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Enrichment of Zinc, Copper, Lead and Nickel in Bottom Sediments from three Environmentally Different Regions off Alexandria, Egypt

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Abstract

Bottom sediment samples from different regions off Alexandria (Sidi Krir, Eastern Harbor and Abu Qir bay) were collected in summer 2009. These samples are characterized by different environment settings and are subjected to pollution from different sources. Concentrations of selected heavy metals (Fe, Cu, Zn, Pb & Ni), grain size analysis, organic matter and carbonate contents were determined. An assessment of the present status of the studied regions was carried out by calculating the enrichment factors (EF), of such metals, using the background concentration level as a base. The results revealed that the Eastern Harbor represents the highest degree of enrichment followed by Abu Qir Bay and Sidi Krir. The high enrichment factors in the Eastern Harbor sediments may be attributed to the consequences of long residence times and the effluent that may accumulate over time, entailing the semi-enclosed basin to have high concentrations of pollutants compared to the more open areas Sidi Krir and Abu Qir Bay. The results of factor analysis showed that, both mean grain size and organic matter are the main controlling factors behind the metal enrichment in sediments.

Key word: heavy metals; sediments; enrichment; Sidi Krir; Abu Qir; Eastern Harbor

1. Introduction

Heavy metals are particular concern worldwide, due to their environmental persistence and biogeochemical and ecological risks (Liu *et al.*, 2003). Marine sediments have often been regarded as the ultimate reservoir for heavy metals in the coastal environment (Sin *et al.*, 2001; Santos *et al.*, 2005); however, if the equilibrium between marine sediments and the overlying water body is broken, marine sediments would transfer most pollutants into sea-water (Valdés *et al.*, 2005). As metal concentration in marine sediments increases, more heavy metals will return to water bodies via chemical and biological processes (Sin *et al.*, 2001). Therefore, heavy metals are one of the serious pollutants due to their toxicity, persistence and non-degradability in the environment (Fang and Hong, 1999; Klavins *et al.*, 2000; Tam and Wong, 2000; Yuan *et al.*, 2004). It derived from natural inputs and anthropogenic emissions, such as parent rock weathering, industrial wastewater, transportation, agriculture and climate (Morillo *et al.*, 2004; El Nemir *et al.*, 2006; Luo *et al.*, 2006).

Accumulation of heavy metals in sediments, even when present in low concentrations in the overlying water column, is dependant on various factors such as the nature of the sediment particles, the properties of the adsorbed compounds and the prevailing physicochemical conditions. Sediments show a great capacity to accumulate and integrate heavy metals and organic pollutants even from low concentrations in the overlying water column (El-Nemr *et al.*, 2007; Tam and wong, 2000).

Since natural and anthropogenic material simultaneously accumulate in sediments, it is difficult to identify the proportion of each source. The problem is exaggerated by the magnitude of the variation in the loading of elements originating from these two sources, as well as, the interaction of elements with sediment grain size, mineralogy and organic carbon content. Several granulometric and geochemical procedures have been developed to compensate for such influences. One procedure involves normalization of metal data to the different size fractions of sediment (e.g. Luoma and Bryan, 1981; Szefer *et al.*, 1995). The obtained information is incomplete because the procedure requires separation steps and therefore does not reveal the bulk element composition of the sediment (Soto-Jiménez and Páez-Osuna, 2001). Geochemical procedures, on the other hand, include normalization in relation to a conservative element such as aluminum (Bruland *et al.*, 1974, Martin and Meybeck, 1979; Windom *et al.*, 1989), iron (Szefer, 1990; Herut *et al.*, 1993; Tam and Yao, 1998), rubidium (Grant and Middleton, 1990) and lithium (Loring, 1990). A normalization procedure is based on the fact that the proportions of a metal in relation to a conservative element are relatively constant in crust (Schropp *et al.*, 1990).

The present study aims at determining the enrichment factors of zinc, copper, lead and nickel in sediment from three environmentally different regions off Alexandria coast. The first region is Sidi Krir, west of Alexandria where the nearshore area is an open-marine environment and is apparently not subjected to direct anthropogenic discharges. The second area is the Eastern Harbor which is semi-enclosed basin and it is subjected to sewage disposal both from land and from boats and vessels. The last region is Abu Qir Bay which is an open semi-circular basin and is exposed to regular discharges of effluents from domestic, industry and shipping activities. Apparently, Abu Qir Bay is expected to be the most polluted region as a result of the diverse effect of effluents from the land-based sources. The Eastern Harbour comes next where its semi-enclosed nature favors trapping of wastes. The enrichment factor for each metal will be computed by normalizing the values of metal concentrations using iron as a conservative metal. In addition, the statistical factor analysis technique will be applied to interpret the major controls influencing the spatial distribution behind the variation of enrichment factors.

2. Area of study

The areas under investigation are:

(1) **Sidi Krir,** which is located at the western coast of Alexandria, is a typical carbonate province with an open-coast environment. It lies between Latitudes 31.05˚ and 31.09˚ N and Longitudes 29.58˚ and 29.70˚E (Figure 1). The nearshore bottom has relatively gentle gradients, whereas, the offshore bottom is very steep with very narrow or missing continental shelf. The shore is mostly sandy, with a relatively wider beach. This area is undergoing both erosion and depostion. The Arab Petroleum pipe Company (SUMED) has constructed a curved jetty at Sidi Krir, about 40 Km to the west of Alexandria. The port is used to anchor small vessels serving the offshore oil tankers. The crude oil delivered to the Mediterranean Sea from the Gulf of Suez (via Trans-Egypt pipelines) is pumped to the storage tanks, and subsequently delivered to tankers through offshore oil terminals (Frihy, 2001).

(2) **Eastern Harbor (EH)** where the sediments characteristics reflect the case of being a transitional boundary between the western province and the Nile Delta province (Warne and Stanley, 1993). It is a shallow, semi-enclosed embayment covering an area of about 2.53 km^2, and it is situated between Longitudes 29˚53' and 29˚54' E and Latitudes 31˚12' and 31˚13' N (Figure 1). The harbor is connected to the Mediterranean Sea through two openings called El-Boughaz and El-Silsilla. The bottom slopes gradually from coastline towards the center of the harbor behind the main opening. The overall average depth of the harbor is about 6.5 m. The southern part of the harbor has been reinforced by concrete blocks while, the northern side is protected by man-made wavebreaker. It is bordered to the east by El-Silsila headland and to the northwest by a long causeway (El-Sayed and Khadr, 1999). The harbor is mainly affected by the municipal disposals of the central part of Alexandria city, which is pumped into the Mediterranean Sea. The main sewage source is Kayet Bay pumping plant. In addition to that, it is mainly affected by several kinds of human activities including fishing, yacht sport, land-based effluents, and boat building workshops, recreation and sailing boats anchoring inside the harbor. The Eastern Harbor received daily an amount of 96383 m^3 of unprocessed sewage (El-Rayis *et al.*, 1996).

(3) **Abu Qir Bay** is a shallow (mean depth 6 m) semi-circular basin, lying about 36 km east of Alexandria city. It is located between Longitudes 30º5' and 30º22' E and Latitudes 31º20' and 31º29' N (Figure 1). The area of the bay is about 360 km^2 with shoreline of about 50 km long. Three main sources dispose their effluents into the bay these are; Tabia pumping station which pumps an average of about 1.5–2.0 million m^3/d, El-Amya Drain at the west which collects mixed industrial and agricultural wastewaters; Maadia outlet (about 2.0 million m^3/d) mainly agricultural drainage water; and Rosetta mouth at the extreme eastern edge where an amount of about 1.2 million m^3/d of river water (Faragallah, 2004). As well as from the other widespread land-based activities, particularly the food, fertilizer, dyes, weaving, chemical and paper manufacturing industries which are concentrated along the bay coast particularly at the south-western part of it.

3. Materials and methods

In summer 2009, bottom sediment samples from Sidi Krir (n = 11); Eastern Harbor (n= 12); and Abu Qir bay (n= 10) (Figure 1) were collected using an Ekman grab sampler. In the laboratory, samples were stored in polypropylene centrifuge tubes and kept in the freezer at (-20°C) prior processing and analysis. Each of the sediment samples was frozen, dried, then ground with a pestle and mortar and sieved to pass the 63µm mesh sieve.

For the total heavy metal concentrations, the powder sediment samples are digested in closed Teflon vessels with mixture of concentrated HNO_3, HF and $HClO_4$ (3: 2: 1 v/v) following the method of Oregioni and Aston (1984). The concentration of metals in extract was measured using Flame-Atomic Absorption Spectrophotometer (FAAS, Shimadzo 6800, with Autosampler 6100). All reagents used, were of analytical reagent grade (Merck, Germany). All laboratory equipments and containers were washed in 10% HNO_3 solutions and rinsed with deionized water prior each use. The precision of the technique was tested by replication analysis of the studied metals. The data revealed that the standard errors were 7.52, 7.9, 8.96 and 6.5% for Cu, Zn, Pb and Ni, respectively.

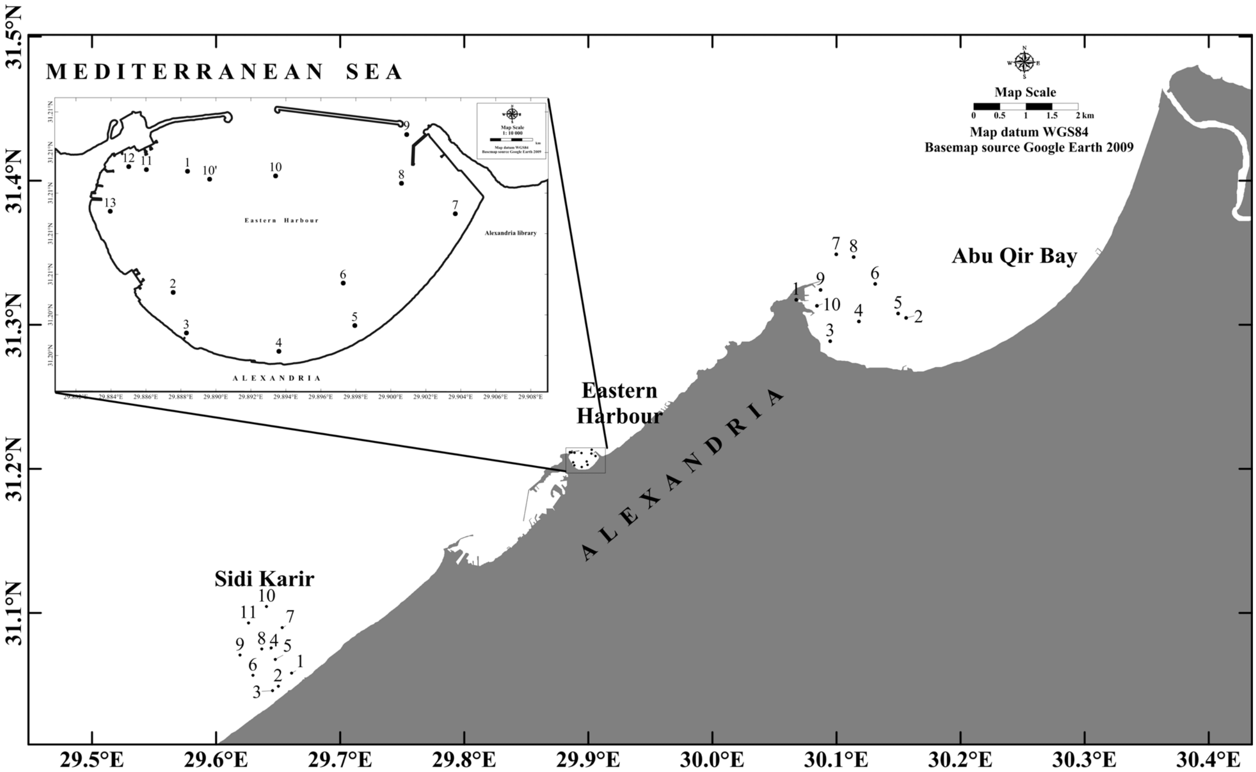


Figure 1. The study areas, Sidi Krir, Eastern Harbour and Abu Qir Bay.

The organic carbon content determined using H_2O_2. About 500 mg of dry sample was weighted in clean dry beaker to which 10 ml H_2O_2 was added and heated to about 100º C, then dried in an oven at 105º C and reweighed until constant weight.

Total carbonates were estimated as described by Molnia (1974). Particle size was carried out according to the standard sedimentological method as described in Folk (1974).

4. Data analysis (R-mode factor analysis)

In the present study, the raw data were classified objectively using factor analysis. The purpose of factor analysis is to reduce the complexity within the similarity matrix of a multivariate data collection, transforming it into a simpler and more easily interpreted factor matrix. The factor analysis technique was applied following the procedure mentioned by Davis (1973) and Jöreskog *et al*. (1978). In the present study two factors have been extracted, since two factors had eigenvalues greater than or equal to one. Since the principal components method has been selected, the initial communality estimates have been set to assume that all of the variability in the data is due to those two common factors.

5. Results and discussion

5.1. Sediment Types

The grain size data revealed that the sediments in Sidi Krir region is composed of different types of sand sized sediments (coarse, medium, fine, very fine). Figure (2) showed that the sediment mean size increases from west to east in the direction of the current regime in the area and stations 4, 5 and 8 which dominated by coarse fraction. The mean size (MzΦ) ranges between 0.23 and 3.18 Φ. The sorting of sediments varies from moderately to moderately well sorted. Pettijohn (1975) noticed that, sorting is dependent on the grain size, in that, coarse sediments (gravels and conglomerates) and fine sediments (silt and clay) are generally more poorly sorted than sand-sized sediments, which are more easily transported and sorted by wind and water.

The mean size (MzΦ) in Eastern harbor ranges from 0.19 to 5.32 Φ. It was found that, the majority of sediments covering the bottom are sand (fine, medium, coarse). The distribution map of bottom sediments based on the mean size (Figure 2) reveals that medium and fine sand fractions are dominant in the western side, while the coarse fractions is restricted to the eastern side. The differences in grain size distribution can be

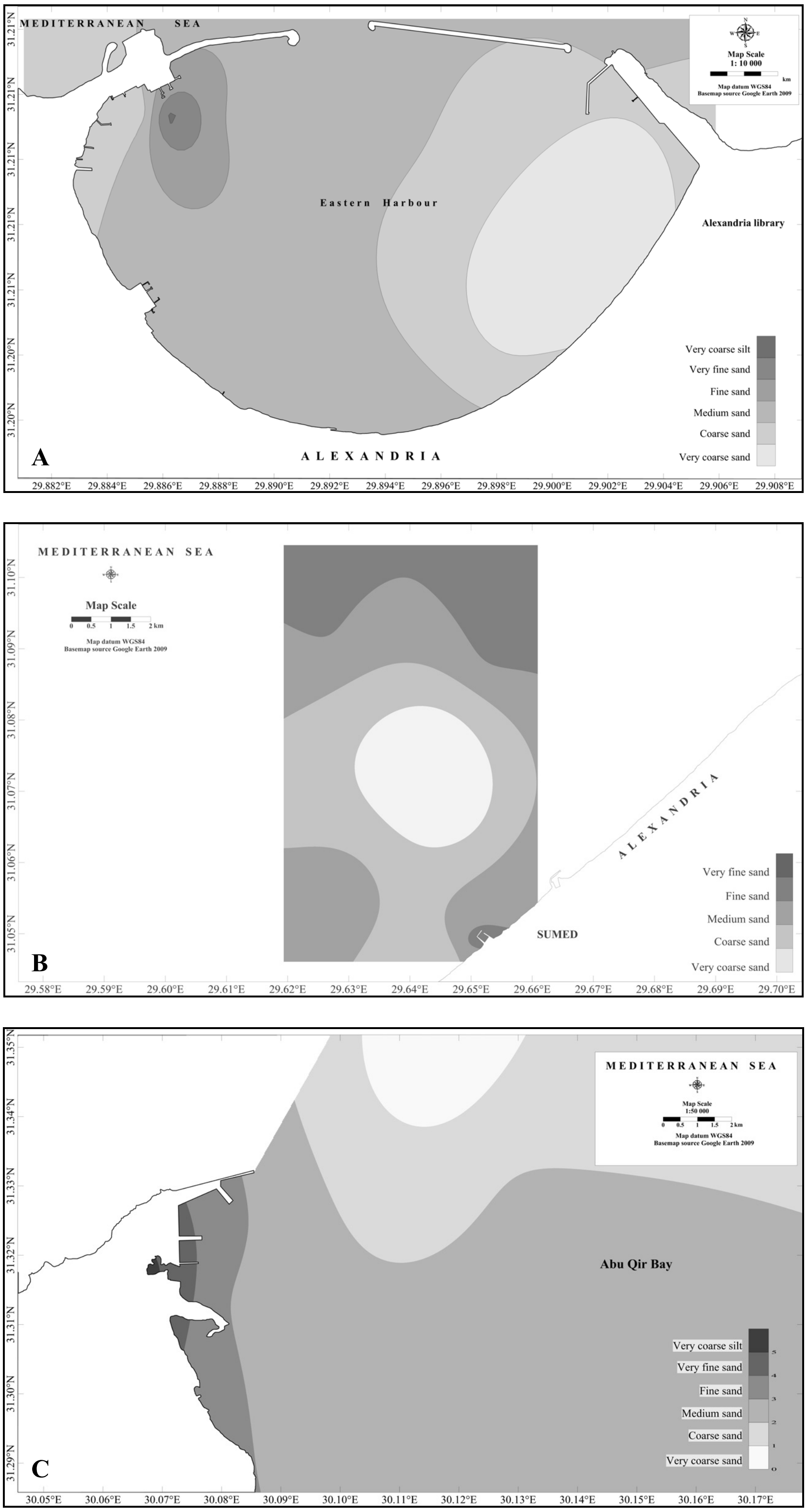


Figure 2. The sediment type distribution in the Eastern Harbour A (upper map), Sidi Krir B (middle map) and Abu Qir bay C (lower map).

attributed to the bottom configuration and dominant current regime of the EH. El-Sayed *et al.* (1980) concluded that the current regime generated during gales, is directed from the open sea through El-Boughaz and then flows counter clockwise to reach the sea again through the other El-Silsilla outlet. Stanley *et al.* (2006) suggested that, human activity in nearshore and port settings has triggered sediment deformation and construction failure.

The inclusive standard deviation (sorting) varies from 0.71 to 1.8. The sediments are generally moderately (42%) to poorly (58%) sorted. Folk (1974) suggested that the main factors controlling sorting are: i) size range of material supplied to environments, ii) type of deposition and iii) current characteristics.

The inclusive graphic mean size in Abu Qir Bay ranges from 1.31 and 5.35 Φ. As shown in Figure (2) the bottom sediments are covered mainly by sand fraction (fine, medium and coarse) except station 1 was covered by medium silt sediments. The sediment is generally moderately to poorly-sorted.

5.2. Organic Matter

The organic matter content in Sidi Krir region ranges from 1.33 to 2.69%. The low organic matter in sediment is due to the decrease in bioactivity and the good aeration of bottom sediments where most of the deposited organic matter are oxidized and washed out. The distribution map (Figure 3) reveals that organic matter content decrease seaward. The maximum value recorded at station 5 which may be due to the presence of amounts of *Posidonia oceanica* mixed with the sediment.

The organic matter content of EH varies between 2.74 and 17.59%. The distribution map (Figure 3) of organic matter shows that the majority part of the study area has values lesser than 4. The high value is restricted to station 11 which affected by domestic wastes from the ships and relatively fine sediments content (mean size 5.22 Φ). Station 1 also has a high value of organic matter (6.3%) due to organic particles disposed with domestic sewage from Kayet Bay pumping station.

The horizontal distribution (Figure 3) of organic matter in bottom sediments of Abu Qir Bay shows presence of high concentration (17.5%) recorded at station 1 (Abu Qir harbor) which is affected by the deposal and wastes of the ships. Also, station 3 has high value of organic matter (5.06%) that reflecting a high rate of organic matter accumulation from drainage water of Tabia outlet. The values of organic matter decrease to value lesser than 2% for the rest of sediments of Abu Qir Bay.

5.3. Total Carbonate

Generally, the total carbonate content in Sidi Krir region is very high varying between 91.4 and 97.5%. The environmental conditions are more suitable for the growth of calcareous organisms. The shells of these organisms are incorporated into the sediments after their death.

In the present study, the values of total carbonate for eastern harbor sediments vary from 73.0 to 92.2% (Figure 4). The major parts of sediments in EH have more than 80% of total carbonate. The enrichment of eastern harbor with carbonate content can be attributed to two factors, the eroded carbonate-rich coastal materials and the mixing of sediment with shell fragments of gastropods, lamellibranches and calcareous debris (El-Wakeel and El-Sayed, 1978).

The carbonate content of Abu Qir Bay ranges between 10.1 and 67.8 %. The high concentration at the west side of the Abu Qir Bay refers to the presence of carbonate grains derived mostly from the carbonate-rich province on the shelf west of Alexandria (El-Sammak, 1987).

5.4. Heavy metals

Table 1 shows the mean concentration, standard deviation, minimum and maximum values of the measured metals in sediments and ERL (Effects-Range Low) and ERM (Effects-Range Median) reported by Long and Morgan (1990) and Long *et al*. (1995).

The concentrations of Cu, Zn, Pb, Ni and Fe in bottom sediments of Sidi Krir region range from 2.56 to 8.43µg/g; 10.71 to 57µg/g; 13.95 to 120.17µg/g, 1.9 to 3.05µg/g, and 149.86 and 681.13 µg/g respectively. The sediments of station 2 are more enriched with Cu, Zn and Pb. The sources might be the crude oil and the water ballast discharges (known to be rich in lead) due to the shipping activities by SUMED Company. Guerra-García and García-Gómez (2005) concluded that the trace metals Cu, Zn and Pb are used in the construction of water pipelines and other pipes, tanks and reservoirs. Cu is also used for anti-corrosion in these pipelines. These metals may dissolve and become incorporate in the urban sewage. Also, the high concentration of Zn can be attributed to increase of man's activities and the domestic sewage from the tourist village.

The metal concentrations were compared to the effect range low (ERL) and effect range median (ERM) (Long *et al.*, 1995) to evaluate the metal pollution status.

The concentrations of metals may be considered as toxic to biota obtained from a biological effects database (Long & Morgan, 1990; Long *et al.*, 1995), which is referred as affect range-low (ERL) according to Table 1.

The Cu, Zn and Ni concentrations in the current study for Sidi Krir never exceeded the ERL value, which indicates that, there is no adverse effect on the benthic marine community in the investigated area. While, all stations experience Pb concentrations are lower than ERL except stations 2 and 10 which recorded values higher than ERL but still much lower than ERM revealing that there is no adverse effect on the biota on almost all stations in the study area.

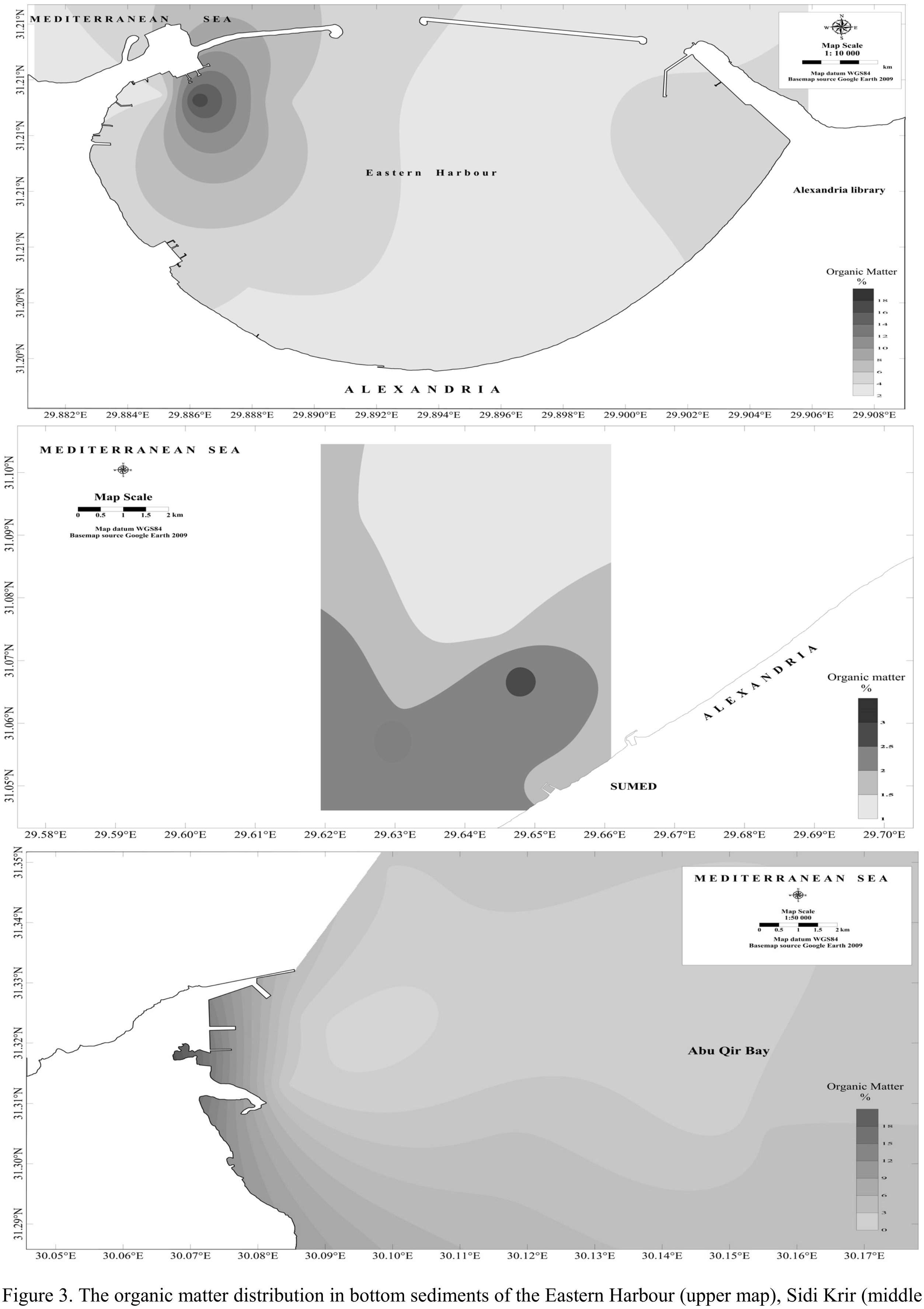


Figure 3. The organic matter distribution in bottom sediments of the Eastern Harbour (upper map), Sidi Krir (middle map) and Abu Qir Bay (lower map).

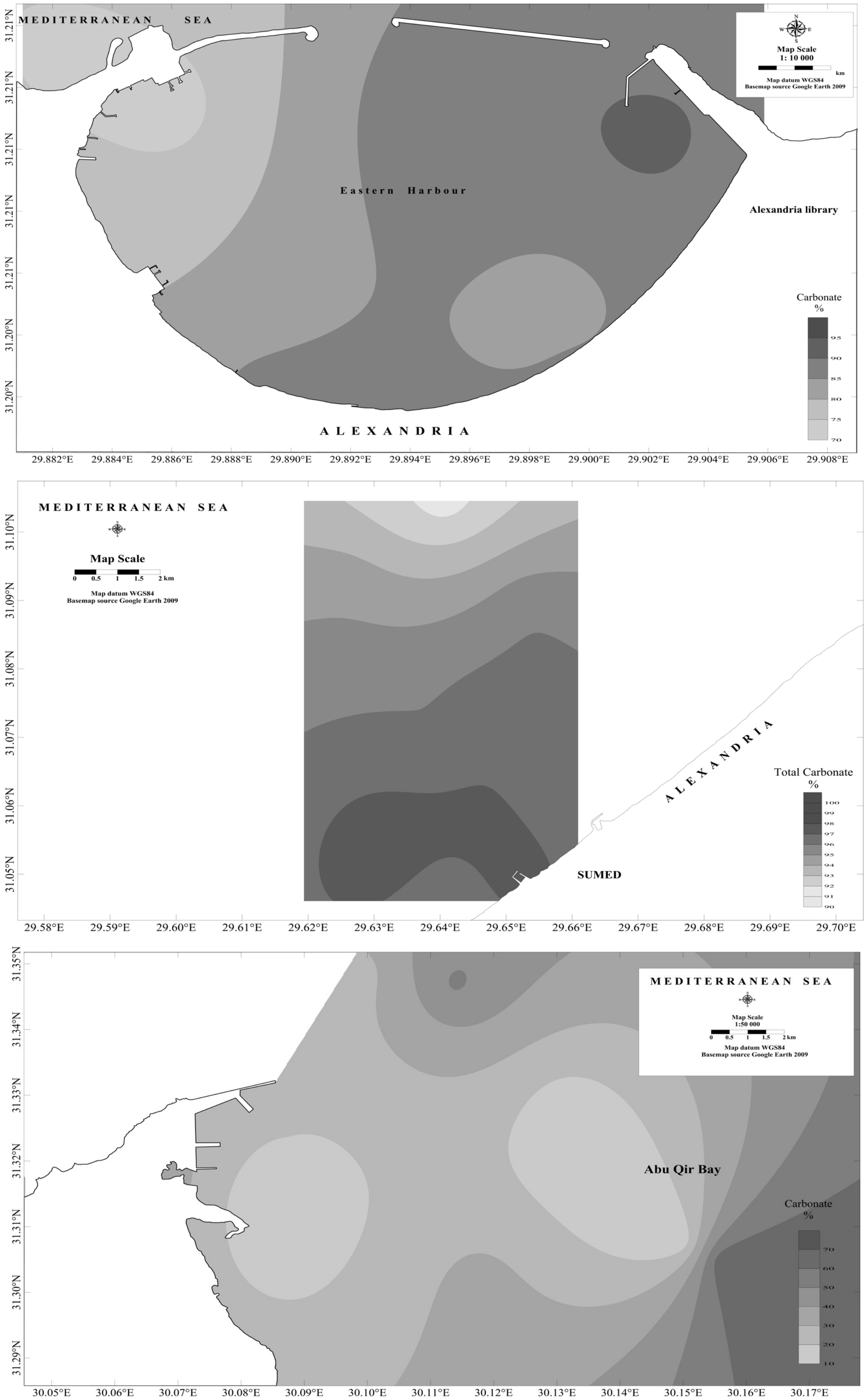


Figure 4. The total carbonate distribution in bottom sediments of the Eastern Harbour (upper map), Sidi Krir (middle map) and Abu Qir Bay (lower map).

Table 1. Minimum, maximum and average concentration of studied metals in the different three regions.

Location		Fe	Cu	Zn	Pb	Ni
Sidi Krir	Minimum	150	2.56	10.71	13.95	1.90
	Maximum	2085	8.43	57.00	120.17	3.05
	Mean	681	4.62	25.33	35.40	2.46
	Standard deviation	643	2.50	18.22	35.98	0.44
Eastern Harbor	Minimum	587	6.79	33.12	22.68	1.30
	Maximum	3754	114.53	337.30	96.77	10.50
	Mean	1582	40.05	102.74	50.69	5.40
	Standard deviation	1042	36.04	80.03	26.15	2.94
Abu-Qir	Minimum	741	3.04	13.64	18.42	3.26
	Maximum	38081	506.41	607.43	264.64	32.76
	Mean	6990	57.73	100.02	50.11	11.37
	Standard deviation	11200	157.80	181.66	75.81	10.03
	ERL	NM	34	150	46.7	20.9
	ERM	NM	270	410	218	51.6

The total concentrations of the four metals in the Eastern Harbor sediment samples are in the ranges from: Cu 6.79 to 114.53µg/g, Zn 33.12 to 337.3µg/g, Pb 22.68 to 96.77µg/g, Ni 1.3 to 10.5µg/g and Fe 587.15 to 3753.53µg/g, respectively (Table 1).

It is obvious that, the sediments of station 1, 11 and 12 are more enriched by Cu and Zn, while Pb exhibits the highest concentration at station 12. This could be attributed to the potential contamination could be mainly derived from the shipping activities and the sewage disposal (Kayet Bay Drain). Another source of heavy metal is the antifouling paints which are used to protect the underwater parts of the vessels and yachts from the development of fouling organisms such as algae and barnacles and are based on organic solvents mixed with highly concentrated toxic metals such as Cu and Zn (Orlic and Tang, 1999).

The concentrations of Zn and Ni in the sediment samples never exceed the ERL which indicate that there is no adverse effect on the marine organisms living in this area. While the concentrations of Pb and Cu are about 50% and 35% respectively in sediment samples that between ERL and ERM, which indicate possible detrimental effects to benthic organisms.

The concentrations of Cu, Zn, Pb, Ni and Fe in bottom sediments of Abu Qir bay range from 3.04 to 506.41 µg/g, 13.64 to 607.43 µg/g, 18.42 to 264.64 µg/g, 3.26 to 32.76 µg/g and 741 to 38081 µg/g respectively. The range 3000-40820 µg/g of Fe is found in some unpolluted areas (Santamaria-Fernandez *et al.,* 2005), while polluted regions are of higher values in range 51000-116000 µg/g (Buykx *et al.,* 2000). Comparing these studies with the present study, one can easily find that our samples are considered unpolluted with iron. In general the high concentrations of heavy metals recorded at station 1 are affected by the deposal and wastes of the ships. Also, highest levels of heavy metals were detected in sediments of station 3 is affected by Tabia pumping station, since it discharges about 2×10^6 m^3 /day from fertilizer industry, textile manufacturing, paper industry and food processing and canning industry.

All stations in the present study show Cu, Zn and Pb concentrations are lower than ERL except station 1 which shows values higher than ERM of Long and Morgan (1990) and Long *et al.* (1995), suggesting that it is deemed detrimental to benthic organisms.

The Ni content for all stations does not exceeded the ERL value except station 1 which exceeded the ERL but still much lower than ERM indicating that this particular region is uncontaminated by Ni.

5.5. Enrichment factor (EF)

Enrichment factor is a good tool to differentiate the metal source between anthropogenic and naturally occurring (Morillo *et al*., 2004; Selvaraj *et al*., 2004; Adamo *et al*., 2005; Vald'es *et al*., 2005; Chen *et al.*, 2007) and it is used as the main index for assessing the extent of the contamination (Chen *et al*., 2007). To assess the enrichment or depletion of trace elements in sediment sample, trace element concentrations can be normalized to an element which is conservative with respect to chemical weathering and which has no significant anthropogenic source. Generally Al or Fe is selected as a normalizing parameter because they are lithophilic elements originating from the soil (Kontas, 2008). Iron was used as a reference element in this study because its presence in marine environment is related to the presence of the other metals.

According to Ergin *et al*. (1991) the metal enrichment factor (EF) is defined as:

$$EF = (Me/Fe)_{sample} / (Me/Fe)_{Back\ ground}$$

Where $(Me/Fe)_{sample}$ is the metal to Fe ratio in the samples of interest;

$(Me/Fe)_{Back\ ground}$ is the natural background value of metal to Fe ratio. In the present work the background values have been taken equal to metal concentrations of west Alexandria coast sediments according to Rifaat and Deghedy (1996); and from the Egyptian Mediterranean continental shelf (Rifaat, 2005).

Birth (2003) suggested that EF < 1 indicates no enrichment, EF < 3 is minor enrichment, EF = 3–5 is moderate enrichment, EF = 5–10 is moderately severe enrichment, EF = 10–25 is severe enrichment, EF = 25–50 is very severe enrichment, and EF > 50 is extremely severe enrichment.

As shown in Table (2), all stations of Sidi Krir region have Cu and Ni enrichment factor are lesser than 1 and fall in the group of elements without enrichment. The Pb and Zn element fluctuated between the group of minor and moderate enrichment.

The combination of normalization techniques confirms that most of the metals are mainly of natural origin, with the exception of some local anomalies which directly associated with petrol from SUMED Company.

Sediments of Eastern Harbor show high degree of metal contamination with EF values (average 32.75 for Cu, 64.17 for Zn, 143.37 for Pb and 3.81 for Ni; Table 2). Pb has the highest EF values among the three studied regions. The EF values for Pb were larger than 50 which indicate the high degree of Pb contamination. Zn has the second highest EF values, while Cu has the third highest EF values. Ni exhibits the lowest EF values among metals studied.

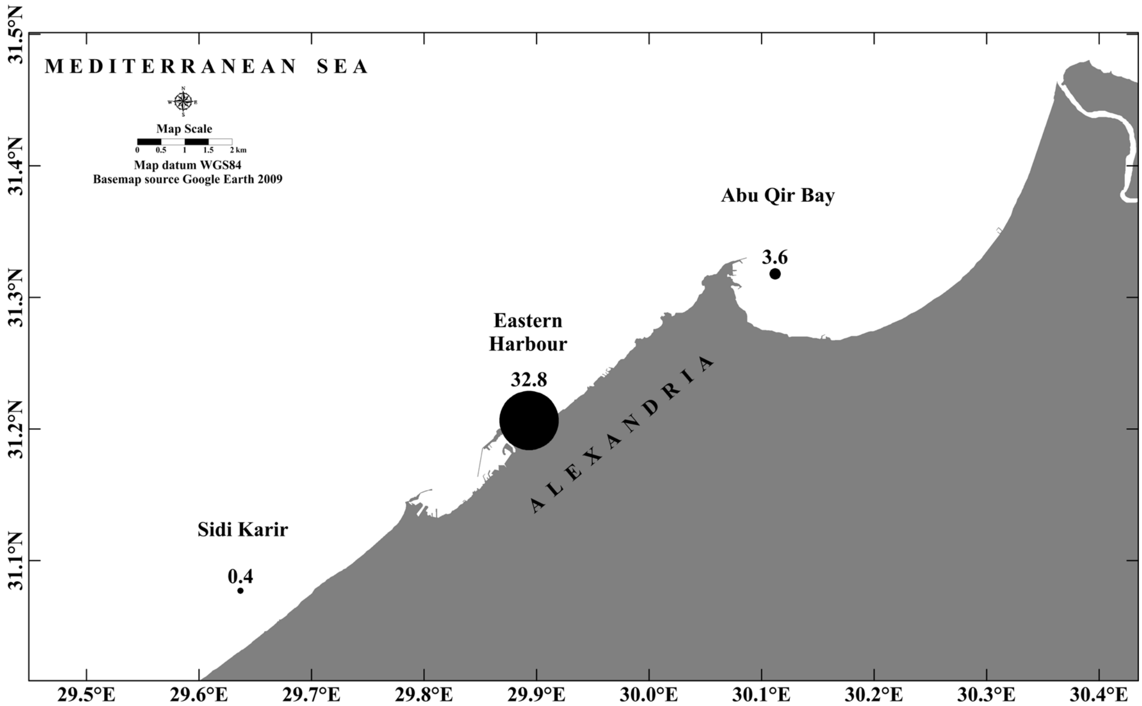
The results of EF in Abu Qir Bay region show that EF (Cu) range from 1.22 to 12.12, EF (Zn) from 3.45 to 30.54; EF (Pb) from 11.42 to 245.27 and EF (Ni) 0.67 to 2.37. From Table (2), it is clear that EF of Pb and Zn is greater than 5 indicating a significant contamination in the study region. In contrast, enrichment factor of Ni is less than 3, suggesting that Ni contamination is not a problem at present.

Finally, the results of normalization routines show that, the sediments of Eastern Harbor region have the highest degree of enrichment values among the studied metals (Figures 5 and 6). It is clear that, Abu Qir Bay comes in the second order of enrichment, while in Sidi Krir region the sediments show the lowest enrichment values. While the high enrichment values in the Eastern Harbor are due to anthropogenic wastes from land-based source and ships' disposals. On the other hand, Abu Qir Bay receives direct inputs from the coastal urban areas (Abu Qir, Edku and Rashid towns), as well as, from the other widespread land-based activities, particularly the food processing industry, fertilizer, dyes, weaving, chemical and paper manufacturing industries. The higher enrichment values of pollutants in the Eastern Harbor compared to Abu Qir and Sidi Krir may be attributed to the consequences of long residence times and the effluent that may accumulate over time, entailing the semi-enclosed basin to have high concentrations of pollutants compared to the more open areas (Parnell, 2003).

The results of factor analysis are shown in Table (3) and Figure 7. It shows that, both mean grain size and the organic matter are important factors affecting the metals enrichment in sediments.

Table 2. Enrichment factor (EF) of metals concentration in sediments collected from different three regions.

St. No.	Sidi Krir				Eastern Harbor				Abu-Qir bay			
	Cu	Zn	Pb	Ni	Cu	Zn	Pb	Ni	Cu	Zn	Pb	Ni
1	0.66	3.37	6.69	0.53	126.07	280.77	145.12	11.03	12.23	9.90	25.68	0.67
2	0.28	2.14	10.04	ND	9.92	13.84	88.79	1.99	2.60	7.88	91.88	2.37
3	0.40	2.06	8.76	0.38	37.30	116.01	144.32	2.17	2.94	8.40	11.01	1.73
4	0.22	1.96	7.48	0.19	49.74	66.78	179.70	4.46	1.43	3.46	13.60	1.46
5	0.24	0.70	3.01	0.09	5.33	12.40	83.93	1.67	1.30	3.86	22.77	1.53
6	0.37	1.67	10.51	0.26	6.84	72.03	96.62	1.05	2.61	8.79	57.16	2.09
7	0.68	4.44	8.83	0.64	22.92	29.70	193.52	ND	1.24	4.00	23.70	1.40
8	0.12	1.18	3.25	0.04	10.93	31.16	224.63	ND	8.30	30.69	236.51	ND
9	0.51	2.86	8.35	0.47	9.40	19.30	86.82	2.05	1.73	23.12	32.20	ND
10	0.27	1.95	4.03	ND	6.22	20.47	83.45	3.08	1.15	3.94	20.43	1.43
11	0.58	2.39	3.31	0.46	80.32	86.04	190.24	9.59				
12					28.06	21.47	95.26	1.01				
Average	**0.39**	**2.25**	**6.75**	**0.34**	**32.75**	**64.17**	**134.37**	**3.81**	**3.55**	**10.40**	**53.49**	**1.59**



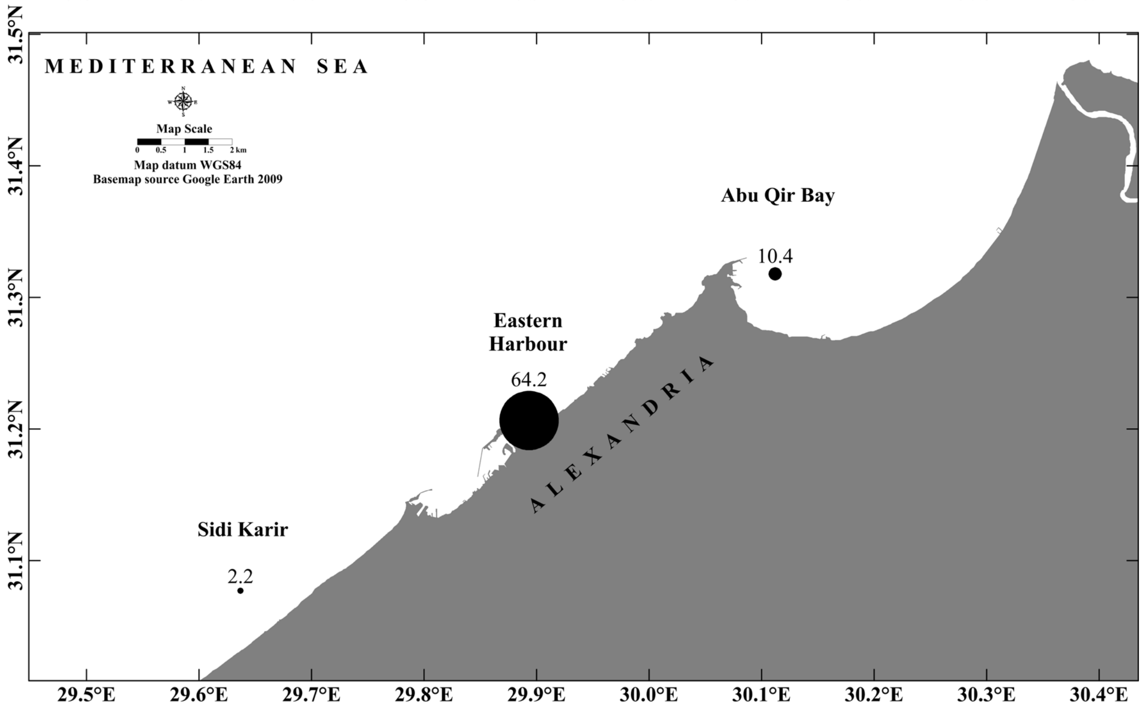


Figure 5: Enrichment factors of copper and zinc in bottom sediment of the studied regions (circles sizes represent average values of EF, average values of EF are shown above the circles).

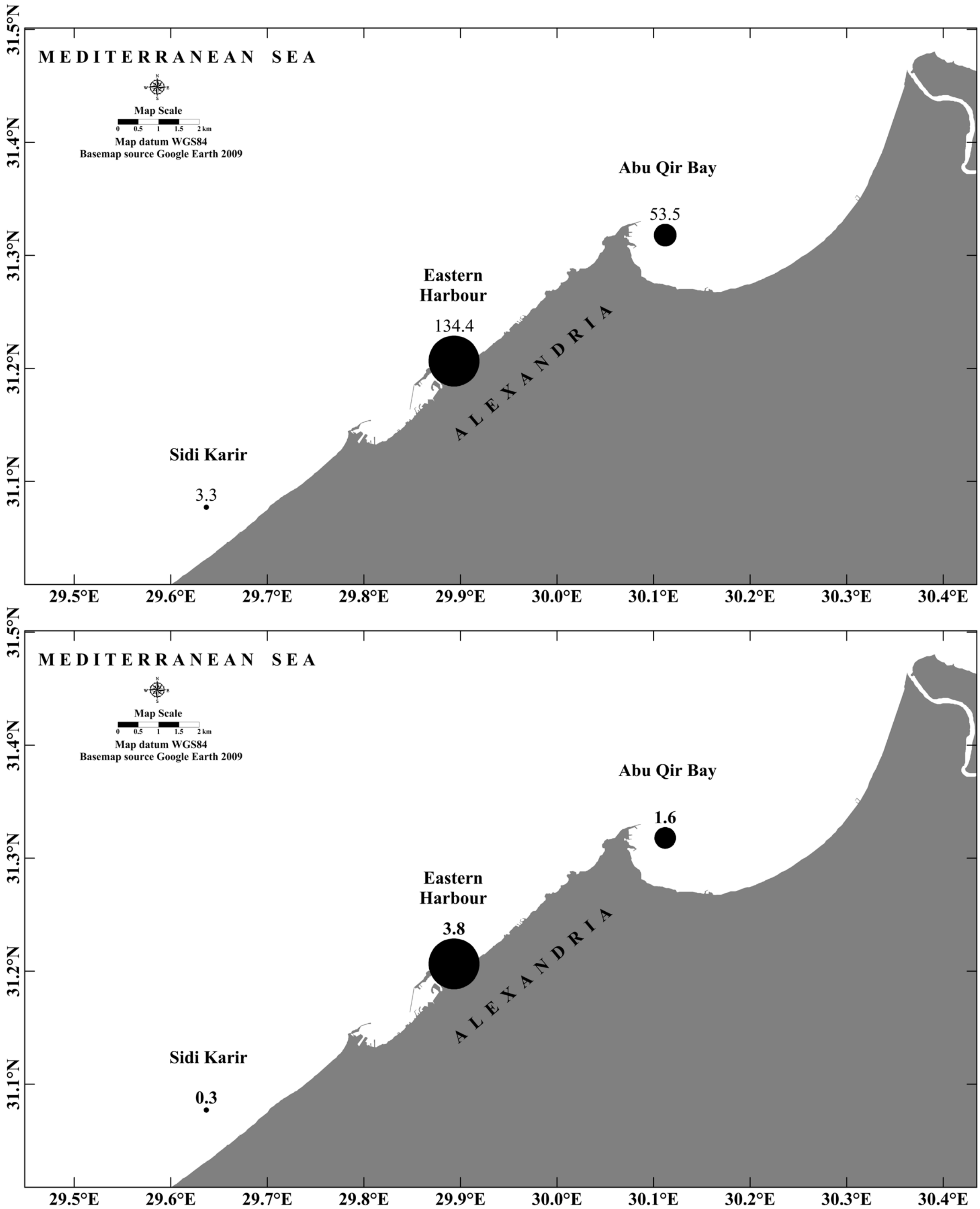


Figure 6. Enrichment factors of lead and nickel in bottom sediment of the studied regions (circles sizes represent average values of EF, average values of EF are shown above the circles).

Factor 1

Statistically, this factor accounts for about 52.72% of the total variance among the variables. It is characterized by the association of organic matter, nickel, lead, zinc, and copper. It represents, an organic factor in which the organic carbon controls the other species and indicates either adsorption onto organic particles (Harding, Brown, 1976 and Arm-strong *et al*., 1976) and/or the formation of organo-metal complexes (Rashid, l97l).The association of organic carbon, and heavy metals has been noted by several authors and indicating the mutual affinities among those elements (Pezetta and Iskandar, 1975). This association may lead to conclude that these elements may act in a synergetic manner. The possible origin of this factor is the enrichment of some elements along with the sewage wastes (Harding, Brown, 1976 and El-Sayed *et al*., l980).

Factor 2

It accounts for about 19.48% of the total variance among variables and shows the association of organic matter, mean grain size of the sediment and its sorting degree. The inverse association is indicated by the negative loading on total carbonate. The relationship of organic matter and the size of the sediment are widely observed by many authors (Zhang *et al*., 2007 and Chen *et al*., 2007). Our data show that organic matter content increases with decreasing grain size of the sediment regardless of the sediment type and that the effect of sorting by natural processes such as washing out and transport plays an important role in this concern. The carbonate content acts as a dilutant (Figure 7) (Spencer *et al*., 1968).

Table 3. Varimax rotated factor analysis matrix for the measured parameters in the bottom sediments from Sidi Krir, Eastern Harbour and Abu Qir Bay.

Factor / Variable	Factor1	Factor2
TCO3	0.28	-0.62
OM	0.40	0.73
Mean	0.19	0.79
Sorting	0.35	0.64
Ni	0.89	0.29
Pb	0.83	0.13
Zn	0.93	0.02
Cu	0.96	0.20
Eigenvalue	4.22	1.56
Variance	52.72	19.48
Cumulative Percentage	52.72	72.20

Shaded cell = significant values

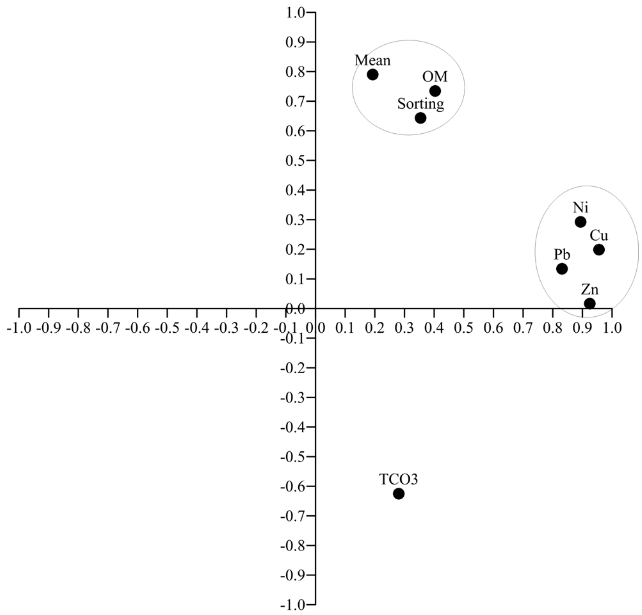


Figure 7. Plot of the varimax rotated factor matrix for the measured parameters in the bottom sediments from Sidi Krir, Eastern Harbour and Abu Qir Bay.

6. Conclusions

The metals-enrichment factor for the three studied regions reveals that the Eastern Harbor had the highest degree of enrichment followed by Abu Qir region then Sidi Krir. It seems that the nature of the region is the most affecting reason causing high values of the metals concentration in sediments. The high enrichment of the Eastern Harbor is due to the consequences of long residence times and the effluent that may accumulate over time, entailing the semi-enclosed basin to have high concentrations of pollutants compared to the more open areas Abu Qir bay and Sidi Krir. Furthermore, the results of factor analysis show that, both the sediment grain size and the organic matter are the controlling factors behind the spatial metal-enrichment distribution in sediments.

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إزدياد تركيزات كل من الزنك والنحاس والرصاص والنيكل فى رواسب القاع لثلاثة مناطق متباينة بيئيا مواجهة مدينة الإسكندرية ـ مصر

منى خميس خليل – أحمد السيد محمد رفعت

المعهد القومى لعلوم البحار و المصايد – الإسكندرية

تم جمع عينات للرواسب القاعية في صيف 2009 من ثلاث مناطق هي المنطقة البحرية أمام الإسكندرية (سيدي كرير ، الميناء الشرقي وخليج أبي قير) مختلفة فى طبيعتها البيئية وتتعرض للتلوث من مصادر متعددة. و قد تم تعيين تركيزات بعض المعادن الثقيلة (الحديد و النحاس و الزنك والرصاص والنيكل) بها إلى جانب الحجم الحبيبى للرواسب وتركيزات المواد العضوية ومحتوى الكربونات. و تم إجراء تقييم للوضع الحالي للمناطق قيد الدراسة وذلك بحساب معاملات إزدياد التركيزات (enrichment factor, EF) للمعادن المذكورة آنفاً مع استخدام عنصر الحديد كعنصر مرجعى. وأوضحت النتائج أن منطقة الميناء الشرقي تمثل أعلى درجة من معاملات إزدياد التركيزات يليها منطقة خليج أبو قير ثم منطقة سيدي كرير. ويمكن تفسير تلك الزيادة في رسوبيات الميناء الشرقي إلى أسباب عدة منها أن فترة دوران المياه داخل الميناء بطيئة للغاية إلى جانب تراكم المخلفات على مدى الزمن وطبيعة الميناء شبه المغلقة وذلك مقارنة بمنطقتى سيدي كرير وخليج أبوقير ذواتا الطبيعة المفتوحة. كما أوضحت المعالجة الإحصائية للبيانات أن طبيعة الرواسب والمادة العضوية هما العاملان المتحكمان فى زيادة تركيزات المعادن فى الرواسب.