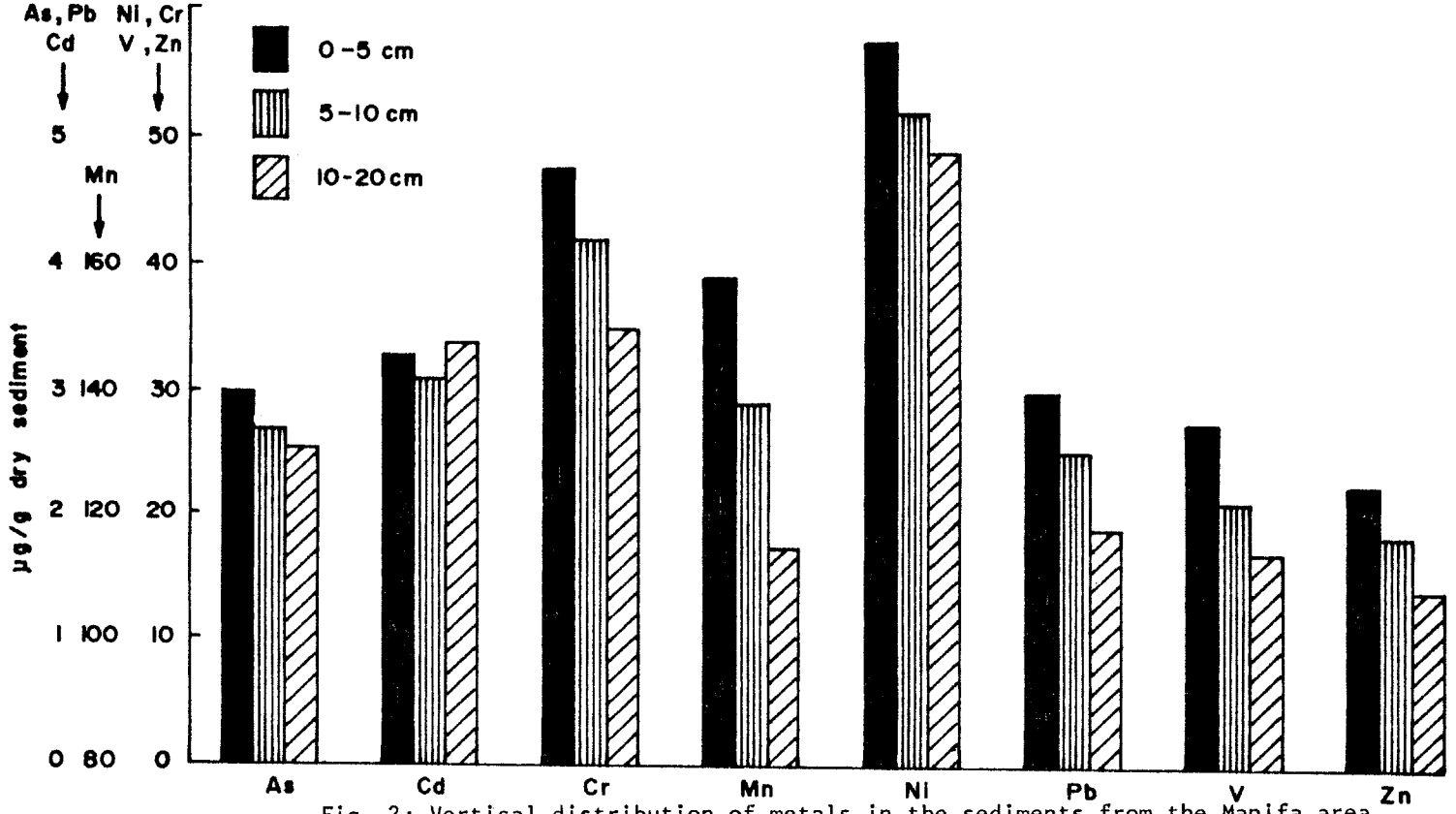

Fig. 2: Vertical distribution of metals in the sediments from the Manifa area

Future studies may be desireable to see if metal pollution in the Manifa area is still going on. The concentrations of Cd, Cr, Ni, Pb and Zn found in the sediments in this study are compared with the available information in the literature in Table 2. The concentrations of Cd found in this study were higher than the Cd concentrations in the sediments from Kuwait Bay, however, the reverse was observed in the concentrations of Pb, Zn, Ni and Cr (Anderlini et al 1982). The concentrations of Cd, Ni and Cr in the sediments from the Arabian Gulf were higher than the values reported for the other parts of the world. The present study was limited to small areas at few locations, To assess metal pollution in the Gulf and to establish a more realistic baseline, it is suggested that a more detailed survey of metal concentrations in the sediments from the coastal areas of Saudi Arabia may be conducted. Furthermore, no attempt was made to determine metal pollution sources in the present study and this aspect should not be overlooked in future investigations.

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REFERENCES

AGEMIAN H, CHAU ASY (1976a,1976b) An improved method for the extraction of mercury from environmental samples. Anal 101:91-96;761-767

ANDERLINI VC, MUHAMMAD OS, ZARBA MA, FOWLER SW, MIRMAND P, (1982) Trace metals in marine sediments of Kuwait. Bull Environ Contam Toxicol 28:75-80

EISLER R, LAPUN RL, TELEK G, DAVEY EW, SOPER AE, BARRY M, (1977) Survey of metals in sediments near Quonset Point, Rhode Island. Pollut Bull 8:260-264

RIUPM, (1982) Trace Metals in Marine Sediments and Water Columns from Saudi Arabian Coastal Areas of the Arabian Gulf. Final Rept. Project 24011, Research Institute, University of Petroleum and Minerals, Dhahran, Saudi Arabia

ROTH I, HORNUNG H, (1977) Heavy metal concentrations in Water, sediments and fish from Mediterranean coastal areas, Israel. Environ Sci Tech 11:265-269

SAHA JG, (1972) Significance of mercury in the environment. Pest. Rev. 42:103-163

SHIBER JG, (1979) Metal concentration in marine sediments from Lebanon. Water Air and Soil Pollut 14:35-42

SOULSBY PG, LOWTHION D, HOUSTON M, (1978) Observations on the effect of sewage discharges into a tidal harbour. Mar Pollut Bull 9:242-245

TAYLOR D, (1974) The natural distribution of trace metals in the sediments from coastal environment, Torbay, England. Estu Coast Mar Sci 2:417-424

USEPA, (1979) Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, EPA-600/4-79-020

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