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Assessment of some heavy metals pollution in Damietta harbor, Egypt

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Abstract

The concentration levels of some heavy metals (Fe, Mn, Zn, Cu, Ni and Cr) in sediments of Damietta harbor and the adjacent Mediterranean Sea area were examined and reported. A total of twenty one surface sediment samples were collected in order to evaluate the levels and spatial distribution of the heavy metals, as well as, their relation with grain size distribution of the sediment and the TOC% content. For previously mentioned metals, the enrichment factors (EF), geoaccumulation index (Igeo) and pollution load index (PLI) have been calculated as various criteria to assess the pollution status of the investigation area. The EF for all metals is ranging from without enrichment to Medium level enrichment. The I_{geo} for all metals is ranging from unpolluted to moderately pollute except for Fe. The PLI for all samples are of low contamination factor except for the sample that collected from the entrance of the harbor i.e. of moderate contamination factor. The concentrations of metals are compared to the effect range low (ERL) and effect range median (ERM) concentration guide lines to assess its biological effect on the aquatic environment. All the samples lie below ERL and/or between ERL and ERM and no samples lie above ERM. Indicating that, the sediments are rarely associated with biological effect.

Keywords: Damietta harbor, Mediterranean Sea, Heavy metals, Enrichment factors, Geoaccumulation index, Pollution load index, Toxicity guide lines.

1. Introduction

The accumulation of heavy metals in marine sediments is due to many natural and anthropogenic factors, such as parent rock weathering, industrial waste water, transportation, agricultural and climatic factors. The distribution of heavy metals is controlled by the same processes of sediment transport and deposition, whereas metal concentration in the sediment changes in space and time (Buccolier *et al.,* 2006).

Sediments are the main repository and source of heavy metals in the marine environment and play an important role in the transport and storage of potentially hazardous metals (Cuong and Obbard, 2006). Metals have significant mobility and can affect the ecosystems through bio-accumulation and bio-magnification processes. They are potentially toxic for environment and for human life (Manahan, 2000).

Since metals accumulate in sediment from both natural and anthropogenic sources occur in the same manner, this makes a difficulty to identify and determine the origin of heavy metal present in sediment. In order to overcome this obstacle, it has been proposed to adopt normalization methods. The purpose of our study is to explore the natural and anthropogenic input of heavy metals and to asses the pollution status in the area. Using enrichment factor (EF), geoaccumulation index (Igeo), as well as pollution load index (PLI).

2. Materials and methods

2.1. Study area

Damietta harbor (A port) is a marine harbor lying just west to Damietta city on the coast of Nile Delta, Egypt. It is constructed in 1982, about 10 km to the west of Damietta outlet of the Nile River (Figure 1). It is generally agreed that, the harbor activities such as loading and off loading of goods, cleaning, ballasting, fueling,… etc contribute to the dumping of significant amounts of wastes directly in to the Sea (Idris *et al*., 2007). So, the environmental assessment is a must together with monitoring study for the pollutants occurring in this critical area as a result of human impacts.

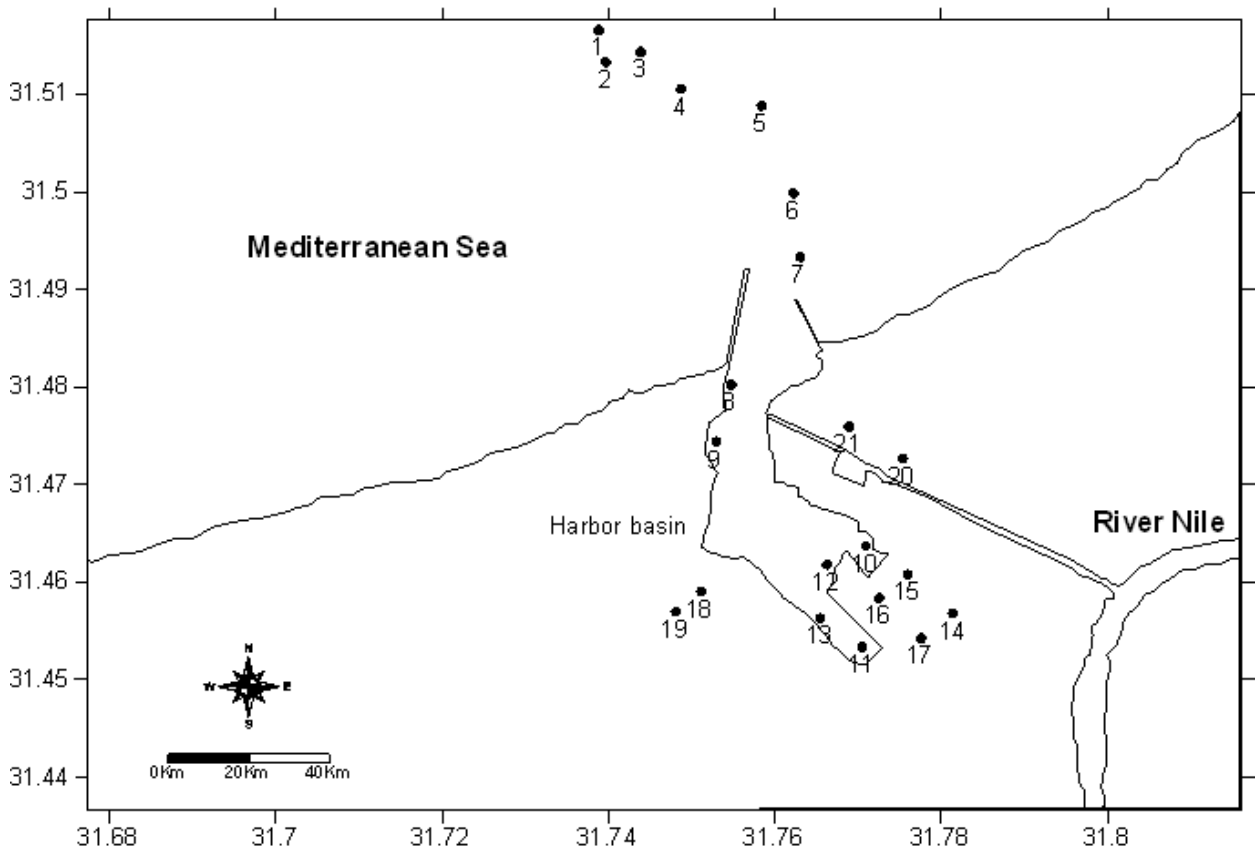


Figure 1. Map for the study area and the samples locations, Damietta harbor-Egypt.

2.2. Sampling locations description

Surface sediment samples were collected during summer 2007 at twenty one stations in Damietta harbor and the area in front of it (Figure 1), using a stainless steel Peterson grab sampler. The station locations were determined using a Geological Positioning System (GPS); sites were chosen to cover areas which are known to be affected by land-based activities. Samples from 1 to 13 were bottom samples. The first three samples were collect from the off shore area at depth of 100 m to be used as reference samples since they were far from the sources of pollution. The other 10 collected from the navigation channel and the harbor basin at depths ranging from 8m to 15m, the Samples from 14 to 21 were collected from the land surface in the harbor surrounding the water basin. The samples were stored frozen until analysis.

2.3. Heavy metal analysis

The total concentrations of heavy metals (Fe, Mn, Cu, Zn, Ni and Cr) were determined according to Oregioni and Aston (1984) using a mixture of nitric, perchloric and hydrofluoric acids with a ratio of (3:2:1). After complete digestion, the residue was transferred to a 25ml volumetric flask with 0.1 M HCL the total concentrations of the measured trace elements were measured using atomic absorption spectrophotometer (AAS), Shimadzu model (6800) of the Central Lab, National Institute of Oceanography and Fisheries, Alexandria branch. The concentrations of trace metals were determined and measured in µg /g (ppm).

The analytical precision was tested by subjecting triplicate sediment samples to the previous procedure for the determination of total heavy metals. The test results (Table 1) show good reproducibility and a precision (expressed as the % Coefficient of variance) of individual extractions varying from < 1 to 12 %. Thus, the CV% calculated for the total heavy metals (Fe, Mn, Cu, Zn, Ni and Cr) was within the range of precision, where the maximum value was 2.80 % for Cu and the minimum value was 0.09 % for Fe.

3. Results and discussion

Salomons and Förstner (1984) showed that the distribution of heavy metals in marine deposits was influenced by sediment texture, clay content, organic carbon, iron hydrous oxides and carbonates. Table 2 illustrates that the silty clay and sandy mud constitute the major part of sediment type in the bottom samples, while the sand fraction constitute the major part of sediment type in land samples.

Total organic carbon reveals its maximum value (2.174 %) in bottom samples at station 11

collected from general cargo dock with sediment types of silty clay, whereas the minimum value (0.095%) was recorded at station 6 collected from the navigation canal. As the land samples consist almost from sand they record much lower values of total organic carbon ranging from 0.246% to 0.546%.

3.1. Heavy metal concentrations

For bottom samples, the range and average concentrations measured in (ppm) are 1215.43-3577.08 (2708.22) for Fe, 373.43-1193.29 (743.87) for Mn, 53.35-198.29 (146.05) for Zn, 7.28-75.94 (44.36) for Cu, (ND)-97.41 (41.32) for Ni and (ND)-122.41 (55.03) for Cr. For land samples the range and average concentrations measured in (ppm) are 2396.02-2795.66 (2567.27) for Fe, 442.37-592.91 (524.14) for Mn, 93.35 – 189.76 (155.89) for Zn, 15.73 – 23.67 (19.07) for Cu, 15.09 – 32.74 (23.65) for Ni and 3.17 – 61.67 (38.39) for Cr, (Figures 2,3,4,5,6 and 7). Examining (Table 3) it is evident that the concentrations of the studied elements do not yet reach to the risk threshold.

Table 1. The precision test of Total Heavy metals in sediment samples (St. 11) in ppm.

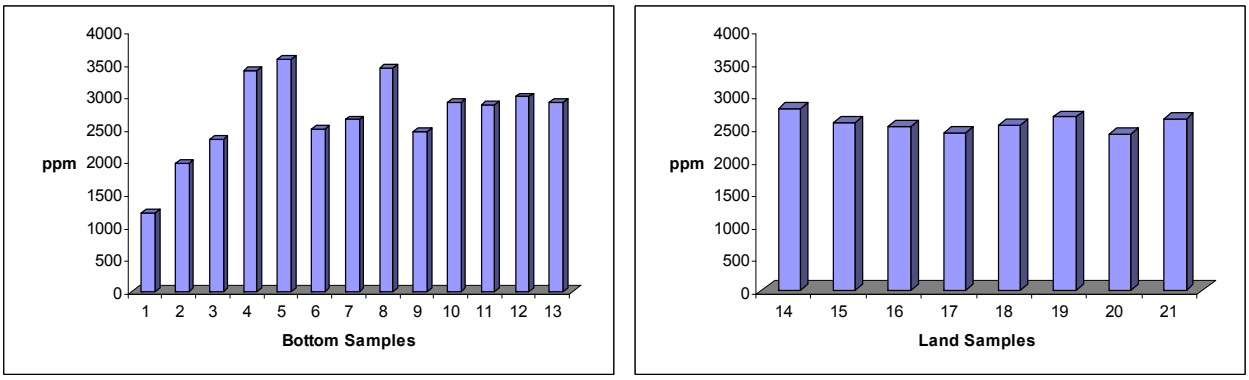
Tri.Test	Fe	Mn	Cu	Zn	Ni	Cr
1	2959.14	779.69	68.79	191.54	66.85	110.09
2	2955.67	774.65	66.46	194.38	67.86	99.71
3	2913.95	746.90	65.09	190.26	66.85	103.49
Mean	2956.26	767.08	66.78	192.06	67.04	104.43
SD	2.64	17.66	1.87	2.11	0.75	5.25
CV%	0.09	2.30	2.80	1.10	1.11	5.03

Table 2. The percentages of Sand%, Silt%, Clay% and TOC% for the samples of the study area.

Samples	Sand%	Silt %	Clay%	TOC%	Nomenclature
Bottom Samples					
1	98.95	0.46	0.46	0.356	Sand
2	98.82	0.5	0.5	0.349	Sand
3	98.54	0.44	0.44	0.199	Sand
4	3.47	11.61	84.92	0.877	Silty clay
5	5.82	7.12	87.06	0.241	Clay
6	24.61	2.09	73.29	0.095	Sandy clay
7	5.96	12.85	81.19	0.486	Silty clay
8	2.79	34.59	62.62	1.526	Silty clay
9	3.46	31.79	64.76	1.421	Silty clay
10	16.71	29.58	53.71	1.105	Sandy mud
11	3.91	31.58	64.52	2.174	Silty clay
12	16.12	32.54	51.34	1.624	Sandy mud
13	4.40	38.83	56.77	1.336	Silty clay
Land Samples					
14	97.93	0.92	0.92	0.273	Sand
15	86.30	0.62	11.85	0.246	Clayey sand
16	90.97	4.37	4.37	0.252	Sand
17	93.30	3.22	3.22	0.318	Sand
18	93.56	2.93	2.93	0.251	Sand
19	92.70	3.45	3.45	0.546	Sand
20	95.78	1.92	1.92	0.429	Sand
21	85.26	0.58	13.9	0.372	Clayey sand

Table 3. Concentrations of metals (ppm) in some selected sediments worldwide compared to study area.

Location	Fe	Mn	Zn	Cu	Ni	Cr	Reference
DamiettaHarbor (Egypt)	2708.22	743.87	146.05	44.36	41.32	55.03	Present Study
Damietta out let (Egypt)	----	2000	221	80	100	73	Rifaat, 2005
AlexandriaCoast (Egypt)	2154	----	52	16.9	----	----	Okbah *et al*., 1998
Mediterranean (Italy)	6098	----	36.1	18.7	8.9	21.8	Rigollet *et al*., 2004
Sudanese Harbor (Sudan)	52.1	451.6	83.6	68.8	102	----	Idris *et al*., 2007
NaplesHarbor (Italy)	----	24	303	64	----	58.9	Adamo *et al*., 2005
BremenHarbor (Germany)	----	----	790	87	60	131	Hamer and Karius, 2002
IzmirHarbor (Turkey)	----	----	182	182	222	108	Filibeli and Yilmaz,1995
BostonHarbor (USA)	----	----	118	67	----	131	Bother *et al*., 1998
New YorkHarbor (USA)	----	----	216	118	36.5	175	USEPA *et al*., 1999
MontevideoHarbour (Uruguay)	----	----	312	89	30	162	Muniz *et al*., 2004
Jeddah-Red Sea (Sudia Arabia)	2070.72	117.57	56.28	20.28	78.16	16.90	Al-Mur B., 2007
Rabigh-Red Sea (Sudia Arabia)	2311.56	217.52	60.21	21.22	84.21	23.30	Al-Mur B., 2007
Yanbu-Red Sea (Sudia Arabia)	2843.09	257.13	72.68	22.08	83.39	26.06	Al-Mur B., 2007
IzmitBay (Turkey)	----	----	930	67.6	----	74.3	Pekey H., 2006
ShenzhengBay (China)	----	----	135	48.8	29.9	----	Hung *et al*., 2003
WesternXiamenBay (China)	----	----	139	44	37.4	75	Zhang *et al*., 2007
GüllükBay (Turkey)	----	----	81	25	----	----	Dalman *et al*., 2006
Gulf of Aden	2454.59	398.55	142.67	59.55	32.12	125.47	Saleh, 2006
Gulf of Mannar (India)	11800-1200	290-301	71-74.06	----	22.63-24.5	148-195	Jonathan *et al*., 2003
EuvoikosGulf (Greece)	35600	536	435	240	----	----	Dassenakis *et al*., 2003
Taranto Gulf (Italy)	31566	893	102.3	47.4	53.3	85.9	Buccolierirt *et al*., 2006
CaspianBay	20000	482	46	19.5	29.8	56.1	De Mora *et al*., 2004
Dead Sea (Jordan)	9899	36.83	----	40.53	41.99	158.25	Kasem, 2001
Red Sea (Yemen)	3078-4236	20.7-65	88.6-138	24.8-39.3	9.3-14.7	15.9-24.5	Hassan *et al*., 2000



a) b)

Figure 2. a) Vertical distribution of total iron concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total iron concentrations (ppm) of land sediment samples.

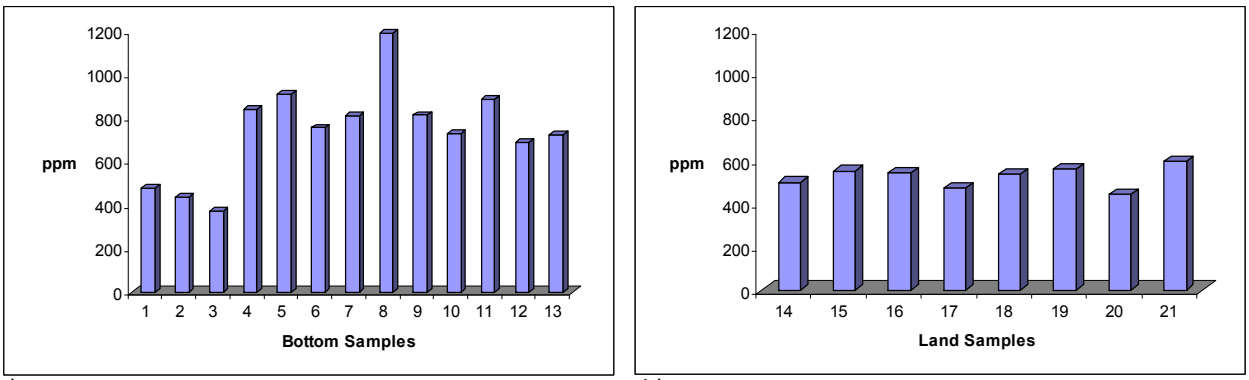


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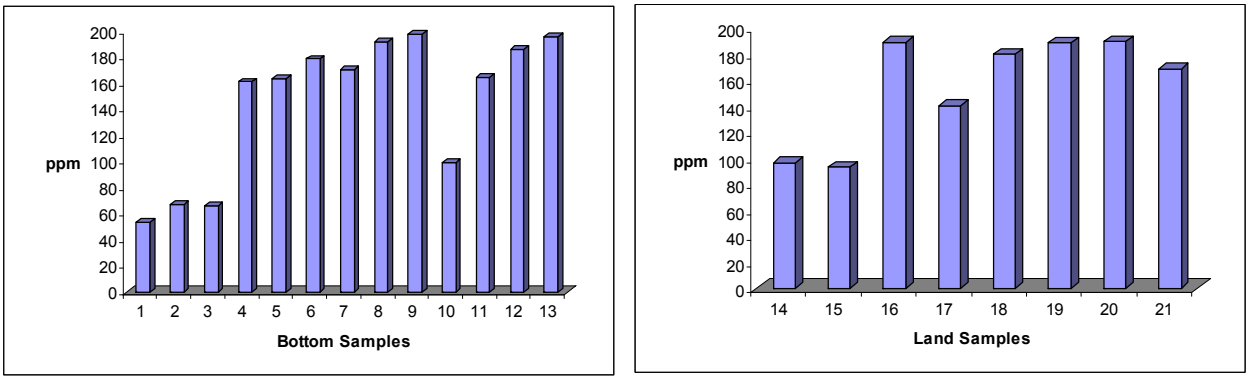
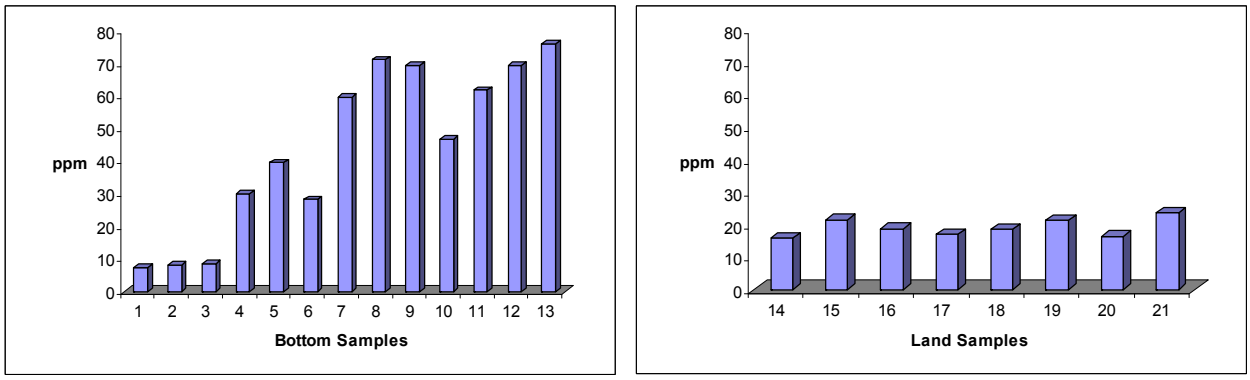
Figure 3. a) Vertical distribution of total manganese concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total manganese concentrations (ppm) of land sediment samples.



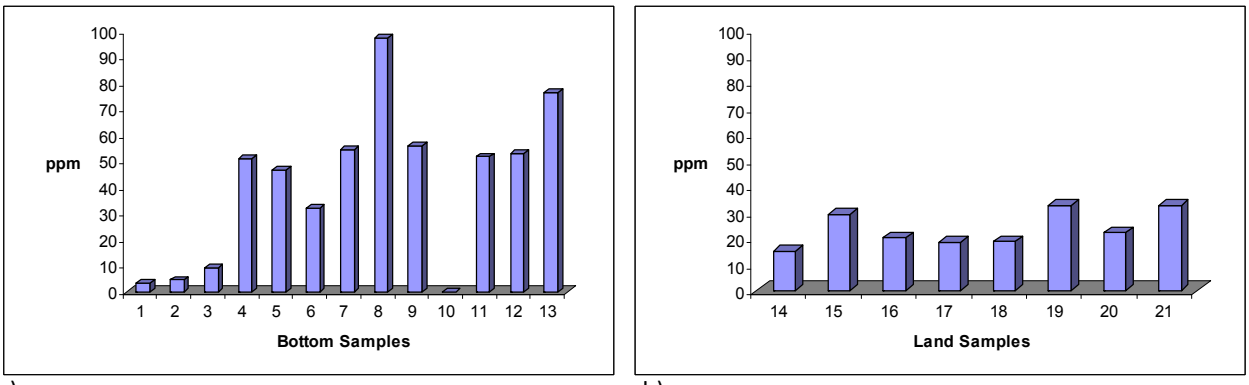
a) b)

Figure 4. a) Vertical distribution of total Zinc concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total Zinc concentrations (ppm) of land sediment samples.



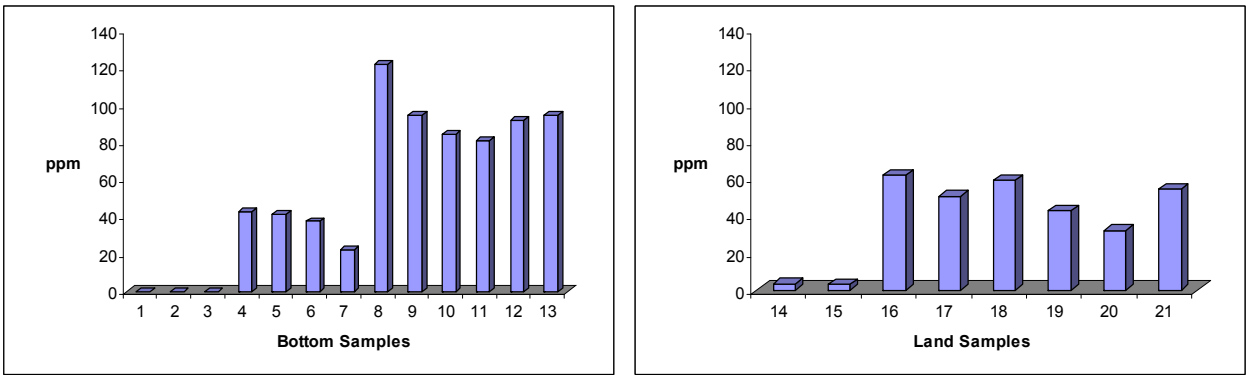
a) b)

Figure 5. a) Vertical distribution of total Copper concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total Copper concentrations (ppm) of land sediment samples.



a) b)

Figure 6. a) Vertical distribution of total Nickel concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total Nickel concentrations (ppm) of land sediment samples.



a) b)

Figure 7. a) Vertical distribution of total Chromium concentrations (ppm) of bottom sediment samples.
b) Vertical distribution of total Chromium concentrations (ppm) of land sediment samples.

3.2. Sediment Quality Assessment

In the present study, concentration of metals are compared to the effect range low (ERL) and effect range median (ERM) concentration guidelines derived from the data base of Long *et al.* (1995) to understand the extent of contamination (Table 4). This database contains measured concentrations and their biological effects of estuarine and marine sediments. Concentrations below the ERL value are rarely associated with biological effects. Concentrations equal / or above the ERL, but below the ERM, indicate a possible range in which effects would occasionally occur. The concentrations equivalent to and above ERM values indicate that the effects would occur frequently.

The toxicity guidelines of heavy metals in sediments are shown at (Table 4). None of metal concentrations in the sediments of the bottom samples is as high as above ERM values. Most of the samples fall in the range between ERL and ERM (9, 8, 9 and 6) samples for Zn, Cu, Ni and Cr respectively. This indicates a possible range in which effects would occasionally occur. While, the rest of the samples fall in the range below the ERL. Indicating that, the sediments were rarely associated with biological effects.

None of metal concentrations in the sediments of the land samples is as high as above ERM values. Most of the samples fall in the range between ERL and ERM for both Zn and Ni (6 and 5) samples respectively. This indicates a possible range in which effects would occasionally occur. While, 2 and 3 samples only fall in the range below ERL for both Zn and Ni respectively. Revealing rarely associated with biological effects. While all the samples fall in the range below ERL for both of Cu and Cr. This indicates that the sediments are rarely associated with biological effects.

Table 4. Toxicity guidelines of heavy metals (μg g^{-1}, dry weight) in sediments from Damietta harbor and adjacent sea area.

Metal	ERL	ERM	< ERL	ERL-ERM	> ERM
Bottom samples					
Zn	150	410	4	9	----
Cu	34	270	5	8	----
Ni	20.9	51.6	4	9	----
Cr	81	370	7	6	----
Land samples					
Zn	150	410	2	6	----
Cu	34	270	8	----	----
Ni	20.9	51.6	3	5	----
Cr	81	370	8	----	----

ERL: EffectRange Low.
ERM: EffectRange Median.
Data from Long et al., 1995 and Long and Morgan, 1990.
(i.e: Fe and Mn are not measured).

3.3. Assessment of Sediment Contamination

3.3.1. Enrichment Factor (EF)

EF is a geochemical approach based on the assumption that, under the natural sedimentation conditions, there is a linear relationship between a reference element (RE) and other elements. If the concentration of a RE changes with a factor, the concentrations of other elements change also with the same factor. It is preferable that a RE meets some requirements including: (a) existing in sediment at a high concentration, (b) free from an anthropogenic enrichment, (c) easily determined by a number of analytical techniques and (d) free from contamination during sampling. Normalization to a RE is usually evaluated by a value called enrichment factor, which is calculated as follows:

$$EF = \frac{(C_{EE}/C_{RE})_{sample}}{(C_{EE}/C_{RE})_{reference\ material}}$$

Where: $(C_{EE}/C_{RE})_{sample}$ is the ratio of the concentration of the examined element in a sample to the concentration of a RE in the same sample.
$(C_{EE}/C_{RE})_{reference\ material}$ is the ratio of the concentration of the examined element in a reference material to the concentration of a RE in the same reference material.

In the current study, EF was calculated using the concentration of a metal of interest to the concentration of Fe in the coarsest sediment grains. The concentration of Fe in that fraction of sediment was adopted because it is considered to be free from anthropogenic contribution, which is more or less equivalent to the crust average of the same element as mentioned by (Martin and Whitfield, 1983), (Table 5).

Table 5. Elements abundance (ppm) in the earth crust.(Martin and Whitfield, 1983).

Metal	Concentration (ppm)
Fe	35900
Mn	720
Cr	71
Ni	50
Cu	32
Zn	127

Elements can be divided in to three major groups with respect to their corresponding enrichment factor value, elements without enrichment (EF< 10), elements with medium-level enrichment (10< EF < 100) and finally highly enriched elements (EF > 100) (Idris , 2008).

The results of enrichment factor of the bottom samples indicate that, there is medium-level enrichment for all studied elements (Mn, Zn, Cu, Ni and Cr) except few samples that recorded without enrichment (Table 6). All the studied elements are not harmful in that area. This medium-level enrichment of manganese may be attributed to the oxidation of organic matter and later liberation of the organically bound manganese (Rifaat, 1996). The medium-level enrichment of Zn and Cu may be attributed to the release of Zn from the anti-fouling paints on ships, as well as, other anthropogenic sources such as, sewage outfall and industrial effluents (Gohand and Chou, 1997 and Bothner *et al.,* 1998). Also, zinc was found with high concentrations in cement that is handled in large volumes in the general cargo and cement terminal area (Pytkowicz, 1992) and (EMDB, 2004). While, the medium-level enrichment of Ni and Cr calculated in the study area was enriched mainly by industrial inputs (Rigollet *et al.,* 2004).

All sediments in land samples recorded medium-level enrichment for Mn and Zn except few samples without enrichment. So, both metals are not harmful in the area. The results of enrichment factor calculations for Cu and Ni in land samples reveal that all samples recorded are without enrichment, indicating no enrichment of both Ni and Cu in that area. Although the enrichment factor calculations for Cr in land samples reveal that half of the samples recorded medium-level enrichment, while the other half of the samples recorded without enrichment chromium still not harmful in that area.

Table 6. Metal enrichment factors in the sediments from Damietta harbor and adjacent sea area.

Samples	Enrichment Factor (EF)				
	Mn	Zn	Cu	Ni	Cr
Bottom samples					
1	19.75	12.41	6.72	2.11	ND
2	11.10	9.63	4.70	1.68	ND
3	7.95	8.01	4.16	2.88	ND
4	12.39	13.45	9.96	10.81	21.29
5	12.75	12.92	12.41	9.37	5.90
6	15.15	20.29	12.74	9.26	7.70
7	15.29	18.22	25.34	14.80	4.32
8	17.29	15.78	23.21	20.33	17.99
9	16.58	22.82	31.72	16.36	19.53
10	12.54	9.64	18.08	ND	14.74
11	12.52	18.30	25.56	17.49	18.27
12	11.51	17.59	25.96	12.76	15.53
13	12.50	19.10	29.35	18.91	16.53
Land samples					
14	8.88	9.75	6.31	3.88	0.63
15	10.65	10.23	9.31	8.12	0.62
16	10.71	21.29	8.31	5.74	12.40
17	9.72	16.38	7.88	5.52	10.57
18	10.55	20.11	8.21	5.29	11.78
19	10.48	20.01	8.94	8.77	8.10
20	9.21	22.39	7.65	6.67	6.78
21	11.23	18.14	10.09	8.93	10.43

3.3.2. Geoaccumulation index

Geoaccumulation index (I_{geo}) has been calculated for analyzed metals. It was originally defined by Müller (1981) in order to determine metals contamination in sediments, by comparing current concentrations with pre-industrial levels. It can be calculated by the following equation;

$$I_{geo} = \log_2 [C_x / (1.5B_x)]$$

Where: C_x is the measured concentration of the examined metal "x" in the sediment,

B_x is the geochemical reference material concentration of the metal "x".

Factor 1.5: is the reference material matrix correlation factor due to lithogenic effects.

It is very difficult to establish B_x values for sediments in the Mediterranean Sea owing to geochemical variability of various areas and different anthropogenic impacts. In this work, B_x values have been taken equal to the earth crust values as we did in enrichment factor calculation (Martin and Whitfield, 1983).

The Geoaccumulation index can assess to the estimation of these pollution processes. Müller has distinguished seven classes of Geoaccumulation index (Müller, 1981) (Table 7). The highest class (class six)

reflects more than 64-fold enrichment above the background values.

Table 7. Müller's classification for Geoaccumulation index (Müller, 1981).

Quality of sediment	class	I_{geo} value
Unpolluted	0	≤ 0
From polluted to moderately polluted	1	0-1
Moderately polluted	2	1-2
From moderately to strongly polluted	3	2-3
Strongly polluted	4	3-4
From strongly to extremely polluted	5	4-5
Extremely polluted	6	> 5

The results of geoaccumulation index (I_{geo}) calculations for iron (Fe) in bottom samples are shown in (Table 8). It indicated that 100% of the samples fall in class 0 (unpolluted). So, this area is unpolluted by iron. For manganese (Mn) 92.3% of the samples falls in class 0 (unpolluted) and 7.7% fall in class 1 (from unpolluted to moderately polluted). For both zinc (Zn) and chromium (Cr) about 70% of the current samples fall in class 0 (unpolluted). While, about 30% fall in class 1 (from unpolluted to moderately polluted).

The results of geoaccumulation index (I_{geo}) calculations for copper (Cu) reveal that there is 54% of the samples fall in class 0 (unpolluted). While, 46% fall in class 1 (from unpolluted to moderately polluted). For nickel (Ni) 83% fall in class 0 (unpolluted) and 17% fall in class 1 (from unpolluted to moderately polluted).

The results of geoaccumulation index (I_{geo}) calculations in land samples are shown in (Table 8). For the back ground values 100% of samples fall in class 0 suggesting that land samples sediments are not enriched by the studied metals.

Table 8. Geoaccumulation index (I_{geo}) values of heavy metals in the sediments from Damietta harbor and adjacent sea area.

Geoaccumulation index (I_{geo})						**Samples**
Cr	**Ni**	**Cu**	**Zn**	**Mn**	**Fe**	
Bottom samples						
ND	-4.39	-2.72	-1.84	-1.17	-5.47	1
ND	-4.02	-2.54	-1.50	-1.30	-4.77	2
ND	-3.00	-2.47	-1.52	-1.53	-4.52	3
0.42	-0.55	-0.67	-0.24	-0.36	-3.99	4
-1.35	-0.68	-0.28	-0.22	-0.24	-3.91	5
-1.49	-1.22	-0.76	-0.09	-0.51	-4.43	6
-2.24	-0.46	0.32	-0.16	-0.41	-4.35	7
0.20	0.38	0.57	0.01	0.14	-3.97	8
-0.17	-0.42	0.53	0.06	-0.40	-4.45	9
-0.33	ND	-0.03	-0.94	-0.56	-4.21	10
0.02	-0.04	0.51	0.01	-0.52	-4.17	11
-0.21	-0.49	0.53	-0.03	-0.64	-4.17	12
-0.17	0.03	0.66	0.04	-0.57	-4.21	13
Land samples						
-4.94	-2.31	-1.61	-0.98	-1.12	-4.27	14
-5.07	-1.36	-1.17	-1.03	-0.97	-4.38	15
-0.79	-1.90	-1.37	-0.01	-1.00	-4.42	16
-1.07	-2.01	-1.50	-0.44	-1.19	-4.47	17
-0.85	-2.01	-1.37	-0.08	-1.01	-4.41	18
-1.32	-1.20	-1.18	-0.01	-0.95	-4.34	19
-1.73	-1.75	-1.55	-0.01	-1.29	-4.49	20
-0.97	-1.20	-1.02	-0.17	-0.87	-4.35	21

3.3.3. Pollution load index

To investigate the pollution state in the study area, pollution load index (PLI) was computed according to Tomolison *et al.* (1980) using the following equation:

$$PLI = (CF_1 \times CF_2 \times \ldots\ldots\ldots CF_n)^{1/n}$$

Where PLI is Pollution load index, CF is Contamination factor which is equal to the concentration of the metal in sediment sample divided by its reference material concentration (Table 9) and n is number of metals investigated.

The following terminologies are used to describe the contamination factor: CF<1 low contamination factor; 1<CF<3 moderate contamination factor; 3<CF<6 considerable contamination factor and CF>6 very high contamination factor (Saleh, 2006).

The pollution load index calculated for all the bottom sediments samples (Table 9) fall in the first terminology (CF<1, low contamination factor) except sample 8 that fall in the second terminology (1<CF<3, moderate contamination factor). This may be attributed to the location of the collected samples from the entrance of the harbor, where it is very active area, but the level of pollution in that area is insignificant, because the value of the calculated PLI was 1.1 only.

The pollution load index calculated for all the land sediment samples (Table 9) fall in the first terminology (CF<1, low contamination factor). Indicating that, the land sediments samples are unpolluted by the heavy metals under investigation.

Table 9. Pollution Load Index values of heavy metals inthe sediments from Damietta harbor and adjacent sea area.

Quality of sediment	**PLN**	**Samples**
Bottom samples		
Low contamination factor	0	1
Low contamination factor	0	2
Low contamination factor	0	3
Low contamination factor	0.81	4
Low contamination factor	0.69	5
Low contamination factor	0.56	6
Low contamination factor	0.65	7
Moderate contamination factor	1.10	8
Low contamination factor	0.86	9
Low contamination factor	0	10
Low contamination factor	0.92	11
Low contamination factor	0.84	12
Low contamination factor	0.92	13
Land samples		
Low contamination factor	0.26	14
Low contamination factor	0.30	15
Low contamination factor	0.50	16
Low contamination factor	0.44	17
Low contamination factor	0.49	18
Low contamination factor	0.53	19
Low contamination factor	0.43	20
Low contamination factor	0.56	21

4. Conclusion

In general, the spatial distribution of heavy metals in the sediments from Damietta harbor and the adjacent sea area is controlled by the association of heavy metals with fine particles (silt-clay) and total organic carbon content. The present study reflects the impact of anthropogenic input as a source for heavy metals to the harbor sediments. The results from these studies indicated that, the heavy metal pollution in Damietta harbor is low, only the entrance part of the harbor recorded medium level of pollution. So, the pollution status of Damietta harbor had not reached the risk threshold.

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تقييم التلوث ببعض العناصر الثقيلة بميناء دمياط ـ مصر

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لقد تم تعيين تركيز بعض العناصر الثقيلة (الحديد, المنجنيز, الزنك, النيكل و الكروم) فى رسوبيات ميناء دمياط و الجزء البحرى المتصل بالميناء. و عليه فقد تم تجميع عدد 21 عينة رسوبيات و ذلك لتعيين تركيز و توزيع العناصر الثقيلة و علاقتها بتوزيع الرسوبيات و نسبة الكربون العضوى.

و لتقييم العناصر الثقيلة سابقة الذكر تم حساب كلا من المعاملات التالية (معامل التغذية EF , معامل التراكم الجيولوجى I_{geo} ، و معامل حمل التلوث PLI) وذلك لمعرفة مصدر العناصر الثقيلة هل من البيئة (طبيعيا) أم نتيجة التلوث.

و بحساب معامل التغذية (EF) وجد انه لكل العناصر الثقيلة التى تم قياسها يتراوح معامل التغذية من بدون تلوث الى متوسط التلوث. بالنسبة لمعامل التراكم الجيولوجى (I_{geo}) تتراوح النسبة من بدون تلوث الى متوسط التلوث لكل العناصر ماعدا عنصر الحديد (Fe) الذى سجل بدون تلوث فى كل العينات. بينما معامل حمل التلوث (PLI) فلقد سجلت كل العينات معامل قليل التلوث ماعدا العينة التى تم تجمعها من مدخل الميناء سجلت نسبة تلوث متوسطة.

وبمقارنة تركيزات العناصر الثقيلة التى تم قياسها مع معايير السمية (Toxicity guide lines) المتمثل بخطى التأثير المنخفض و المتوسط (ERL & ERM) وذلك لتقييم مدى التأثير البيولوجى على البيئة البحرية, فقد كان جميع العينات تقع بين خطى التأثير المنخفض و المتوسط وهذا يدل على ان تلك الرسوبيات لا تمثل تأثير مباشر على الحياه البحرية بالمنطقة فى الوقت الحالى.