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Metal Pollution in the Sediments of Alexandria Region, Southeastern Mediterranean, Egypt

A. A. El-Sammak,[1,2] T. A. Aboul-Kassim[1,3]

[1]Alexandria University, Faculty of Science, Oceanography Department,
Alexandria, Egypt
[2]United Arab Emirates University, Faculty of Science, Geology Department,
Al-Ain, Post Office Box 17551, United Arab Emirates
[3]Environmental Geochemistry Group, College of Oceanic and Atmospheric Sciences,
Oregon State University, Corvallis, OR 97331, USA

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Sediment can be considered as a heterogeneous mixture of dissimilar particles (detritus, organic and inorganic debris, plankton cells, etc.). These particles themselves can be considered in turn as a complex assemblage of different inorganic and organic components (Martin *et al.* 1987). In fact, sediment analysis can reflect the current quality of the system and the pollution history of a certain area. Metals are not necessarily fixed permanently by the sediment, but may be recycled via biological and chemical agents, both within the sedimentary compartment and also back into the water column (Salomons and Förstner 1984).

Alexandria is the main summer resort in Egypt (about 4 million citizen and two million summer visitors). About 40% of the nation's industry surround the city (Nasr, 1995). The present paper aims to quantify metals concentrations in the sediments of Alexandria coastal areas.

The area of the study covers the coastal strip along Alexandria city from Agami in the west to Maamoura in the east (Figure 1). The area is covered with well-sorted sand that differs locally in the origin, type of sediments and texture (El-Wakeel *et al.,* 1984). More than 18 x 106 m^3 of untreated sewage and wastewater were discharged annually from large numbers of outlets into Alexandria coastal water through local sewerage system (Abdel-Moati, 19911). Pollutants are produced from industrial, anthropogenic and agricultural activities (Nasr 1995). The direct discharge of raw sewage and industrial wastewater causes high rate of pollution to the coastal waters off Alexandria (Nasr 1995).

MATERIALS AND METHODS

A total of 18 sediment samples (include reference samples) collected by hand or skin diving, during May 1993, from the foreshore area, along the extent of Alexandria coast. The study area was divided into five zones.

Correspondence to; A. El-Sammak, United Arab Emirates University

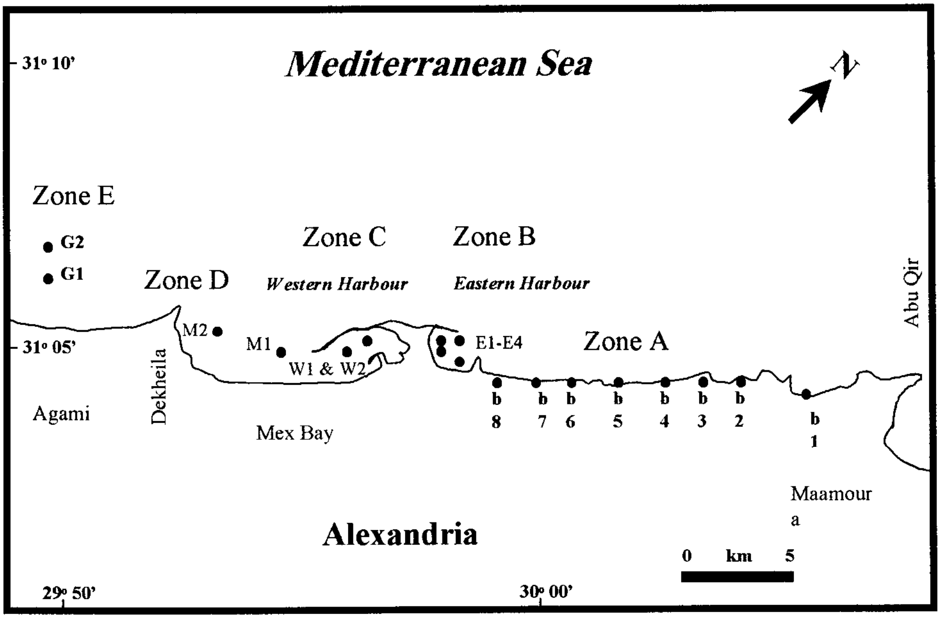

Figure 1. Area of study and stations sampled.

From east to west: zone A represents the coast between Maamoura to Shatby, zone B includes samples from the Eastern Harbour; zone C represents the Western Harbour and Zone D contains samples from Mex Bay, in addition to the reference samples from Agami innershelf and middle-shelf area (Zone E). Samples were washed with distilled water several times to remove salt, oven dried at 50°C. total metals contents in the sediment samples were analyzed using ICP-MS. For the leached part acetic acid/ammonium acetate (pH 5.94) were used. Reproducibility was checked by duplicate analyses of the samples. NCSS and STATISTICA statistical packages were used for evaluating the data.

RESULTS AND DISCUSSION

Table (1) shows the maximum, minimum and average ± standard deviation of the geochemical data as well as the calculated pollution load index. Most of the elements show significant correlation with each other. Sr and Ca show a positive correlation with each other. This positive correlation may indicate that both Sr & Ca are incorporated with $CaCO_3$ in the form of aragonite. Aragonite-type minerals show preferential substitution with large cations (Milliman 1974). On the other hand, Mg shows very weak negative correlation with all metals except with Ca and Sr. It has weak positive correlation with both of them. This may indicate that Mg is also performing to be incorporated in the carbonate fractions rather than silisclastic portion.

Table 1. Descriptive statistics of geochemical data and the calculated Pollution Load Index.

Element (ppm)	Maximum	Minimum	Average ± St. Deviation
T. Co	75.6	1.2	50.24 ± 19.5
T. Ni	130.1	3.52	85.7 ± 34.1
T. Zn	179.3	10.2	101.8 ± 43.9
T. Ba	321.0	33.0	213.2 ± 74.0
T. Mn	1741.0	34.0	1105.4 ± 443.3
T. Sr	6030.0	159.0	1364.0 ± 618.0
T. K (%)	1.76	0.096	1.195 ± 0.446
T. Na (%)	2.32	0.832	1.608 ± 0.373
T. Mg (%)	3.41	0.123	1.149 ± 0.757
T. Ca (%)	42.15	1.57	6.05 ± 11.3
T. Fe (%)	17.67	0.159	10.36 ± 4.13
T. Si (%)	33.41	1.404	16.1 ± 8.65
L. Co	0.73	0.004	0.412 ± 0.2
L. Ni	3.56	0.255	2.202 ± 0.82
L. Zn	0.94	0.255	0.536 ± 0.2
L. Ba	11.22	0.011	5.35 ± 3.23
L. Mn	200.4	3.1	126.8 ± 53.25
L. Sr	44.4	23.3	32.01 ± 7.04
L. K	2160.0	560.0	1560.1 ± 421.8
L. Na	10051.0	5178.0	7932.8 ± 1532.3
L. Mg	3000.1	925.0	2056.8 ± 515.1
L. Ca	14970.0	3588.0	6310.3 ± 3061.7
L. Fe (%)	3.55	0.435	1.516 ± 1.103
L. Si	125.11	27.3	91.47 ± 23.73
Pollution Load Index	1.77	0.151	1.279 ± 0.417

The Principle component factor analysis is preformed on the geochemical data. The principal component factor analysis, at its simplest, can be regards simply as an ordination technique, for reducing multivariate data into fewer dimensions. Principle Component analysis transform an original set of N variables into a net set of N principle components. Although there are as many as principle components as variable, the transformation is such that the first and second components almost invariably account for a far proportion of the total value (Rock 1988). Factor 1 and Factor 2 explain 82.57% of the total variance. Both factor 1 and 2 weigh on their negative side Ca and Sr. On the other hand, Factor loads most of the other elements on its positive side, except for Mg, where its load lies on the negative side of factor 1 with a very low value. Factor 2, loads only Mg on the its positive side. Figure (2) shows the spatial distribution of the different elements with respect to both factors. It is clear that, Sr and Ca are always incorporate with each other in the form of Aragonite. Fe is the metal locates on the negative of factor 2. The spatial distance between Fe and Si indicates that Fe is mostly associated with clay fractions. The clustering of the other metals together may indicate the syngenetic sources of these metals. Mg on the other hand may estimated to be associated with carbonates and silicates fractions.

To quantify the magnitude of pollution by different metals, the contamination factor (CF) is used (CF = metal concentration in sediments / base value for shallow marine sediments) (Salomons and Förstner 1984). The calculated contamination factors are found to fall in the following sequence:

$$Co > Ni > Fe > Sr > Mn > Ba > Zn$$

Pollution Load Index (PLI) is used to find out the mutual pollution effect at different stations by the different metals: PLI is calculated according to the following equation (Salomons and Förstner 1984).

$$PLI = \sqrt[7]{CF_{Co} * CF_{Zn} * CF_{Ba} * CF_{Mn} * CF_{Sr} * CF_{Ni} * CF_{Fe}}$$

PLI varies between 0.151 and 1.77 with an average of 1.279 ± 0.417. Figure (3), shows the variation of PLI at different stations. In general, there is an increase of PLI toward the western side. The Eastern Harbor (zone B) and Mex bay (zone D). These two zones are said to the most polluted areas at Alexandria beach (El-Sammak and Aboul-Kassim 1998).

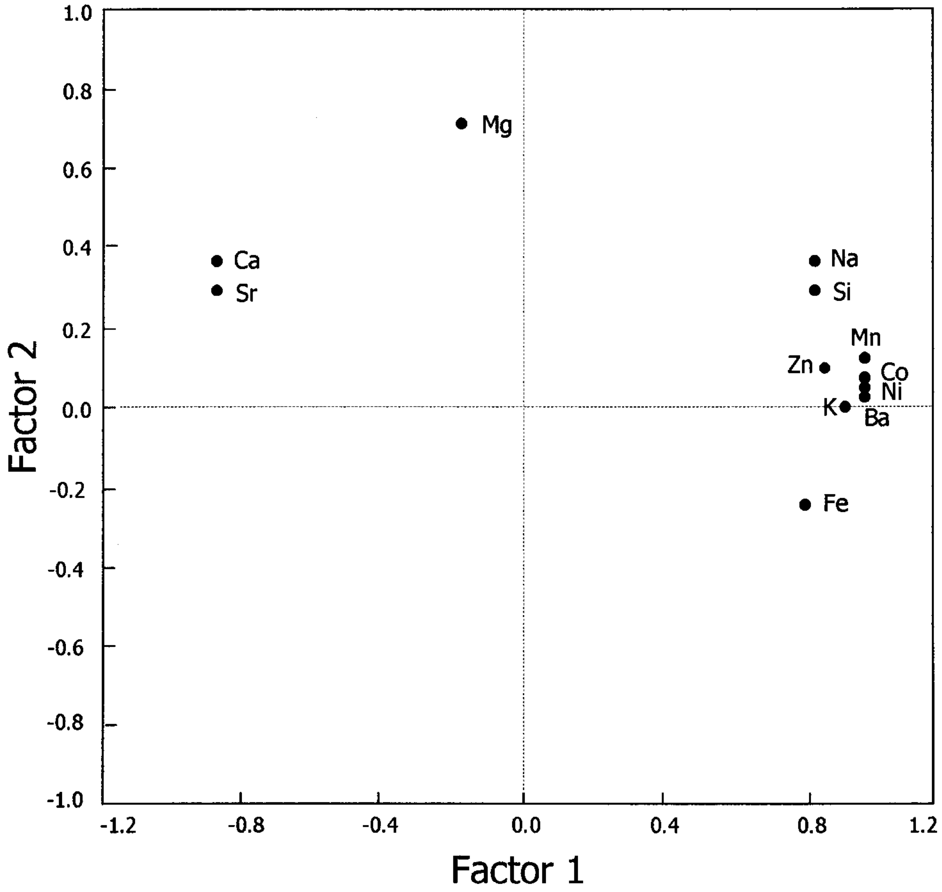

Figure 2. Principle component factor analysis association of different elements with respect to factor 1 and 2.

Chernoff face analysis is used to interpret visually the extent of pollution at different stations. Chernoff diagram is designed using caricatures of human face to represent multivariate data. Chernoff face diagram is contrived using the contamination factors for Co, Ni, Zn, Ba, Mn, Sr and Fe as well as the Pollution Load Index of these metals. PLI is used for the mouth smile. It is clear from the diagram (Figure 4), that Mex bay is the most contaminated area, while some stations at zone B is also highly contaminated with metals.

The tree diagram for the 18 stations is constructed to shows the similarities between the different stations as well as to confirm the results obtained from Charnoff analysis (Figure 5). Most of the samples from zone A are clustering together. Zone B and zone D are almost characterized by their higher contents of their metals contents. Zone E (Ref. Zone) is almost characterized by their low concentrations of different metals.

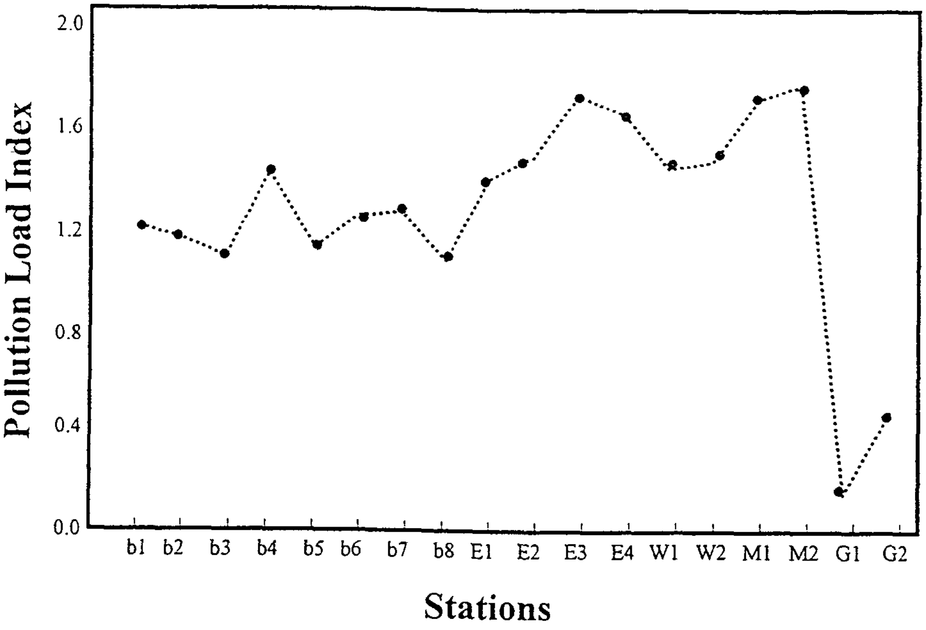

Figure 3. Pollution load index distribution at different stations.

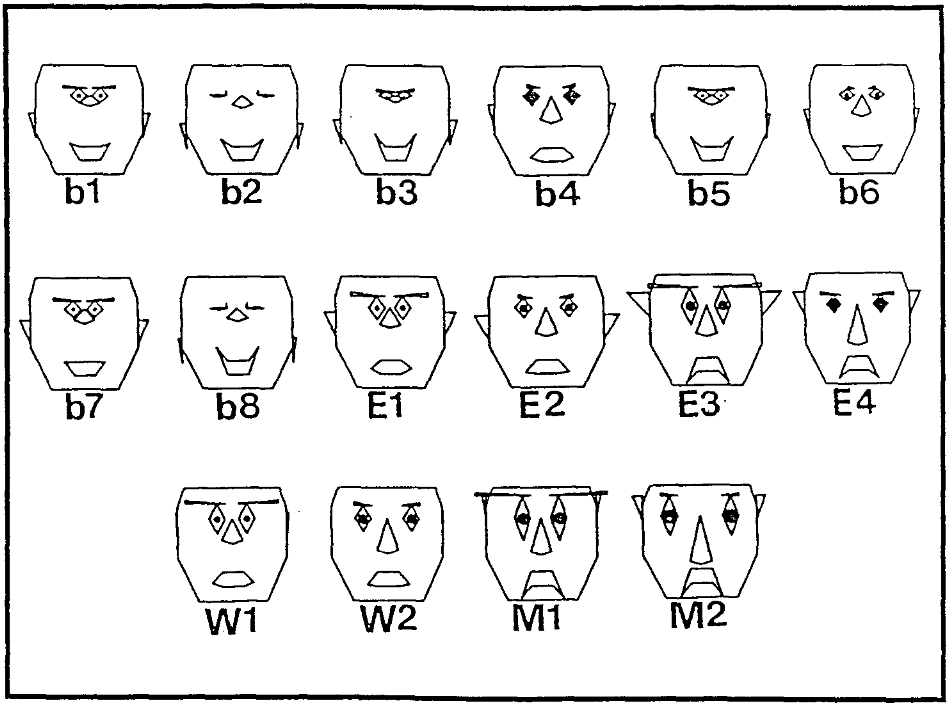

Figure 4. Chrenoff face analysis for the different stations.

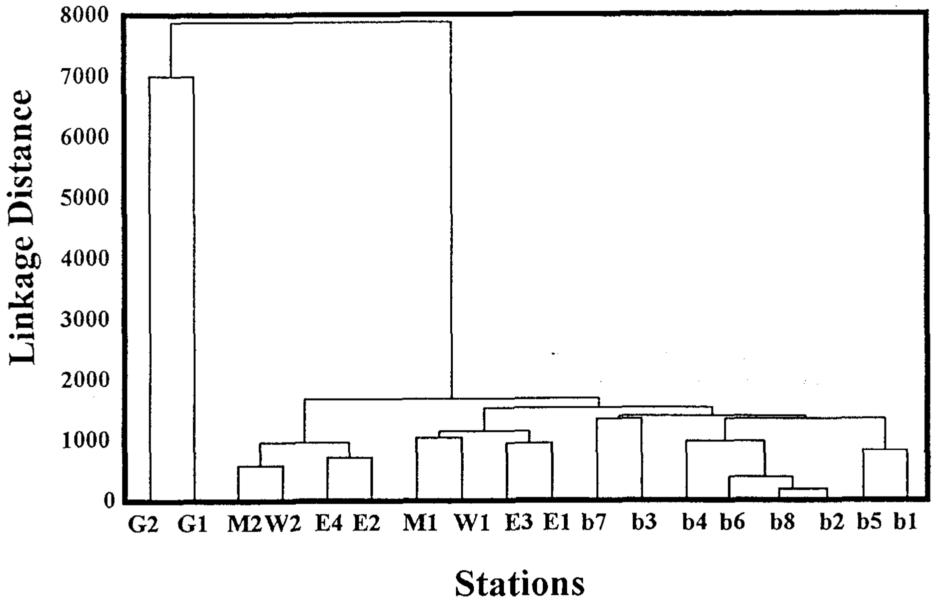

Figure 5. Tree diagram shows the similarities between stations.

It is concluded that, Pollution increases in the west direction. This area distinguishes by the extensive industrial activities. In general pollution extend in the study area is controlled by the sources and the enormity of the different pollutants.

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REFERENCES

Abdel-Maoti MAR, (1991) An input/output flux for lead in a coastal Bay off Alexandria region, Water Air Soil Pollut 59: 261-269.

El-Sammak AA, and Aboul-Kassim TA, (1998) Copper and Lead Concentrations in then sediments of Alexandria Region Southesatern Mediterranean, Egypt. Fresenius Enviro Bull 7(¾): 126-133.

El-Wakeel AK, El-Sayed MKh and Mahmoud BA, (1984) Particle size distribution in the nearshore sediments off Alexandria, Egypt. J Fac Mar Sci King Abdulaziz Univ 4: 99-111.

Martin, JM, Nirel P, and Thomas, AJ, (1987) Sequential extraction techniques: Problems and Problems. Mar Chem 22: 313-341.

Milliman JD, (1974) Marine Carbonate, Springer-Verlag. 375pp.

Nasr SM, (1995) Geochemistry and granulometric normalization for heavy metals in te bottom sediments off Alexandria, Egypt. Proceedings of the second Conference on the Mediterranean coastal environment. MEDCOAST 95, Tarragona Spain. 1473-1481.

Salomons W, Förstner U, (1984). Metals in the hydrocycle. Springer-Verlage, :63-98.

Rock NMS, (1988). Numerical geology. Lecture Notes in Earth sceinces, XI. Springer-Verlag, 427pp.