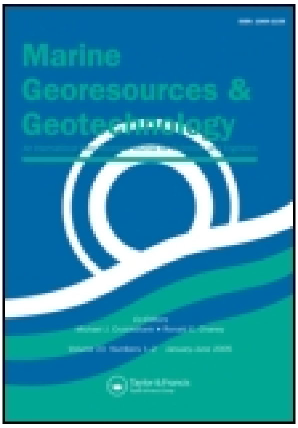

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Distribution and Enrichment of Heavy Metals in Recent Sediments of Safaga Bay, Egypt

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The present study was undertaken for assessing the level of heavy metals such as iron, manganese, zinc, copper, nickel, cadmium, lead, and cobalt in recent sediment samples of Safaga Bay, Egypt. Concentration of heavy metals in sediments shows significant variability and ranges from 863.37 to 1144.93 ppm for Fe, 64.29–586.8 ppm for Mn, 2.7–12.68 ppm for Zn, 3.01–7.2 ppm for Pb, 1.53–3.29 ppm for Ni, 0.55–1.57 ppm for Co, 0.16–1.37 ppm for Cu, and 0.22–0.4 ppm for Cd.

Sediment pollution assessments were carried out using an enrichment factor and geoaccumulation index. The calculation of enrichment factor showed that Cd is enriched by 4.1 due to phosphate sources in Safaga Bay. The Geoaccumulation index results revealed that there are positive and negative correlations between Fe, Zn, Mn, Pb, Ni, Cu, Co, and Cd indicating that these metals have complicated geochemical behaviors.

Keywords Egypt, enrichment factor, geoaccumulation index, heavy metals, Safaga Bay, sediments

Introduction

Heavy metals in marine waters and their corresponding sediments have become a significant topic of concern for man and aquatic life (Marcovecchio et al. 2010). Heavy metals are one of the more serious pollutants in our natural environment due to their toxicity, persistence, and bioaccumulation problems (Tam and Wong 2000). In order to avoid the pollution of toxic metals in the marine environment, it is necessary to establish the data and understand the mechanisms influencing their distribution in marine environment (Raj and Jayaprakash 2008).

The metals pass from water to sediment and vise versa under certain conditions by different processes, such as ion exchange, metal substitution, adsorption, and dissolution. Beltagy (1982) attributed the variation in the metal content in the Red Sea to the selective utility of these elements by different marine organisms and airborne material transported to the sea. Metals in the pure form are normally only available to marine organisms if they become oxidized (corrode) and their oxidation products

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are soluble in seawater (Waldichuk 1985). Many investigations have dealt with recent sediments and human impact on the Egyptian Red Sea coast (*e.g.*, El-Sayed 1984; El-Mamoney 1995; Ziko et al. 2001; Helal and Abd El Wahab 2004; Mansour et al. 2005; Madkour et al. 2006 and Madkour and Ali 2009). However, investigations including the impact of heavy metals on recent sediments in Safaga Harbors are still rare. Therefore, this article examines briefly the distribution of heavy metals to avoid the pollution of toxic metals in the marine environment.

The Study Area

Safaga Bay is a shallow water bay with a maximum depth of 70 m, situated on the western side of the Red Sea between lat. 26° 37′ & 26° 52′ N and long. 33° 56′ & 34° E, (Figure 1). The bay is bordered by a narrow arid coastal plain on the west, and east and south by very steep slopes, while the northern border is formed by the prominent peninsula of Ras Abu Soma. The N-S oriented Safaga Island (Gazirat Safaga) equally subdivides the bay into northern and southern parts. Both parts are distinctly separated by a shoal and connected only by a narrow channel.

Additionally, the prevailing water current runs from north to south, whereas, the southern bay is deeper than the northern one. Various bottom facies were recorded, such as coral reefs, seagrass, sand, and muddy bottoms. The northern bay is characterized by the common occurrence of coral reef communities, seagrass beds, and pure sand bottoms, especially at the base of the steeper slope, which is inhabited by coral reefs, while the southern bay is famous for its mud bottom. Coral reefs are less abundant and consist mainly of soft ones. Safaga bay was strongly affected by the long-term impacts of Safaga harbour and the emanated smothers from Abu Tartour phosphate project. These impacts reach the sediments and cover almost all the tidal flat fauna and flora, in addition to the lagoon fauna and flora.

Sampling and Analysis

The samples in a grid pattern (Figure 1) from seawater (30 samples) and marine sediments (30 samples) were taken at different points off the Safaga coast in June and July 2008. Water samples (500 ml) were filtered for the estimation of dissolved metals content. Filtrate and the collected water samples (500 ml each) were preserved with 2 ml concentrated nitric acid to prevent precipitation of metals (Clesceri 1998). Sediment samples were air-dried and ground into fine powder using agate mortar and passed through 1 mm sieve. Further, 2 g of fine powder sediment samples were taken in conical flasks to which 8 ml of aquaregia and 50 ml of distilled water were added. Then the sample was evaporated to near dryness on a hot plate using a sand bath. Residue was dissolved by adding 5–10 ml of dilute nitric acid to the conical flasks. After cooling to room temperature, samples were filtered and the filtrate was made up to 50 ml with distilled water. Heavy metals analyses were performed using an atomic absorption spectrophotometer using acetylene gas as fuel (at 8 psi) and air as an oxidizer (Vanloon 1980).

Results and Discussion

Total Phosphorous Content in Sediments and Water

The recent sediments of Safaga bay recorded the highest maximum of total phosphorous contents (9675.8 ppm), the minimum content (808.97 ppm), averaging

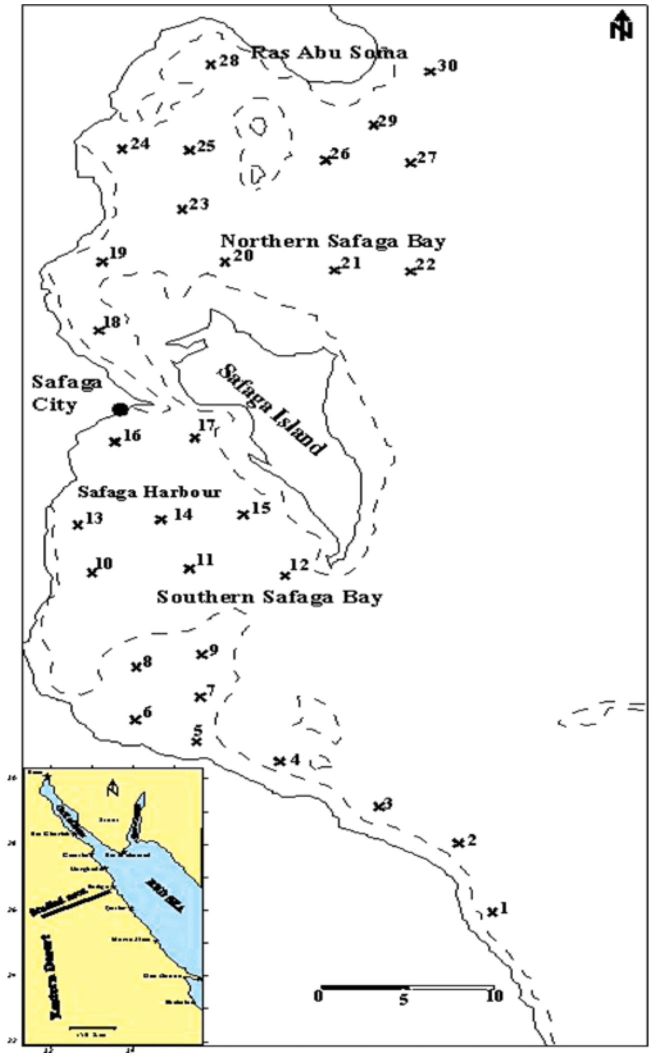

Figure 1. Locations of studied samples from Safaga Bay, Egypt.

(4939.33 ppm) as shown in (Table 1). This is significantly attributed to the fine suspended particles and the huge amounts of smothers emanating from the phosphate harbor, in addition to the domestic and sewage materials from coastal activities.

Nutrient Content in the Seawater

Nutrients are mainly nitrogen and phosphorous compounds dissolved in the seawater, and the available salts for consuming by the different organisms. The main sources of the nutrients are rivers, sewage, agriculture, stock rearing, industry, and atmospheric deposition (Mansour et al. 2005). Nutrients in the Safaga Bay are listed in Table 2.

Table 1. Heavy metals and Phosphorous contents in sediments of Safaga Bay

S. no.	Depth	P	Fe	Zn	Mn	Pb	Ni	Cu	Co	Cd
1	Beach	5389.6	1112.61	12.68	431.71	6.69	2.96	1.26	1.42	0.26
2	2	4320.6	863.37	2.70	64.29	7.20	1.99	0.16	0.83	0.35
3	5.3	4468.9	958.18	3.62	119.53	5.38	1.72	0.27	1.07	0.35
4	10	7520.6	1006.23	5.38	157.71	5.60	1.84	0.36	0.82	0.28
5	15	3951.7	1065.92	5.20	170.57	5.31	1.87	0.56	0.64	0.28
6	17	7437.9	1144.93	11.33	368.31	7.09	3.29	1.37	1.33	0.33
7	20	7968.9	1086.03	8.87	349.19	3.01	3.13	0.92	1.57	0.31
8	24	5268.9	1134.16	11.51	424.66	4.31	2.99	1.07	1.18	0.28
9	28	5010.3	1125.54	10.24	300.38	7.09	2.04	0.79	0.87	0.26
10	27	993.79	1074.54	5.36	221.89	4.33	2.34	0.41	0.57	0.37
11	30	5548.2	1101.12	8.03	286.8	7.08	2.64	0.91	0.96	0.31
12	34	808.97	971.83	3.32	88.91	5.56	1.53	0.26	0.71	0.40
13	7	2913.7	1110.46	7.10	187.68	4.65	2.23	0.62	0.98	0.30
14	14	9675.8	1009.9	4.17	110.27	5.54	1.56	0.41	0.68	0.36
15	30	5133.6	1081.15	7.99	289.7	6.99	2.44	0.88	0.59	0.22
16	16	5694.8	1105.42	8.26	269.44	6.21	2.58	0.96	0.98	0.31
17	34	3830.2	1051.36	6.446	221.80	6.54	2.19	0.68	0.75	0.31
18	16.5	5684.8	1104.42	7.26	270.44	5.91	2.58	0.96	0.98	0.30
19	Beach	5587.6	1111.65	10.99	432.77	4.77	2.89	1.08	1.19	0.25
20	25.4	4131.3	1104.35	8.43	323.27	4.32	2.66	0.74	0.87	0.35
21	27.2	1001.6	1054.33	5.33	220.77	4.22	2.33	0.40	0.56	0.34
22	29.2	5539.2	1100.12	7.79	586.8	7.01	2.54	0.89	0.91	0.30
23	26.5	5686.9	1138.15	11.31	422.63	4.21	2.97	1.06	1.16	0.26
24	15.5	5591.8	1100.92	7.29	279.42	5.9	2.89	0.88	0.97	0.31
25	26. 4	999.77	1064.24	5.31	211.87	4.30	2.31	0.39	0.55	0.34
26	30.7	5340.9	1091.13	8.01	288.25	7.03	2.54	0.89	0.77	0.26
27	33.5	5230.2	1077.12	8.20	287.96	7.00	2.45	0.89	0.65	0.22
28	21.7	6050.1	1095.19	8.65	336.23	3.66	2.89	0.83	1.22	0.33
29	15.5	6813.75	1037.91	4.68	140.42	5.42	1.71	0.48	0.66	0.32
30	33.4	4585.55	1071.25	7.22	255.02	6.79	2.36	0.78	0.76	0.28
Min.		808.97	863.37	2.7	64.29	3.01	1.53	0.16	0.55	0.22
Max.		9675.8	1144.93	12.68	586.8	7.2	3.29	1.37	1.57	0.4
Average		4939.33	1071.78	7.42	270.62	5.64	2.42	0.74	0.91	0.30
St. dev.		2071.74	60.09	2.61	118.28	1.23	0.48	0.31	0.27	0.04

N.B.P. = total phosphorus content in ppm, depth in meter, Min. = minimum content, Max. = maximum content, St. dev. = standard deviation.

Beside these external sources, in shallow areas, sediment particles may be resuspended by waves, upwelling currents, wind generated currents, and storms; bound inorganic and organic nutrients may dissolve. Also, nutrients in interstitial water of bottom sediments may diffuse back into the water column (Cruzado 1992). Depending on the concentration of inorganic and organic substances and the activity of the microorganisms, the prevailing redox potential in the water column and the

Table 2. Nutrient contents in the Safaga Bay water (μg/L)

S. no.	Depth	TP	NH_3	NO_2	NO_3
1	Beach	17.67	249.57	25.78	84.46
2	2	31.23	93.25	58.07	111.41
3	5.3	30.23	82.39	56.72	136.41
4	10	16.38	205.32	76.44	100.07
5	15	17.23	205.50	13.62	77.04
6	17	16.80	184.95	11.20	81.62
7	20	15.53	189.27	13.62	82.52
8	24	14.23	207.55	29.09	80.50
9	28	15.94	196.82	14.38	80.42
10	27	20.26	137.72	96.79	91.06
11	30	17.24	291.01	24.72	78.07
12	34	17.28	251.95	36.10	86.62
13	7	20.26	271.02	31.39	121.11
14	14	18.76	237.93	47.25	119.22
15	30	18.38	262.98	34.86	106.26
16	16	18.67	255.97	37.40	120.80
17	34	20.65	233.24	12.79	113.68
18	16.5	19.66	244.60	25.10	122.24
19	Beach	20.15	238.92	18.95	103.96
20	25.4	24.11	100.51	32.36	106.14
21	27.2	17.24	165.67	21.27	111.82
22	29.2	20.73	246.45	39.78	98.17
23	26.5	16.09	230.19	33.72	95.22
24	15.5	24.14	154.72	38.92	99.92
25	26. 4	18.11	251.89	21.62	108.11
26	30.7	15.49	132.36	24.59	125.8
27	33.5	18.97	254.72	31.81	104.05
28	21.7	23.28	119.54	22.47	122.18
29	15.5	12.07	149.06	24.32	127.30
30	33.4	24.16	100.5	32.36	86.14
Statistical analysis	Stdev.	4.23	60.61	18.91	17.13
	Min.	12.07	82.39	11.20	77.04
	Max.	31.23	291.01	96.79	136.41
	Average	19.36	198.19	32.92	102.74

N.B. TP = total phosphorus content, depth in meter, St. dev. = standard deviation, Min. = minimum values, Max. = maximum values, Aver. = average.

sediment pore waters determines whether the system tends to fix or lose nutrients. Many factors are controlling the nutrient distributions and enrichments in certain locations (Cruzado 1992).

It is clear that the higher total phosphorous content in the studied area may be attributed to many different natural and artificial parameters, such as algal effect, high landfill effect, and the water mixing in these lagoons. Table 2 shows that the maximum content of total phosphorous in the Safaga Bay water as 31.23 μg/L, while the minimum content is 12.07 μg/L, averaging 19.36 μg/L.

The ammonia has maximum content of 291.01 μg/L with an average content of 198.19 μg/L, while the nitrite shows the average value of 32.92 μg/L and an average content of 102.74 μg/L.

Distribution of Heavy Metals

The present study was undertaken for assessing the level of heavy metals such as iron, manganese, zinc, copper, nickel, cadmium, lead, and cobalt in sediments (Table 1) and water (Table 3) samples in order to assess the extent of environmental pollution in Safaga Bay, Egypt. Two factors contribute to the deleterious effects of heavy metals as environmental pollutants: heavy metals can not be destroyed through biological degradation as is the case with most organic pollutants; and heavy metals tend to accumulate in the environment especially in the bottom sediments by association with organic and inorganic matter through processes of adsorption, complex formation, and chemical combination.

Heavy metals concentration and their distribution in recent sediments of Safaga bay show remarkable variability. The concentrations of these metals range from 863.4 to 1145 ppm for Fe, 64.29–586.8 ppm for Mn, 2.7–12.68 ppm for Zn, 3.01–7.2 ppm for Pb, 1.53–3.29 ppm for Ni, 0.55–1.57 ppm for Co, 0.16–1.37 ppm for Cu, and 0.22–0.4 ppm for Cd.

In water, heavy metals have been ranged from 14.72–66.96 μg/L for Fe, 1.55–5.85 μg/l for Zn, 0.55–1.98 μg/l for Mn, 0.39–2.42 μg/l for Pb, 0.09–1.72 μg/l for Ni, 0.03–0.76 μg/l for Co, 0.1–1.29 μg/l for Cu, and 0.04–0.51 μg/l for Cd (Table 4).

In sediments, the concentrations levels were found in descending order of Fe > Mn > Zn > Pb > Ni > Co > Cu > Cd, while in seawater, iron and zinc were more abundant followed by manganese, lead, nickel, copper, cobalt, and cadmium concentrations. Increasing of iron in both sediments and seawater may reflect the bioaccumulation in marine organisms. The main source of manganese in the marine environment is represented by natural terrestrial contributions or by human impact, such as landfill and dredging operations (Madkour and Ali, 2009).

Geochemical Mobilization of Heavy Metals

Regional distribution of heavy metals (Figure 2) in the marine environment indicates that the concentrations of Fe, Mn, Zn, Pb, Ni, Co, and Cu in sediments and seawater decrease seawards in Safaga Bay; whereas, Cd showed a reversed spatial pattern. Cadmium is mainly associated with carbonates where the marine organisms uptake Cd from the seawater surface (Bender and Gagner 1976). Cadmium is highly toxic and originates from anthropogenic activities. Enhanced mobilization of Cd from phosphorites by contact with the seawater was observed.

In Figure 2, lead and zinc show a different behavior with a greater proportion in the sediment at sample 22. The sediments are moderately enriched in Pb and Zn with concentrations varying from 4.22 to 7.01 ppm for Pb and 5.33 to 7.79 ppm for Zn. The concentration of both Pb and Zn in sediments increases seawards, implying that these metals may be remobilized and carried by organic matter. In Figure 3, no significant relationship was found either between each heavy metals in seawater or in concentrations, indicating that these metals have complicated geochemical behaviors.

Table 3. Heavy metals content in seawater of Safaga Bay

S. no.	Depth	Fe	Zn	Mn	Pb	Ni	Cu	Co	Cd
1	Beach	50.16	2.02	1.40	0.54	0.42	0.14	0.11	0.07
2	2	44.24	2.19	1.22	0.64	0.57	0.13	0.05	0.11
3	5.3	66.96	2.72	1.75	1.25	0.49	0.24	0.03	0.16
4	10	41.17	2.35	1.39	0.68	0.28	0.18	0.07	0.14
5	15	37.41	1.76	1.30	1.06	0.23	0.16	0.08	0.11
6	17	37.19	2.02	1.56	0.93	0.25	0.17	0.13	0.15
7	20	59.17	2.61	1.39	1.11	0.28	0.19	0.12	0.13
8	24	33.88	5.85	1.16	2.42	0.37	0.37	0.12	0.14
9	28	30.96	1.55	0.97	1.07	0.24	0.12	0.09	0.09
10	27	42.75	4.67	1.50	1.28	0.34	1.26	0.09	0.25
11	30	24.83	3.52	1.03	1.42	0.19	0.21	0.06	0.15
12	34	25.96	1.99	1.06	2.15	0.17	0.11	0.08	0.13
13	7	59.55	2.99	1.38	1.01	0.16	0.14	0.07	0.16
14	14	39.41	2.97	1.31	1.04	0.21	0.15	0.14	0.13
15	30	22.81	2.20	1.24	1.06	0.69	0.34	0.59	0.09
16	16	23.48	1.80	0.88	0.89	0.11	0.29	0.63	0.08
17	34	28.62	3.26	1.19	0.77	0.18	0.30	0.76	0.07
18	16.5	31.24	1.79	0.55	0.39	0.14	0.15	0.31	0.51
19	Beach	28.50	4.37	1.98	1.30	0.96	0.13	0.14	0.06
20	25.4	21.05	4.73	0.98	1.79	0.09	0.29	0.18	0.08
21	27.2	17.84	3.74	1.22	0.96	1.72	0.44	0.19	0.09
22	29.2	18.12	2.11	0.92	1.22	0.55	0.14	0.22	0.08
23	26.5	22.84	4.69	0.60	1.01	0.16	0.10	0.17	0.29
24	15.5	23.72	4.16	0.80	1.29	0.20	0.12	0.15	0.05
25	26. 4	42.79	4.87	1.61	1.29	0.38	1.29	0.19	0.27
26	30.7	19.26	1.68	0.99	1.48	0.25	0.13	0.21	0.07
27	33.5	21.01	2.19	1.08	0.94	0.16	0.10	0.25	0.07
28	21.7	46.23	2.29	1.26	0.83	0.44	0.24	0.18	0.11
29	15.5	18.24	1.69	0.86	0.79	0.09	0.11	0.21	0.05
30	33.4	14.72	2.06	0.89	1.07	0.48	0.20	0.39	0.04
Min		14.72	1.55	0.55	0.39	0.09	0.1	0.03	0.04
Max		66.96	5.85	1.98	2.42	1.72	1.29	0.76	0.51
Average		33.14	2.89	1.18	1.12	0.36	0.26	0.20	0.13
St. dev.		13.77	1.20	0.32	0.43	0.32	0.29	0.18	0.09

N.B. All measurements in ppm, S. = standard deviation, Min. = minimum values, Max. = maximum values, depth in meter, St. dev. = standard deviation.

The correlation analysis of concentrations data (Table 5) shows strong positive and weak negative correlations between Fe, Zn, Mn, Pb, Ni, Cu, Co, and Cd, indicating that these metals have complicated geochemical behaviors. Strong positive correlations of heavy metals may be due to the high contribution of terrigenous fragments. Weak negative correlation was observed for Cd with others. This indicates that Cd was not associated with others and it has a different anthropogenic source.

Table 4. Statistical summary of estimated parameters and enrichment factor of heavy metals in seawater and sediments

Parameters	Fe	Zn	Mn	Pb	Ni	Cu	Co	Cd
In sediments (ppm).								
S	60.09	2.61	118.28	1.23	0.48	0.31	0.27	0.04
Min.	863.37	2.70	64.29	3.01	1.53	0.16	0.55	0.22
Max.	1144.93	12.68	586.80	7.20	3.29	1.37	1.57	0.40
Aver	1071.78	7.42	270.62	5.64	2.42	0.74	0.91	0.30
EF	–	0.3	1.3	1.12	0.14	0.1	0.2	4.1
In seawater (μg/L).								
S	13.77	1.20	0.32	0.43	0.32	0.29	0.18	0.09
Min.	14.72	1.55	0.55	0.39	0.09	0.10	0.03	0.04
Max.	66.96	5.85	1.98	2.42	1.72	1.29	0.76	0.51
Aver	33.14	2.89	1.18	1.12	0.36	0.26	0.20	0.13
EF	??	??	??	??	??	??	??	??

N.B. S. = standard deviation, Min. = minimum values, Max. = maximum values, Aver. = average, EF = enrichment factor of heavy metals in sediments.

Enrichment Factor of Heavy Metals

In the present study, enrichment factor was used to assess the level of contamination and possible anthropogenic impact in sediments of Safaga bay. To identify anomalous metal concentration, geochemical normalization of the heavy metals data to a conservative element, such as Al, Fe, and Si, was employed. In this study, iron was also used as a conservative tracer to differentiate natural from anthropogenic components (Schiff and Weisberg, 1999; Baptista et al. 2000; Mucha et al. 2003). According

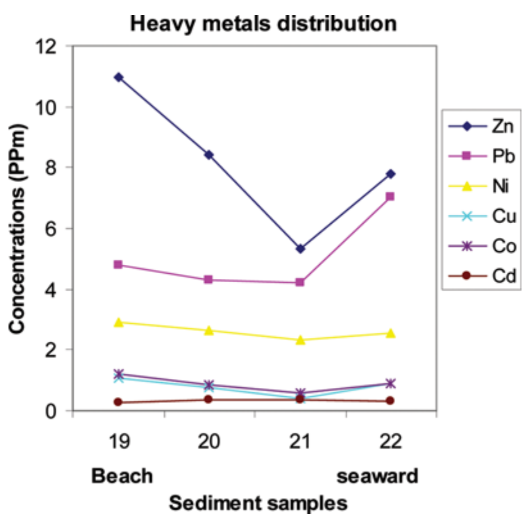

Figure 2. Distribution of heavy metals in sediments.

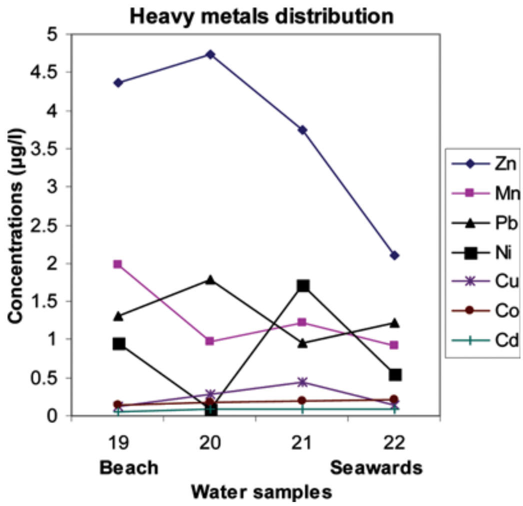

Figure 3. Distribution of heavy metals in water.

to Ergin et al. (1991) the metal enrichment factor (EF) is defined as follows (eq. 1):

$$EF = \frac{(M/Fe)_{sample}}{(M/Fe)_{background}} \tag{1}$$

where EF is the enrichment factor, (M/Fe) sample is the ratio of metal and Fe concentration of the sample, and (M/Fe) background is the ratio of metal and Fe concentration of a background. In this study, the background concentrations of Fe, Mn, Zn, Pb, Ni, Co, Cu, and Cd were taken from Turekian and Wedepohl (1961) with respect to average shale (Förstner and Muller 1973) to quantify the extent and degree of metal pollution. It is shown how it is possible to distinguish between heavy metal enrichment of sediments derived from geological sources and from man-made pollution, respectively. Zhang and Liu (2002) reported that whereas EF values between 0.5 and 1.5 indicate the metal is entirely from crustal materials or natural processes; whereas EF values greater than 1.5 suggest that the sources are more likely to be anthropogenic. The highest average EF is seen for Cd with a value of 4.1 (Table 4).

Table 5. The correlation analysis of concentrations data

	Fe	Zn	Mn	Pb	Ni	Cu	Co	Cd
Fe	1.00							
Zn	0.83	1.00						
Mn	0.76	0.84	1.00					
Pb	−0.11	0.02	−0.01	1.00				
Ni	0.72	0.82	0.80	−0.15	1.00			
Cu	0.82	0.93	0.82	0.17	0.85	1.00		
Co	0.37	0.66	0.54	−0.20	0.68	0.63	1.00	
Cd	−0.48	−0.60	−0.48	−0.32	−0.34	−0.58	−0.14	1.00

Table 6. Geoaccumulation index classification (Förstner et al. 1993)

I_{geo} values	I_{geo} class	Contamination intensity
>5	6	Very strong
>4-5	5	Strong to very strong
>3-4	4	Strong
>2-3	3	Moderate to strong
>1-2	2	Moderate
>0-1	1	Uncontaminated to moderate
<0	0	Practically uncontaminated

This suggests that Cd is from anthropogenic inputs, including fertilizers and pesticides used in agricultural activities. Therefore, the sediments of Safaga bay have been contaminated by these two metals in the recent years.

Geo-Accumulation Index (I_{geo})

To quantify the degree of anthropogenic contamination and compare different metals that appear in different ranges of concentration in sediments, an approach to indexing geoaccumulation, $\boldsymbol{I_{geo}}$, was used (Müller and Suess 1979). A quantitative check of metal pollution in aquatic sediments was proposed by Müller and Suess as equation and is called the Index of Geoaccumulation (eq.2) that is the enrichment on geological substrate:

$$I_{geo} = \ln\ (\mathrm{Cn}/1.5 \times \mathrm{Bn}) \tag{2}$$

where Cn = measured concentration of heavy metals in sediment, and Bn = geo-geochemical background in average shale of element n, 1.5 is the background matrix correction factor due to lithogenic effects.

Karbassi et al. (2006) reported that $\boldsymbol{I_{geo}}$ values can be used effectively and more meaningfully in explaining the sediment quality. In addition, Soto-Jimenez and Paez-Osuna (2001) mentioned that the input of metals into sediment that are located seawards to be low in total concentration of most of the elements and this could be due to the mixing of enriched particulate material with relatively clean marine sediments. Förstner et al. (1993) listed geoaccumulation classes and the corresponding contamination intensity for different indices, which are shown in Table 6.

The geoaccumulation index indicated that Cd, Co, Cu, Pb, Ni, Zn, Mn, and Fe moderately to extremely pollute the recent sediment. This study shows that the major sources of metal contamination in Safaga bay are land-based anthropogenic ones.

Conclusions

In sediments, the concentration levels were found to be in the order of Fe > Mn > Zn > Pb > Ni > Co > Cu > Cd. Iron and Mn showed almost consistent concentrations distributed over all sampling areas. The high concentration of heavy metals can be attributed to natural terrestrial contributions or by human activities in

Safaga Harbors. The possibility of pollution is investigated in terms of enrichment factors for cadmium in near and offshore samples due to phosphorites sources in Safaga Bay.

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