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Heavy Metal Pollution in Bottom Sediment, Dubai, United Arab Emirates

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The city of Dubai was well known since old history as an important commercial center. Dubai creek can be considered as the focal point of Dubai. It has a great importance for trading and aesthetic values. It provides an important means of transport, water sports and other activities. The creek is daily used by myriad of people. It is used as a harbour for small cargo and fishing vessels. Industries located on the waterfront such as the ship-docking yard, private ship-builders and repairs also use the creek. The creek also serves the municipality to discharge excessive treated water from Sewage Treatment Plant (STP), and construction companies for the discharge of ground water. Day to day activities conducted by these activities and industries certainly do have negative impacts on the creek in many ways. They through solid waste; dumping used oil, chemical substance and wastewater. According Dubai Municipality's violations record for January-October 1999, disposal or littering formed 47% of the violations, while oil spill, painting vessels, and wastewater discharge comprised 34%, 14% and 5% respectively of the total violation imposed (*source: Dubai Municipality, Environmental Department, Personal Communication*).

The present study aims to quantify the metals pollution using statistical methods and simple quantification method (Pollution Load Index, PLI). Normalization of the data to reduce the effect of grain size on the metals contents will also be done using organic carbon and carbonate as normalizers. It also aims to compare the results of the present study to other areas to assess levels of contamination in Dubai creek.

MATERIALS AND METHODS

Dubai creek is a seawater intrusion system that makes tight U-turned around Al-Ras band with no hydro-dynamically significant fresh water input. The creek divides into two sectors: the upstream (Al Garhoud bridge to the end) and downstream (creek mouth till Al-Garhoud bridge) refers as lagoon and channel respectively. The creek is approximated 13 km long. Its width varies from 100 ± 10 m at the mouth and 1200 ± 100 m at the shallow head. The depth of the creek varies in the range of 5.5 ± 1.0 m and 7.0 ± 1.0 m during ebb and flood tide

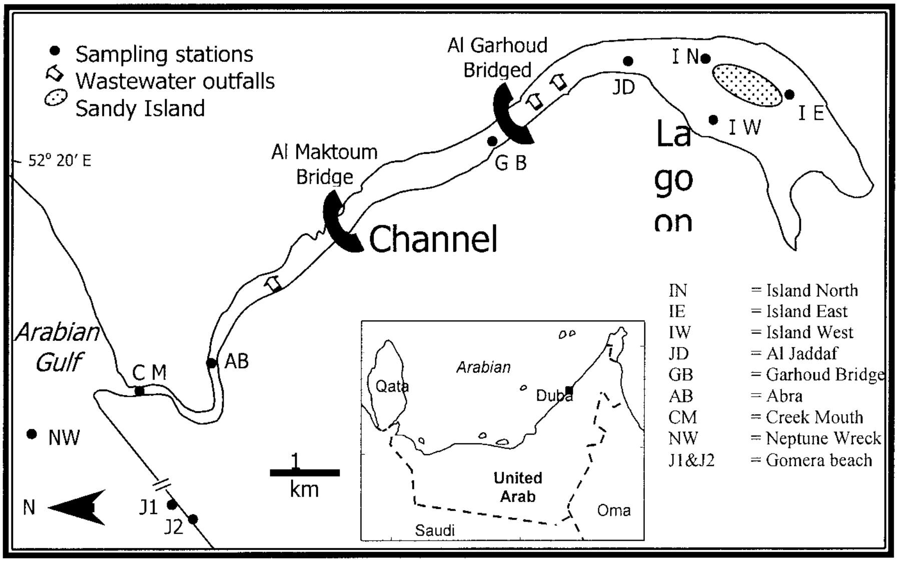

Figure 1. Dubai Creek showing the sampling stations.

respectively. Dubai creek is alkaline, the salinity of the creek water is 39.0 ± 1.0‰ which is comparable with the salinity of the gulf water (Environmental protection and safety section, MESU, 1997). The water temperature varies from 21°C in winter to 34°C in summer with annual average temperature of 29°C (Environmental protection and safety section, MESU, 1997).

Samples were collected, by grab sampler, during October 1998, from creek channel, creek lagoon, off creek and from Gomera beach (Figure 1). The total and leachable (Bioavailable) parts of Zn, Cd, Pb, Ni and Co were analyzed according to the method described by Loring and Rantala (1992). The acetic acid was used to remove the leachable portions of the studied metals. The residual fractions were extracted using concentrated hydrofluoric acid. The total metals' concentrations are equal to the sum of the residual fractions and the leachable fractions. ICP-MS was used for determination of metals concentrations. Total Inorganic Carbon (TIC) (carbonate contents) were analyzed according to the method of Moilnia (1974). The method described by Gaudette *et al.*, (1974) was used for organic carbon (OC) determination. The precision and accuracy of the results were checked by applying the same procedure on triplicates of some selected samples and checked the results against Certified Reference Materials (MESS-1, Marine Sediment Reference Material). The precision and accuracy were within the acceptable limits (<5%).

RESULTS AND DISCUSSION

Table (1) illustrates the results of the different metals, OC and TIC concentrations at different stations. No obvious variations can be observed in the metals contents between different stations. Total Pb decreases in the island stations (creek lagoon). On the other, the leached part decreases at Al-Grhoud Bridge and Al-Jadaf stations. Organic matter increases in the lagoon stations (IN, IW and IE) and experiences the minimum values in the creek channel. Carbonate shows the antipodal distribution pattern to that of organic carbon (Figure 2). The lagoon stations exhibit the lowest values for carbonate, while the channel stations have the highest values for carbonate contents.

Table 1. Results of the present study for different stations (metals' concentrations are in ppm).

Sample #	OC %	TIC %	L.Zn	T.Zn	L.Cd	T.Cd	L.Pb	T.Pb	L.Co	T.Co	L.Ni	T.Ni
NW	0.02	91.00	0.70	25.00	1.01	5.28	8.00	50.00	4.80	23.25	3.46	35.00
CM	0.00	80.00	0.67	27.50	0.98	6.25	7.44	46.50	4.32	19.50	4.48	39.00
AB	0.04	82.00	0.63	24.50	1.04	5.48	7.77	50.00	4.88	22.50	3.94	35.25
GB	0.03	63.00	0.70	27.50	0.88	5.95	3.42	47.50	3.92	19.75	3.98	35.50
JD	0.06	59.00	0.69	25.00	0.80	5.75	5.68	46.25	4.40	20.50	4.16	37.50
IN	0.25	66.00	0.72	26.50	0.98	7.20	6.86	53.50	3.73	18.00	4.17	39.00
IW	0.24	59.00	0.51	24.35	1.20	5.75	6.80	39.25	3.92	19.00	3.62	34.50
IE	0.19	64.00	0.61	23.25	0.88	3.83	7.76	35.75	4.24	20.00	3.90	37.25
J1	0.02	91.00	0.60	24.00	0.80	4.83	7.44	44.00	3.60	18.50	4.16	38.25
J2	0.00	89.00	0.70	25.00	1.22	5.00	8.00	48.00	3.44	19.25	3.68	35.25

Pollution Load Index (PLI) is used in order to find out the mutual effect of the different studied metals. PLI is calculated according to the following equation (Salomons and Förstner, 1984).

$$PLI=\sqrt[5]{CF_{Cd} \times CF_{Pb} \times CF_{Co} \times CF_{Ni} \times CF_{Zn}}$$

CF is the Contamination Factor. CF is the concentrations of a metals divided by the background value for this metal. Back ground value used here is the standard shallow water sediment reported (Wedepohl, 1978; Salomons and Förstner, 1984) Figure (3) shows the values of PLI for different stations. Notwithstanding the low values of the PLI comparing to the other areas (Tomlinson *et al.*, 1980, El-Sammak, 1995), it is obvious that there is a slightly decrease in the values of PLI toward the lagoon area. Gomera beach exhibits low values comparing with the values for the channel area. In order to reduce the effect of grain size, many parameters had been suggested as normalizers (Förstner and Wittmann, 1981). In the present study TIC and OC are used as normalizers. Scatter plots between the concentrations of OC and TIC vs. the concentrations of each metal were constructed. Natural geochemical population of the investigated trace metals in relations to both variables can be defined through data calculated along the regression line with the 95% confidence limit (Nasr, 1995). This means that there is a 95% probability that points which fall outside the confidence limits are from

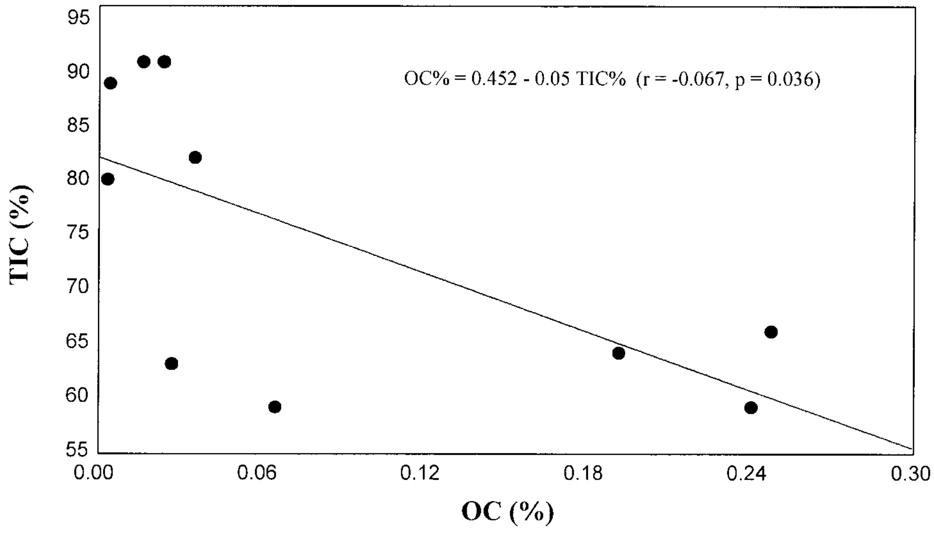

Figure 2. Relation between organic carbon (OC) and total inorganic carbon. (TIC).

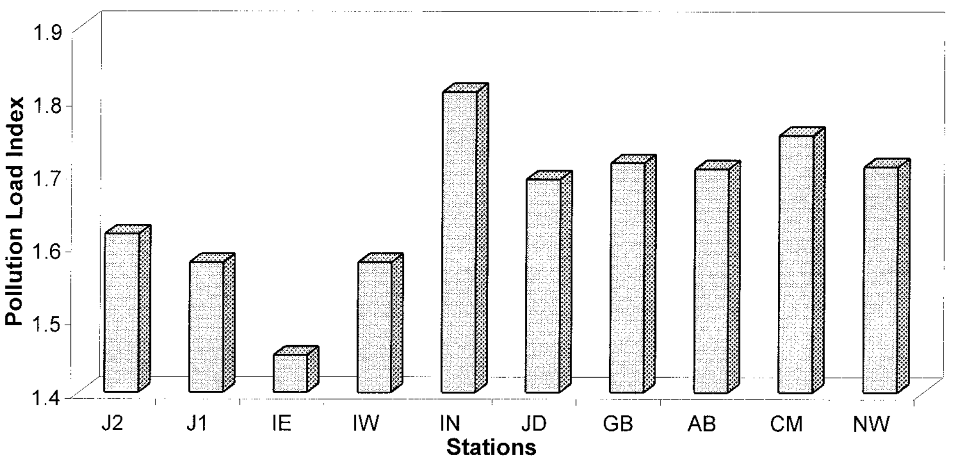

Figure 3. Pollution Load Index (PLI) calculated for different stations.

different or anomalous populations, i.e. pollution is indicated (lmam, 1992, Nasr, 1995). It is obvious that only few stations fall outside the 95% confidence limit for both organic carbon as well as total carbonate (Figures 4). This may indicate that pollution is very low.

Figure (5) shows the percentages of the bioavailable portions to the total metals contents. Cd and Pb have the highest percentages of the bioavailable fractions in the lagoon area. On the other hand, the percentage of the bioavailable fraction for Ni decreases from the creak mouth towards the channel area.

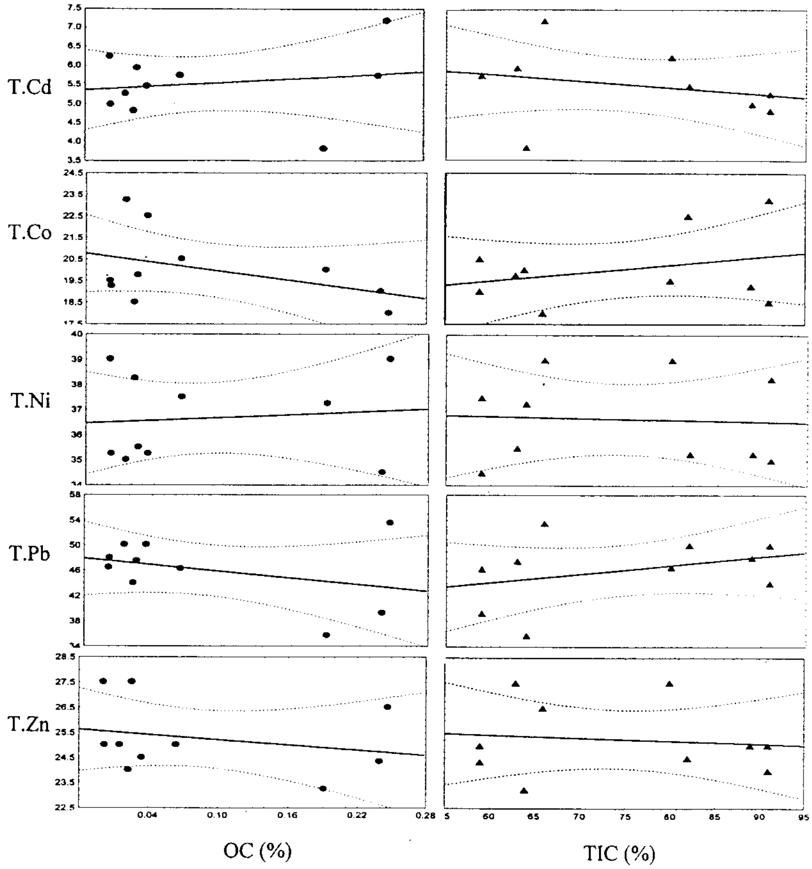

Figure 4. The relationships between total heavy metals and both organic carbon and total inorganic carbon contents showing the 95% confidence limits.

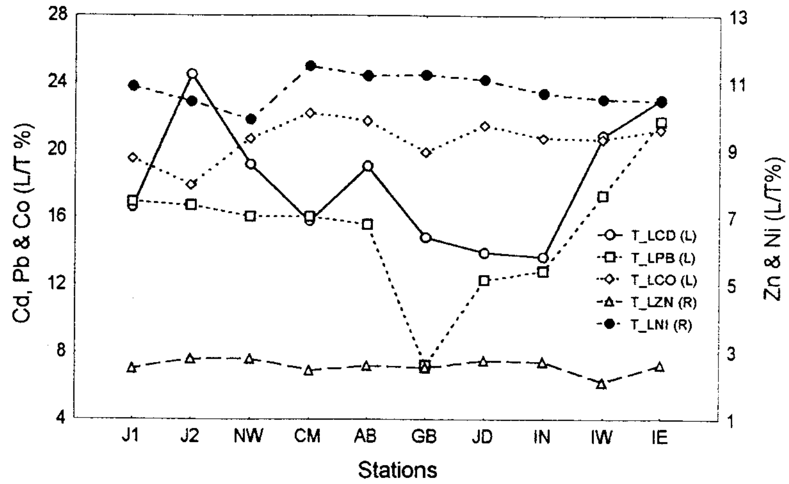

Figure 5. Ration of the leached metals to the total metals for different stations.

According to Abu-Hilal & Khordagui (1992), Dubai creek and its nearshore sediments exhibited higher range and mean concentrations of heavy metals. The coastal station showed the lowest element concentrations, which tended to increase in the sediments of stations inside the creek. They also mentioned that the stations in the channel area had the highest metals concentration due to their location within the deep internal portion of the creek, where they receive increasing quantities of wastewater from many several outlets in addition to the waste from Dubai Dry Dock and hundreds of boats. They also mentioned that an important feature of element distribution in Dubai region is the high concentrations of the heavy metals in the top layer (upper 1-2 cm) of the examined sediments, compared to the other subsurface samples. They mentioned that the concentration in the top layer is 2-18 times higher than the bulk of the samples.

Using the data from the unpublished report (*Environmental protection and safety section, MESU, 1997*), it is clear that there are some increases in the metals' concentrations of the studied short cores in the upper 10 cm comparing to the concentrations at the core interval 10-20 cm from the core-top (Table 2). The percentages of the increases range between 10.8% for Zn and 38.8% for Pb. These increases may indicate an increase in the pollution load with time. The upper 10 cm of the core should be deposited after the deposition of the lower layers. Such distinctly high metals and/or organic carbon concentrations in the top layer of recently deposited surface sediments is usually common in areas receiving anthropogenic inputs of metals and organic matter (Abu Hilal and Khordagui 1992).

Table (2) shows a comparison between the present results with the previous results provided by different authors working on the same study area or in similar environments. Taking into consideration the differences in the methods used for determination of heavy metals, the present study is slightly higher than the previous studies. Noting that the metals' concentrations in Dubai creek are still low if they compared with the metals' concentrations in well-known highly polluted areas. It is also important to note that Dubai creek is a semi-enclosed basin where most of the pollution sources are dumping in it, hence, increasing pollution.

In order to reveal the similarities between different sampling stations, single linkage cluster analysis was constructed. The resulted tree diagram (Figure 6) reveals that Dubai creek can be divided into two distinct regions. The first group of clustered stations are those located in the upper channel area up to Abra area, Gomera beach, off the creek and the creek mouth stations. The second group of stations can be discriminated into two subgroups. The first subgroup contains the stations from Jadaf, Garhoud bridge and island north (IN), while the other subgroup includes those stations that are located in the lagoon area (IE and IW). This discrimination is mainly depending upon the nature of the channel and the lagoon areas as well as the sources of pollution. The area from Abra to the deep internal portion of the creek receives increasing quantities of wastewater from many several outlets in addition to the waste from Dubai Dry Dock and hundreds of boats (Abu Hilal and Khordagui 1992). As a matter of fact, out from the thirty-

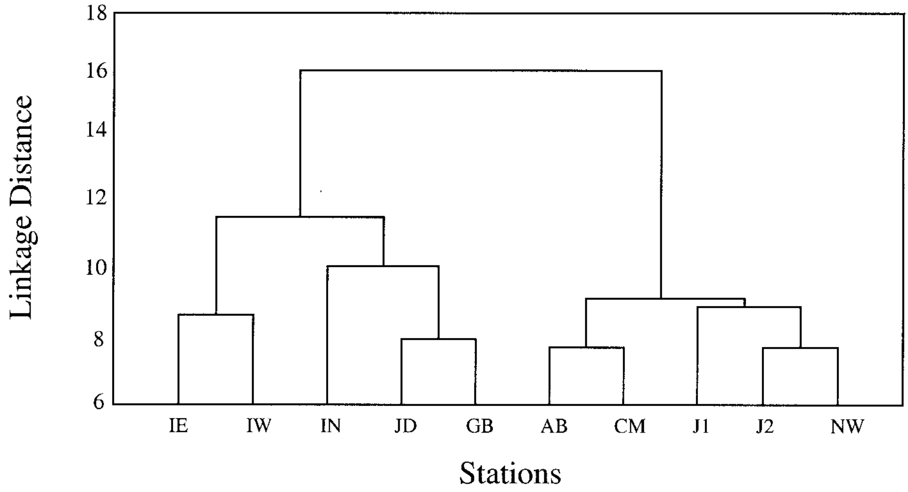

Figure 6. The cluster analysis showing the similarities between different stations.

Table 2. Comparison between the present study and the previous studies.

AVERAGE (ppm) (RANGE)	Cd	Co	Ni	Pb	Zn
1. Coastal area UAE, Arabian Gulf	5.54	10.88	27.0	29.42	77.1
	4.32 9.55	6.01 25.9	8.01 214.5	9.03 57.0	3.01 534.0
2. Coastal area UAE, Arabian Gulf	0.03	0.73	9.0	6.06	31.2
	0 0.12	0 3.4	0.4 35.4	0.0 35.4	0.4 142.0
3. Kuwait, Arabian Gulf	1.46 2.54	ND	36.01 102	2.5 35.0	27.0 75.0
4. The Arabian Gulf	0.14	ND	386 637	5.6 25.6	27.0 43.0
5. Iraq, Arabian Gulf	0.26	2.01	10.1	3.65	13.7
	0.1 1.0	0.1 1.0	5.0 14.0	2.0 - 6.0	8.0 38.0
6. Dubai Creek	5.3	10.4	27.2	28.1	42.1
	4.5 6.4	5.0 12.0	11.0 241.5	21.0 43.9	15.0 109.0
7. Dubai Creek (0 10 cm)	3.0	ND	64.0	109.0	75.0
8. Dubai Creek (10 20 cm)	3.0	ND	57.0	72.0	33.0
Present Study	5.53	20.01	36.65	46.1	25.26
	3.83 7.2	18.0 23.25	34.5 39.0	53.5 35.8	23.3 27.5

1. Abu-Hilal and Khordgui 1992 2. Salman et al. 1987. 3. Abayachi and Douaboul 1986.
4. A-Hashimi and Salman 1985 5. Shriadah 1998. 6. Shriadah 1998.
7. *Environmental protection and safety section, MESU, 1997(unpublished report)*

three wastewater outfalls, dumping to Dubai creek, only six of them are dumping at the creek lagoon (Hassan, 2001).

Generally the present results are mostly comparable to the previous published data, especially those on the same area. The discrimination of the area into two regions is mostly based on the organic matter contents, carbonates content as well as the variation in the metals contents. The lowest values for PLI are found in stations located in the lagoon area, while the highest PLI values are found in the stations located in the creek channel. The normalization of the data using organic matter and carbonate as normalizers indicates that most of the stations fall inside the 95% confidence limit band which reflects the natural background composition of different metals. On the other hand the few samples fall outside the 95% band verify the man-made impact on the metals contents in the investigated area. The history of the metals pollution in the creek depicted from the previous data indicates an increase in pollution load with time. A management program including a strategy for reducing and/or regulating the accumulating of the pollutants in the creek should be proposed.

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