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Trace Metals in Marine Sediments of Kuwait*

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Kuwait, like other Gulf States, is experiencing an unparalleled period of urban and industrial development. The massive increase in capital derived from the petroleum industry since 1973 has contributed to the rapid expansion of construction projects, population, and investment in diversified light industry. The environmental consequences of such development are presently unknown. Pollutant levels of trace metals associated with urban and industrial wastes are undoubtedly entering coastal waters. In Kuwait, pollutant metals may be derived from refinery and fertilizer plant wastes, power desalination plant effluents, discharges from a large chlor-alkali plant, solid waste disposal and municipal storm drains. In addition to these anthropogenic sources, trace metals may be transported into Kuwait's coastal waters either adsorbed to suspended riverborne sediments from the urban and industrial centers of the Shatt Al-Arab drainage (Figure 1), or associated with airborne fallout sediments deposited during severe seasonal dust storms. Owing to the extremely shallow depth, high temperature and salinity, and limited circulation that characterize waters of the upper Gulf, the effects of pollutants entering this region may be magnified. With the exception of a few unpublished reports (MINISTRY OF PUBLIC HEALTH 1976, 1977a, b; SZUCS AND OOSTDAM 1977; BU-OLAYAN 1979), there are no data concerning trace metal inputs or concentrations in Kuwait. This report presents the results of analyses for ten trace metals (Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V and Zn) in marine surface sediments from Kuwait and discusses the effect of grain size and total organic content on the observed concentrations of these metals.

MATERIALS AND METHODS

Sampling and Sample Analyses

Sampling sites were selected to provide representative coverage of the various bathymetric regimes and to obtain samples adjacent to suspected input sources within Kuwait Bay and along the southern coast. A total of 54 surface sediment samples were collected between January and March 1979. All samples were collected using an aluminum, 0.25 m^2 Van Veen grab sampler coated with a two-part epoxy paint. Only the top 2 cm of undisturbed sediment were collected from the center of the sample using an acid-rinsed, plastic scoop. The samples were placed in precleaned, polyethylene containers and frozen immediately.

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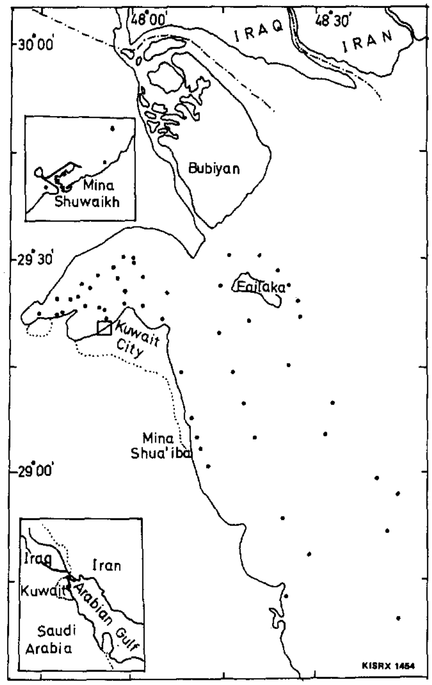

Fig. 1. Surface sediment sampling sites, during January-March 1979.

Aliquots of the same samples were also obtained for grain size and total organic carbon analyses to determine the effect of these sedimentological parameters on trace metal concentrations. Sedimentological analyses were carried out using standard sieving and pipette techniques (FOLK 1974) whereas organic carbon was determined by the method described by EL-WAKEEL and RILEY (1957).

Samples were prepared for the analyses of all metals except Hg by drying the sediments in an oven at 60°C for 24 hours. Samples for V analyses were leached with 1 N HCl at 90°C for 12 hours while samples for the other eight elements were leached with 8 N HNO_3 at 90° for 4 hours. All samples were then centrifuged, decanted, rinsed with de-ionized water and the supernatants combined. Analyses, were performed on a Perkin-Elmer, Model 305 B AAS, using standard conditions.

Mercury analyses were performed on wet sediments by the cold vapour technique on a Coleman Model 50 Mercury Analyser (U.S. ENVIRONMENTAL PROTECTION AGENCY 1979). All values are reported as part per million dry weight, except Fe, which is reported as percent dry weight.

RESULTS AND DISCUSSION

Distribution of Trace Elements

The concentration ranges and distributions of the test metals, except Hg, are illustrated in Figures 2a-d and 2e-i. The data indicate that the metals Cr, Fe, Mn, and

Ni were similarly distributed. In general, the highest concentrations of these metals were observed in sediments within Kuwait Bay and along the southern coast with concentrations decreasing in the southerly offshore areas (Figure 2a-2d).

Distributions of the metals Cd, Cu, Pb, V and Zn were similar to each other in that the highest concentrations were observed around the two commercial ports in Kuwait, Mina Shuwaikh and Mina Shuaiba (Figure 2e-i).

The mean concentration and range of the test metals, except Hg, are compared with values reported for some other world areas in Table 1. Only those areas described as unpolluted or as control sites are included in this table as being comparable to present conditions in Kuwait. The data indicate that trace metal concentrations observed in Kuwait sediments are within the range of values reported for comparable areas. Nickel concentrations are, however, higher than reported values whereas V values are lower, which may perhaps be related to the petroleum-rich sediments of the region.

Mercury concentrations observed in this study ranged from below the detection limits of the method employed (<0.01 ppm) to a value of 10.3 ppm at a single site adjacent to a chlor-alkali plant effluent outfall. The mean concentration (0.06 ppm) of Hg values above the detection limit and excluding those recorded in sediments adjacent to the chlor-alkali plant is slightly higher than the general background level (<0.05 ppm) for Hg in coastal marine sediments as reported by KNAUER (1976).

Influence of Grain Size and Organic Carbon on Trace Metal Content

The concentrations of trace metals in marine sediments are known to be affected by several natural and anthropogenic factors (FORSTNER and WITTMAN 1979). In this study two of these factors, grain size and organic carbon content, were investigated to determine their relative influence on observed trace metal distributions.

The results of the grain size and organic carbon analyses and the results of all trace element analyses except Hg and V were subjected to simple correlation analysis. The results, presented in Table 2, indicate that the mean grain size in phi units (Mz ϕ) and the organic carbon content of identical samples were significantly correlated ($r = 0.44$ at $p < 0.05$), whereas trace element concentrations in these sediments were variously correlated. In general, the elements Cr, Cu, Fe, Mn, Ni and Zn were all highly correlated with mean grain size, whereas only the elements Cu, Ni, and Zn showed significant correlation with organic carbon content.

Other authors such as CRECELIUS et al. (1975) and FRIGNANI et al. (1979) have observed a similar relationship between trace element concentration and grain size of sediments, whereas some researchers (e.g., MACKAY et al. 1972; RAMONDETTA and HARRIS 1978) have suggested that organic carbon content was a more significant factor in determining trace element content in sediments. Our results suggest that the concentrations of most of the trace elements analyzed in Kuwait sediments are dependent on both grain size and organic carbon content.

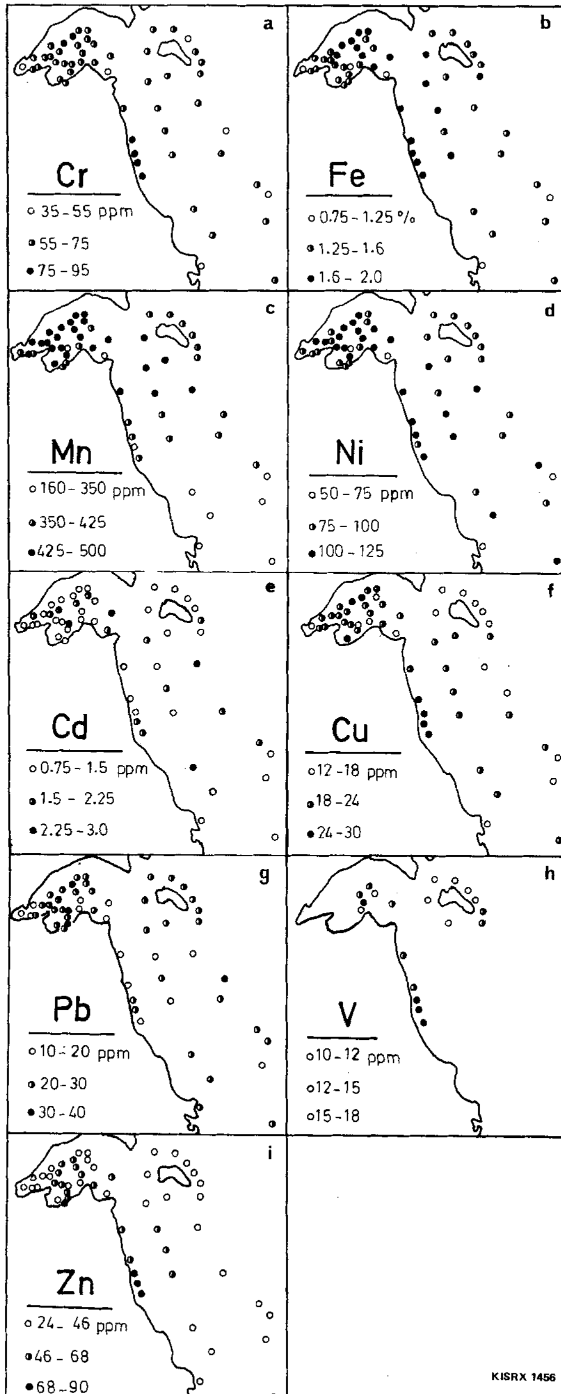

Fig. 2. Distributions and mean concentrations of Cr, Fe, Mn, Ni, Cd, Cu, Pb, V, and Zn in surface sediments of Kuwait.

TABLE 1

Comparison of trace metal concentrations in unpolluted sediments of comparable areas (ppm dry weight, except Fe as % wt).

Area	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Gulf of Paria[a]		100	19		2000	31	20	130	
Soanich Inlet; oxic sediments[b]		86	38		370	33	20	110	88
Baltic Sea[c]		90	78		4030	43	25	130	110
Nearshore Atlantic Sediments[d]		100	48	6.0	850	55	20		95
Firth of Clyde (control site)[e]	1.6	33	16	1.4	355	30	42	63	85
Shallow water sediments (Japan)[f]	0.2	30	27	3.3	390	14	55	63	51
Nice to Monte Carlo[g]	(0.1-2.3)	(12-30)			(95-320)	(95-33)	(35-95)		(45-114)
Kuwait Coastal sediments[h]	1.5	69	21	1.5	410	97	23	14	45
	(0.8-3.0)	(73-120)	(31-51)	(0.7-2.0)	(167-500)	(55-120)	(12-50)	(10-18)	(24-89)

[a] HIRST, 1962; [b] GROSS, 1967; [c] MANHEIM, 1961; [d] WEDEPOHL, 1960; [e] HALCROW *et. al.*, 1973; [f] YAMAMOTO, 1968; [g] RENFRO and OREGIONI, 1974; [h] this study.

TABLE 2

Results of simple correlation analysis of trace metal concentration vs grain size and organic carbon content of Kuwait sediments.

Parameter	n	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn	OrgC
Cr	54	-0.07								
Cu	54	-0.12	0.46							
Fe	54	-0.10	0.33	0.15						
Mn	54	-0.02	0.14	-0.03	0.82					
Ni	54	-0.03	0.15	0.32	0.70	0.87				
Pb	54	-0.03	0.15	0.01	0.53	0.29	-0.54			
Zn	54	-0.03	0.17	0.08	0.48	0.20	-0.03	0.05		
Org.C	29	-0.15	0.25	0.70	0.31	0.18	0.45	0.01	0.82	
Mzϕ	54	-0.02	0.31	0.40	0.64	0.51	0.77	0.36	0.50	0.44

$r = 0.268$, $p < 0.05$, $n = 52$
$r = 0.367$, $p < 0.05$, $n = 27$

The results of the correlation analysis also suggest that grain size and/or organic carbon content of sediments may account for the relatively higher concentrations of some metals at some of the sampling sites, especially the elements Cr, Cu, Fe, Mn, Ni and Zn. However, the higher concentrations of Cd, Hg and Pb observed at some locations appear to be derived from pollutant sources of these metals. More comprehensive investigations of the potential sources of trace metal pollutants in Kuwait and the factors that control their distribution are currently under way.

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