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HEAVY METALS CONTENT AND GRAIN SIZE OF SEDIMENTS FROM SUEZ BAY, RED SEA, EGYPT

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ABSTRACT

Heavy metals distribution (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, V and Zn) and grain size analysis were investigated in the inshore and offshore sediments of Suez Bay (northern part of the Gulf of Suez). Data of the grain size indicated that sandy sediments dominated most of the study area, covering the offshore part of the bay; while coarse-grained sediments were distributed in the nearshore stations. Concentration of metals in the bulk sediments and < 63 µm fraction (Fe > Mn > V > Zn > Pb > Ni > Co > Cr > Cu > Cd) revealed the effect of the pollution sources, specially at the stations in front of the sources. Where the stations in front of the petroleum activities were characterized by high levels of V, Cu and Pb, while the stations in front of electric power stations had high values of Cr and Ni. In addition, the inter-elemental relationships between the studied metals showed the importance of the pollution sources which affect the metals content of sediment, whereas Ni was strongly associated with V (r = 0.975) indicating that the metals resulted from the same sources. Determination of metals in 7 grain size fractions of sediments indicated that the distributions of metals in inshore and offshore sediments depended on the amount/type of pollutant and the nature of the sediment composition. Most of the studied metals were gradually increased with decreasing the grain size of sediments and chiefly associated with the clay (and silt) forming mineral phases. This trend reflects combination effects of possible industrial pollution with the natural constituents of sediments.

INTRODUCTION

Sediments show strong tendency to accumulate contaminant, especially heavy metals, and analysis of these sediments thus constitutes a rapid means of obtaining time integrated information concerning a range of limnological variables (Carral *et. al*., 1995). Knowledge of sedimentology and chemistry (heavy metals) of the sediments deposited in marine area is a key condition for identification of their sources and assessment of their transport-dispersion patterns. It is very important also for every environmental study requiring discrimination between natural and anthropogenic conditions of particulate material and the trace element associated with them; in particular, this knowledge is essential in the analysis of heavy metals distribution. Comparison of heavy metals distribution with grain size allowed the identification of the area where the sediment fine fraction appears affected by heavy metal anthropogenic contamination (Leoni and Sartori, 1996).

The investigated area (Suez Bay) is located between longitudes 32^{o} 28$^{\backslash}$ and 32^{o} 35$^{\backslash}$ E and latitudes 29^{o} 53$^{\backslash}$ and 29^{o} 57$^{\backslash}$ N. The bay is shallow extension of the Gulf of Suez, roughly elliptic in shape, with its major axis in the NE - SW direction (Fig. 1). The average length along major axis is about 13.2 km, its average width along minor axis is about 8.8 km. The mean depth is 10 m, and

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the horizontal surface area is about 77.13 km^2. The bay is connected to the Gulf of Suez through most of its south eastern side, where a channel is dredged to depth of 20 m to serve navigation purposes, and it is connected to the Suez Canal by a dredged channel of 12 m depth through the north eastern side of the bay (Meshal, 1967). The northern part of the bay is occupied by the city of Suez.

The Suez Bay has two sources of water: The Suez Canal and Gulf of Suez waters. The circulation in the Suez Bay can followed generally by following the proper characteristics of these two water types. Meshal (1967) found that seawater from the Gulf of Suez enters the bay on the eastern side (Sinai side) while, it leaves the bay on the western side. The seawater from Suez Canal is deflected to the western coast. Therefore, there is a persistent anticlockwise circulation in the bay.

UNEP (1997) reported that the sediments of the southern part of the Suez Canal – north of the bay – were mainly composed of sandy-mud (90 % mud and 10 % sand). A dominant north ward sediment transport was observed due to the strong tidal currents existing at this area.

The Suez harbour has always been an important Egyptian gate on the Red Sea since historical times. The growing activity of this harbour has led to an increasing rate of urbanization in the whole region. Taking advantage of the site location, several industries have been established along the western coastal stretch of the Suez Bay down to Adabyia in the south. These growing industrial activities coupled with the fact that Suez represents the south entrance of the Suez Canal have resulted in the transformation of the whole Suez Bay into large harbour. More than 100 ships and tankers are waiting daily for crossing the canal to the Mediterranean.

The bay receives sewage and garbage both from the city of Suez and from ships awaiting transit through the Suez Canal. It also receives wastes from the industrial complex south of the Suez, including oil refineries, fertilizer plant, power stations and other industries. All refuses coming from the different sources are discharged directly or indirectly into the bay. These refuses contain very large variety of chemical residues including heavy metals (Hamed, 1992 and El-Moselhy, 1993). Such undesirable inflows disrupt the ecological balance and affect the quality of water for human use.

For these reasons, the recent studies were carried out on heavy metals distribution and their accumulation in bottom sediment of the Suez Bay (El-Moselhy, 1993; Hamed, 1992 and 1996; Abd-ElAzim, 1996 and 2002; El-Moselhy *et al.*, 1999; Povlesen, *et al.*, 2003 and El-Moselhy and Gabal, 2004). The work of the present study encompasses the study of sediment composition (Grain size) in Suez Bay. It is mostly aimed to study the distribution of heavy metals through the different grain sizes of the bay's sediments.

MATERIALS AND METHODS

Seventeen sediment samples were collected from the Suez Bay during 2002. Sampling carried out to uniformly cover most of the bay. Nine surficial offshore and eight surficial inshore sediment samples were selected for this study as shown in Fig. 1. Samples were collected from the selected stations using Van-veen grab (Amini Ranjbar, 1998). After description, bulk sediment samples were subjected to grain size analysis by combination of wet sieving (Krumbein and Pettijohn, 1938, Lotfy *et al.,* 1987). Where 100 g of each sample was splitted as representative subsample for grain size analysis, which carried out using standard set of sieves, shaken in a rotap shaker for 20 minutes. The sieves were arranged with 1 Ø interval, which were 2.0, 1.0, 0.5, 0.25, 0.125, 0.063 and < 0.063 mm. These sieves had the equivalent -1, 0, 1, 2, 3, 4 and 5 Ø values, respectively. The collected sieves fractions were accurately weighted and subsample from different fraction was kept for metals analysis. In addition, subsamples from the central part of the grab were taken to avoid contamination, kept in pre-cleaned plastic bags, dried in the lab and stored until metals analysis in the bulk sediment.

Heavy metals in sediments were determined according to (Tessier *et al*., 1979 and Perin *et al*., 1997). The sediments were digested with 5 : 1 mixture of HF and $HClO_4$ acids. 1g (dry weight) sample was digested by 2 ml $HClO_4$ and 10 ml HF to near dryness, subsequently a second addition of 1 ml of $HClO_4$ and 10 ml of HF and evaporated to near dryness. Finally, 1ml of $HClO_4$ alone was added and the sample was evaporated until the appearance of white fumes. The residue was dissolved in 12N HCl and diluted to 25 ml with deionized water. The metals were determined by flame Atomic Absorption Spectrophotometer, Perkin Elmer model Aanalyst 100. The results obtained were expressed in µg/g.

Data quality control

All chemicals used were pure analytical grade and reagent blanks were processed with each batch of samples. The precision and accuracy for the method of metals determination in sediments were checked by replicate measurements of the studied metals in sediments sample. Precision was found in the range of 5.9 – 16.4 % for all metals.

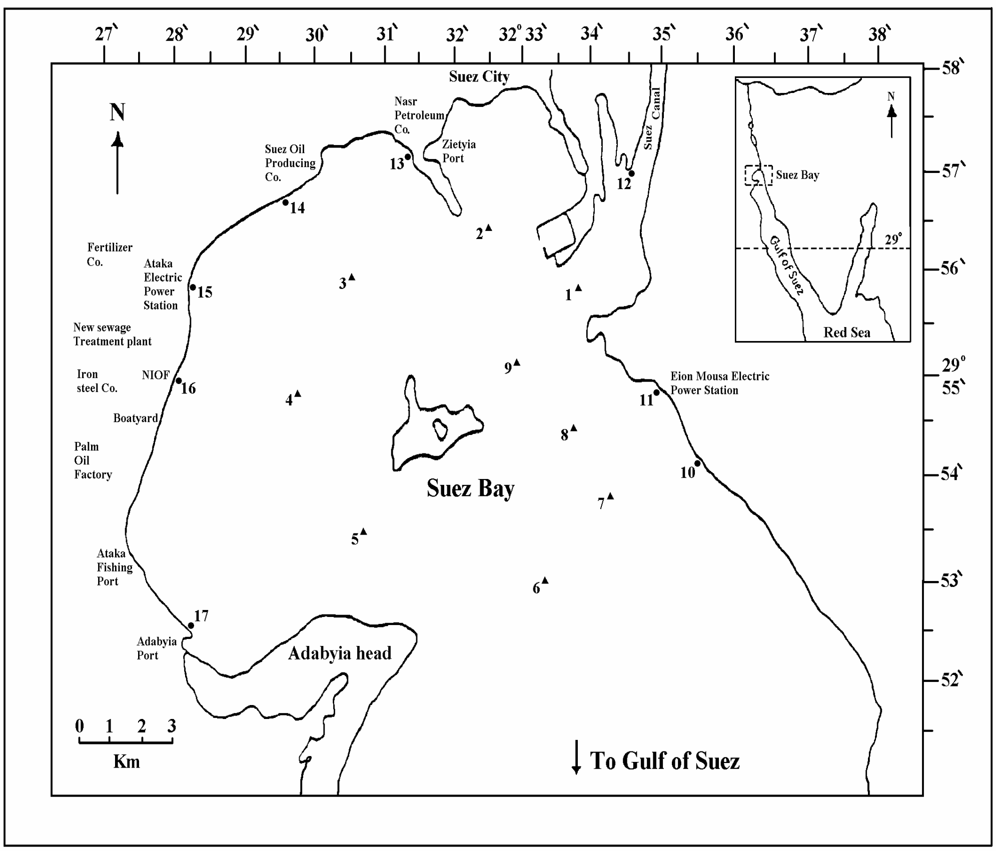

Fig. (1): Map of the Suez Bay showing the different pollution sources, offshore and inshore sampling stations

RESULTS AND DISCUSSION

Grain size composition

The spatial distribution of sedimentary faces is illustrated in Fig. 2, and the sedimentological analysis data are simplified by the classification [gravel, sand and pan (slit and clay)] as shown in Table 1. In addition, the grain size parameters: mean size, skewness, Kurtosis and sorting are given in Table 1.

Grain size analysis indicated the different depositional environments of the sediment (Shata, 2000). In the present study, sandy sediments were dominated most of the investigated area, which cover the offshore part of the bay. Coarse-grained sediments were distributed in the inshore stations, which are commonly low in depth. As well as, clear increasing trend of the silt-clay fraction with offshore stations was recorded. Sedimentological study on the Suez Bay showed that the mean size of sediments ranged from 0.19 Ø at station 8 to 3.16 Ø at station 14 (i.e. from coarse to very fine sand). Sorting varied from 0.52 Ø to 2.56 Ø (i.e. from moderately to very poorly sorted). Its oscillation reflected the unstable condition in the bay (Lotfy, 2002). The frequency distributions of mean size and sorting showed that there was general tendency for sorting to improve with the graphic mean size values, and the sorting improve shoreward. The skewness of Suez Bay sediments ranged between -0.43 to 0.15. About 35 % of the samples were positively skewed (i.e. finely skewed), while 65 % of the sediments were negatively skewed (i.e. coarsely skewed). Related to the nearing to the shore, the sediments had no distinct distributions (i.e. had wide range from negatively skewed to positively skewed). The kurtosis values of the Suez Bay sediments ranged between 0.61 Ø and 2.50 Ø.

Heavy metals

The concentrations of heavy metals in the bulk sediments of Suez Bay are shown in Table 2. The sequence of metals contamination follows the decreasing order: Fe > Mn > Zn > Pb > Ni > Co > Cr > Cu > Cd. At the offshore area, station 2 had high concentrations of metals, particularly Cu (25.92 µg/g), Ni (22.53 µg/g), Pb (30.52 µg/g) and Zn (67.29 µg/g). This station is affected by heavily oil processing at Zietyia Port and the effect of ships discharges which used antifouling paints containing metals such as Cu. Inshore station (No. 13) of the same area recorded the absolute highest value of Cu (34.52 µg/g). Offshore and inshore stations (No. 8, 9 and 15) located in front of the electric power stations were characterized by high concentration of Co, Ni, Cr and Fe in their sediments, which is mainly due to the use of metal alloys in bombs and containers for heating the water steam to produce electricity. High concentration of Cd at offshore station (No. 5) in front of Adabyia Port, as well as Pb and Zn at the inshore station (No. 17) may be due to the loading and unloading activities in this area, in addition to the wastes of some industries (as vegetable oil factories and chemical industries) near this station. The variety of the concentrations of heavy metals in bulk sediments of Suez Bay may be attributed to the effect of type and amount of pollutant arrives to it and the characteristic nature of the area (Mohapatra, 1988).

The influence of grain size on metal contents in sediments can be partially corrected by analyzing the same particle size class for all samples. The < 63 µm fraction was chosen in order to minimize the loss of metal by desorption (Carral *et al.,* 1995). Spatial distribution of heavy metals in sediment of the study area revealed that Suez Bay may be affected by different sources of pollution (sewage and garbage from the Suez City and ships awaiting transit area, industrial effluents including oil refineries, fertilizer plant, power stations and other industries). Table 3 shows the concentrations of heavy metals in the same grain size (< 63 µm). High concentrations of Cd, Co and Fe in the inshore and Cu in the offshore of Port Tawfiq at the entrance of the Suez Canal reflected the navigation activities through the canal and the effect of ships pass and transit using antifauling paint including these metals (Cu, Cd and Fe). In addition the influence of electric power stations to introduce special metals as Ni and Cr to the inshore and offshore sediment samples near those stations (No. 8, 9 and 15). The characteristics metals for oil pollution activities such as V, Cu and Pb (FAO, 1992) were highly found at stations 2 and 13, which are the offshore and inshore stations of Zietyia Port and oil refineries concentrated at that area. The corresponding increase of heavy metals in sediments of some stations than others indicated that the industrial effluents from the nearby region were the primary source of pollutant input in the area (Lin and Chen, 1996).

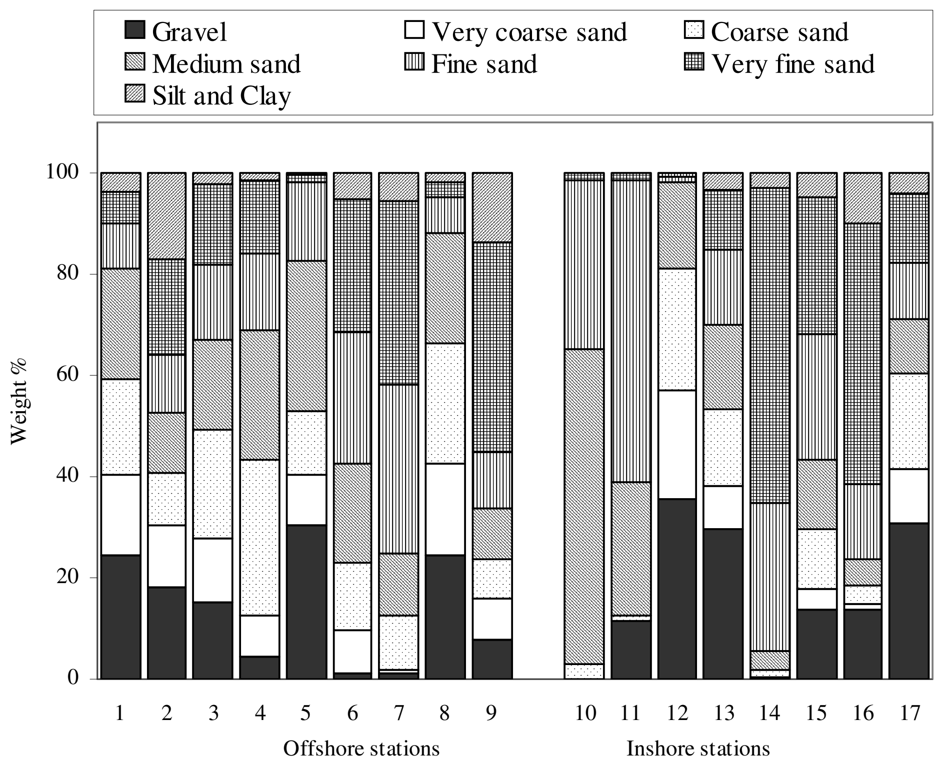

Fig. (2): Spatial distribution of grain size composition (weight %) of the sediments from Suez Bay

Table (1): Grain size fraction and parameters of the Suez Bay sediments.(*)

St. No	Gravel %	Sand %	Pan % (Silt & clay)	Mean size	Skewness	Kurtosis	Sorting	
1	24.37	71.98	3.646	0.46	0.04	0.87	1.78	(Poorly sorted)
2	18.2	60.75	17	1.62	0.03	0.84	2.56	(V. poorly sorted)
3	15.15	82.7	2.141	1.07	-0.01	0.82	1.83	(Poorly sorted)
4	4.261	94.25	1.485	1.48	0.15	1.00	1.37	(Poorly sorted)
5	30.22	69.48	0.294	0.39	-0.25	0.61	1.61	(Poorly sorted)
6	1.2	91.68	7.117	2.00	-0.22	0.95	1.42	(Poorly sorting)
7	1.035	91.31	7.658	2.53	-0.31	1.28	1.13	(Poorly sorting)
8	24.26	73.7	2.03	0.19	-0.01	0.88	1.52	(Poorly sorted)
9	7.71	78.41	13.88	2.33	-0.37	1.32	2.14	(V. poorly sorted)
10	----	99.94	0.052	1.88	0.05	1.24	0.52	(M. sorted)
11	11.31	88.69	----	1.96	-0.05	2.50	1.02	(Poorly sorted)
12	35.65	64.23	0.108	0.30	0.06	0.67	1.25	(Poorly sorted)
13	29.66	67.01	3.314	0.70	-0.01	0.65	2.01	(V. poorly sorted)
14	----	96.94	2.965	3.16	-0.13	1.35	0.58	(M. sorted)
15	13.61	81.38	5	1.76	-0.42	0.97	1.82	(Poorly sorted)
16	13.65	76.34	10	2.50	-0.43	2.18	1.97	(Poorly sorted)
17	30.91	64.25	4.833	0.62	0.14	0.65	2.07	(V. poorly sorted)

(*): according to Folk (1968) and Lotfy (2002)

Table (2): Concentration of heavy metals (µg/g) in the bulk sediments of Suez Bay.

St. No	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn
1	3.53	11.16	9.94	7.67	481.3	63.58	13.84	25.02	21.87
2	2.61	12.21	32.09	25.92	492.8	136.8	22.53	30.52	67.29
3	3.66	10.46	9.97	5.62	468.4	52.08	14.48	19.76	25.95
4	3.13	10.83	18.91	8.65	483.2	84.06	17.5	22.81	30.96
5	3.99	10.22	3.36	3.56	435.1	23.13	13.11	19.24	8.39
6	3.7	10.23	10.66	4.28	511.8	78.6	13.88	24.37	16.17
7	2.76	9.13	18.31	4.99	573.4	126.4	13.01	17.36	17.62
8	3.06	14.21	33.68	10.18	494.2	145.3	21.64	22.9	40.12
9	2.78	13.82	30.47	8.11	497.1	163.6	18.89	18.99	31.91
10	3.72	10.51	4.34	3.28	433.1	17.1	12.06	18.72	6.35
11	3.31	9.27	4.97	3.22	430.6	29.39	11.08	17.76	6.47
12	3.21	9	5.61	4.45	458.2	43.47	11.76	20.04	11.49
13	2.78	7.95	9.79	34.52	480.8	62.29	14.29	38.65	27.95
14	3.24	8.77	9.61	8.34	472.6	61.45	11.46	20.28	20.45
15	---	10.02	19.46	13.24	485.5	82.02	106.9	22.16	57.95
16	2.92	8.93	13.02	5.27	471.9	82.13	21.99	18.52	18.07
17	2.63	8.19	13.64	21.47	479.1	53.94	14.21	40.29	64.99

Table (3): Heavy metals concentrations (µg/g) in < 63µm fraction of Suez Bay sediments.

St. No.	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
1	2.96	10.75	21.73	126.1	781.2	130.6	16.65	41.51	59.71	118.2
2	2.24	12.59	37.06	19.84	905.1	182.6	21.29	38.70	116.7	68.43
3	2.57	13.09	25.93	22.01	810.2	167.1	17.93	33.46	75.21	34.75
4	3.03	7.56	29.91	20.18	811.2	176.4	22.15	38.63	91.70	52.93
5	4.18	9.81	15.08	79.82	1168	108.1	18.26	76.18	41.73	76.87
6	2.88	26.65	23.94	28.04	1374	236.2	15.19	43.59	55.36	46.20
7	2.29	13.83	36.89	13.32	802.9	311.6	17.79	28.91	89.36	38.31
8	2.65	15.67	46.09	42.53	903.2	246.3	29.29	35.78	116.6	83.52
9	2.27	16.08	36.48	11.24	821.1	34.20	24.19	34.49	94.81	46.38
10	2.88	8.49	12.10	6.56	789.6	88.19	11.14	26.56	37.80	20.47
11	2.82	9.50	25.42	4.51	777.5	277.3	11.63	23.75	55.21	12.61
12	2.99	13.74	20.83	57.19	1418	185.3	16.62	69.01	58.66	93.19
13	2.31	10.17	24.46	120.5	872.7	163.0	23.50	69.27	71.59	112.4
14	2.69	10.56	33.15	24.46	901.4	263.9	17.37	33.37	72.76	56.17
15	1.50	11.23	35.63	18.96	808.4	194.5	167.0	32.89	380.0	94.08
16	1.86	9.29	27.42	8.84	787.8	202.7	42.15	26.60	100.7	28.60
17	1.97	9.63	23.78	33.49	849.9	115.2	15.34	62.65	56.77	120.3

Comparison of the present results with others from similar environment (Table 4) indicated that the present concentrations were in the range with those recorded in other studies except Ni and V which exhibited high concentrations in the present study. This may be attributed to the fact that the Suez Bay is characterized by the petroleum activities and oil production which contain high values of Ni and V (FAO, 1992). In addition, most of the present metals exhibited concentrations higher than those recorded by Bryan (1985) for typical sediments.

The inter-elemental relationships between the studied metals (Table 5) showed the importance of the pollution sources which may effect the metals content of sediments. The concentrations of Zn, Cu and Fe and to a lesser extent, Cd, were all associated with Pb. Whereas Ni was strongly associated with V ($r = 0.975$) indicating that the metals resulted from the same source exhibit the same behavior with each other. Consequently, the source of heavy metals and dilution from inshore to offshore, according to the environmental conditions, were the two primary factors controlling the heavy metals distribution in the sediments (Lin and Chen, 1996).

Not all metals were grain size controlled, even though grain size was found to be one of the major factors controlling heavy metals distribution in sediments (Lin and Chen, 1996a). As shown in Table 6 and Fig. 3, low metals concentrations were occasionally observed in coarse grained sediments, most of the investigated metals were gradually increased with deacreasing the grain size of sediments and chiefly associated with the clay (and slit) forming mineral phases. Rajkumar *et al.* (1992) noted that the metals entering marine coastal areas become associated with sediments, especially the smaller particles; Leoni and Sartori (1997) found that most of the trace metals were highly correlated with the finest granulometric class (clay). This result was reflected in the highest metal levels at stations possess highly clay content. This trend reveals combination effects of possible industrial pollution with natural constituents of the sediments.

Summary and Conclusion

The sedimentological and metal analyses of the sediments provide a valuable way for improving the knowledge of the prevailing hydrodynamic conditions and for assessing the sediment source - transport- deposition sequences in Suez Bay. The analysis of heavy metals in sediments of Suez Bay indicated that, as far as the fine fraction is concerned, the highest metals content may be mostly ascribed to man's influence. Regulation in the quantity and quality of industrial effluents in the region is urgently needed.

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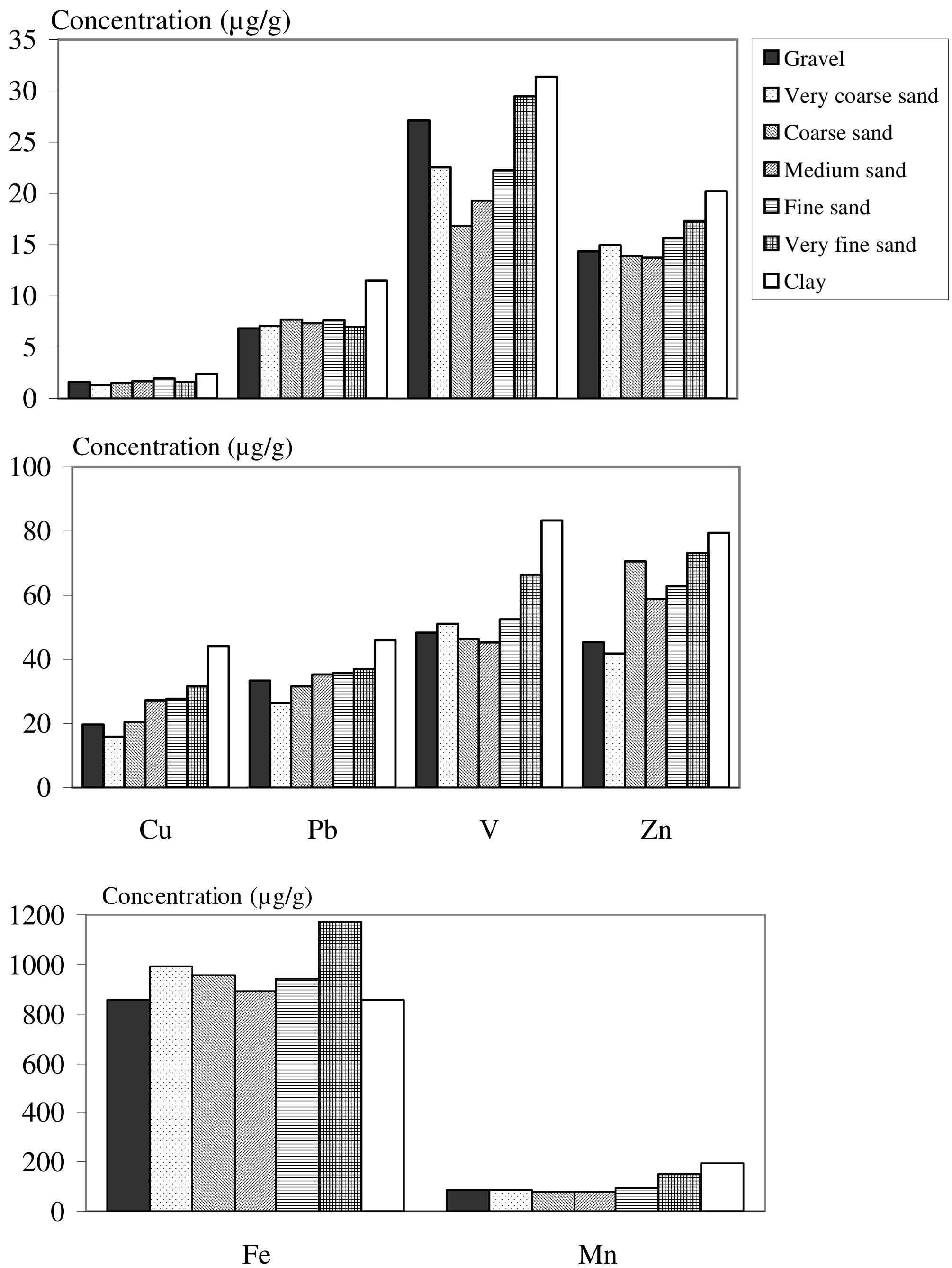

Fig. (3): Mean concentrations of heavy metals ((µg/g) in different grain size of sediments from Suez Bay

Table (4): Comparison of the present levels of heavy metals in sediments (µg/g) with reported levels of different regions.

Regions \ Metals	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn	References
India	2.29	37.25	39.89	103.38	69.8x103	860.15	105.08	54.08	--	169.6	Mohapatra, 1988
Finland	1.06	--	85.0	43.0	4.50%	5000	42.0	50.0	76.0	175.0	Leivuori, 1998
Australia	0.85	--	3.80	5.80	5650	61.0	8.0	54.1	--	--	Nicholson et al.,1990
Iran	1.20	--	--	87.5	--	--	52.6	51.8	--	278.5	Amini Ranjbar, 1998
Italy	--	20.00	128	35	--	--	91.0	40.0	130	110.0	Leoni and Sartori, 1996
U.A.E.	5.54	10.88	11.57	18.34	--	96.62	27.0	29.42	--	77.10	Shriadah, 1998
Alexandria	--	75.60	--	--	17.67%	1741	130.1	--	--	179.3	El-Sammak& Aboul Kassim, 1999
Manzala Lake	5.97	57.71	184.6	73.29	1.15%	1716	99.16	87.9	--	89.95	El Sabrouti and Abaza, 1997
Suez Gulf	0.7-4.2	0.3-2.6	0.2-0.9	4.9-20	369-2969	45-341	1.1-9.3	4.0-24	--	17-38	Hamed, 1996
Suez Canal	1.4-3.06	12-44.7	28-104	10.6-55	2275-2847	245-484	14-54.2	20-134	51-269	10.4-88	Abd El-Azim, 2002
Suez Bay	1.29-3.9	--	--	3.7-16.2	--	--	--	18-29.2	--	10.4 -50	Abd El-Azim, 1996
Suez Bay	1.5 -4.2	7.5-26.6	12.1-46	4.5-126	777.5-1418	34.2-263	11.1-167	23.7-76	37-380	12.6-120	Present study
Typic sediment	0.30	10.0	37.0	19.0	1.9x 104	420	28.0	39.0	--	98.0	Bryan, 1985

Table (5): Inter-elemental relationships in < 63 µm sediment fraction of Suez Bay sediments.

	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
Cd	1									
Co	0.005	1								
Cr	- 0.507 *	0.231	1							
Cu	0.341	-0.087	-0.306	1						
Fe	0.464	0.582 *	-0.283	0.198	1					
Mn	-0.128	0.196	0.417	-0.234	0.06	1				
Ni	- 0.533 *	-0.072	0.307	-0.133	-0.173	0.052	1			
Pb	0.393	-0.014	-0.409	0.666 *	0.587 *	-0.338	-0.165	1		
V	- 0.591 *	-0.03	0.48	-0.2	-0.227	0.121	0.975 *	-0.247	1	
Zn	-0.075	-0.08	0.008	0.738 *	0.172	-0.252	0.212	0.683 *	0.191	1

* Significant at $p < 0.05$

Table (6): Heavy metal concentrations (μg/g) in different grain sizes of sediments of some stations along Suez Bay.

Metal	Station	Gravel	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Clay	Bulk sediments
Cd	2	1.44	1.71	0.55	1.41	1.48	1.46	2.24	2.61
	8	1.63	1.76	1.74	1.33	2.06	0.14	2.65	3.06
	11	1.4	0.63	1.41	1.66	1.26	2.62	2.82	3.31
	13	1.39	0.92	1.88	2.69	2.34	1.82	2.31	2.78
	16	2.12	1.35	1.95	1.28	2.51	2.03	1.97	2.63
Co	2	8.21	13.37	7.95	6.26	8.59	6.81	12.59	12.21
	8	9.58	7	11.23	10.03	11.83	9.1	15.67	14.21
	11	4.86	6.03	5.41	4.56	2.77	5.59	9.5	9.27
	13	4.54	3.58	6.92	8.54	8.08	6.88	10.17	7.95
	16	6.96	5.26	6.83	7.3	6.85	6.47	9.63	8.19
Cr	2	36.14	46.47	31.8	31.46	35.13	33.69	37.06	32.09
	8	41.14	28.43	25.42	23.71	32.47	39.28	46.09	33.68
	11	5.91	13.63	6.88	5.31	4.12	29.5	25.42	4.97
	13	29.5	8.7	6.2	12.79	15.34	15.89	24.46	9.79
	16	22.89	15.53	13.84	22.17	24.26	29.08	23.78	13.64
Cu	2	27.74	32.57	23.48	19.42	29.91	22.67	19.84	25.92
	8	25.64	9.33	7.14	13.77	7.97	18.69	42.54	10.18
	11	2.024	5.53	2.21	2.18	1.65	4.18	4.51	3.22
	13	29.47	19.35	48.81	67.68	61.26	80.69	120.6	34.52
	16	13.53	12.91	20.79	33.24	37.85	31.63	33.49	21.47
Fe	2	1043	1322	1148	1107	1244	1084	905.1	492.8
	8	1084	993.4	1055	1137	1174	1270	903.3	494.2
	11	629.5	1130	678.9	601.1	544.1	1865	777.5	430.6
	13	754.7	667.3	868.4	804.5	741	867.3	849.4	480.8
	16	754.7	835.8	1038	809.4	1015	776.9	849.9	479.1
Mn	2	160.8	177.4	123.1	106.9	137.3	114.2	182.6	136.8
	8	111	92.11	96.39	84.59	120.8	108.4	246.1	145.3
	11	40.5	61.84	36.63	35.85	22.5	315.2	277.3	29.39
	13	50.39	52.23	62.58	75.9	70.21	115	163	62.29
	16	53.51	43.7	71.91	77	104.9	93.29	115.2	53.94

Table (6): Cont.

Metal	Station	Gravel	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Clay	Bulk sediments
Ni	2	23.65	28.33	18.26	16.79	23.43	19.35	21.29	22.53
	8	20.13	14.75	13.8	12.73	16.41	21.14	29.29	21.64
	11	6.584	14.94	8.571	6.99	5.209	12.17	11.63	11.08
	13	9.669	7.706	14.99	18.29	16.76	18.6	23.5	14.29
	16	11.61	8.996	13.92	13.76	16.37	15.24	15.34	14.21
Pb	2	28.42	42.07	20.64	22.17	26.88	28.27	38.7	30.52
	8	16.35	13.65	15.83	11.71	18.73	15.04	35.78	22.9
	11	12.51	25.21	14.16	10.44	8.574	16.92	23.75	17.76
	13	69.92	19.75	54.17	71.57	63.92	57.72	69.25	38.65
	16	39.92	31.6	53.29	60.75	60.42	66.99	62.65	40.29
V	2	84.24	116.3	69.42	77.82	90	86.62	116.7	NM
	8	90.34	67.77	65.37	51.74	77.41	94.64	116.6	NM
	11	14.84	28.27	16.82	16.64	13.62	57.35	55.21	NM
	13	21.91	15.57	39.3	37.22	36.14	50.82	71.59	NM
	16	30.55	27.37	40.83	43.22	45.4	42.73	56.77	NM
Zn	2	87.32	105	181.9	59.93	95.98	67.71	68.43	67.29
	8	39.29	25.47	23.65	28.62	25.93	68.25	83.52	40.13
	11	8.759	21.09	9.462	16.51	10.06	22.77	12.61	6.474
	13	37.07	17.59	42.52	91.82	50.45	83.57	112.4	27.95
	16	54.59	40.19	95.11	97.39	131.7	123.7	120.3	64.99

NM: not measured

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