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Contamination of Coastal Sediments in El-Hamrawein Harbour, Red Sea, Egypt

[1]Hashem Abbas Madkour, [2,3]A. El-Taher, [4]Abu El-Hagag N. Ahmed, [1]Ahmed W. Mohamed and [4]Taha M. El-Erin

[1]National Institute of Oceanography and Fisheries, Red Sea Branch, Hurghada 84511, Egypt
[2]Department of Physics, Faculty of Science, Al-Azher University, Assuit Branch, 71542 Assuit, Egypt
[3]Department of Physics, Faculty of Science, Qassium University, Buraydah, 51452 Saudi Arabia
[4]Shore Protection Authority, Egypt

Corresponding Author: Dr. Atef El-Taher, Department of Physics, Faculty of Science, Al-Azher University, Assuit Branch, 71542 Assuit, Egypt

ABSTRACT

This study deals with the environmental problem of increased heavy metals concentrations in the coastal sediments due to preparation and shipment operations of phosphate ore in El-Hamrawein harbour, Egyptian Red Sea coast. It represents a baseline information about the human impacts and could be useful for management and further development of the area Grain size, contents of carbonate, organic matter and phosphorus as well as concentration of some polluting heavy metals were determined in the coastal sediments. The study coastal sediments are mainly fine sand showing high concentration of heavy metals with average 1796, 542, 42.2, 17.8, 38.5, 42.2 and 2.3 ppm for Fe, Mn, Zn, Cu, Pb, Ni and Cd. The results indicate that the distribution of the heavy metals in the surface sediments is particularly affected by the high contribution of phosphate ore loading operations as shown by the positive correlation between the phosphorous and these metals. It is suggested that the study sediments are relatively contaminated comparing with the other Egyptian Red Sea coastal sediments. The phosphate dust accelerates nutrient level, creating algal development and possible eturophication which detriment of corals and other life forms. Therefore, an environmental monitoring and management program is proposed in the study area.

Key words: Heavy metals, coastal sediments, natural inputs, El-Hamrawein harbour, Red Sea

INTRODUCTION

The study of the contaminant heavy metals in the coastal sediments of El-Hamrawein harbour along the Egyptian Red Sea coast is a subject of much interest due to the strong influences of phosphate shipment operations as well as the derived materials from the nearby wadis (e.g., Wadi Hamrawein), on the marine environment in this area and its surroundings. Phosphate loading operations at El-Hamrawein harbour create immense clouds of dust, which depending on the wind direction, then settle down on the adjacent coastline or directly fall in the water. These dust is leading to the abnormal increase of the nutrient content causing a deflection in the environmental stability. Rock phosphates contain large amounts of metals especially zinc and cadmium as impurities (McMurtry *et al.*, 1995). The ecological risk produced by metals largely depends on their forms in water, the capacity of metals for complexing, sedimentation and bioaccumulation (Tessier *et al.*, 1985; Mcintosh, 1991). In marine environment, sediments are an important source for assessing heavy metals pollution, as they have a long residence time.

Many investigations have dealt with recent sediments and human impact on the Egyptian Red Sea coast (El-Sayed, 1984; El-Mamoney, 1995; Nawar *et al.*, 1997; Mansour, 1999; Mansour *et al.*, 2000; Ziko *et al.*, 2001; Dar, 2002; Madkour, 2004; Mansour *et al.*, 2005; Madkour, 2005; Madkour *et al.*, 2008; El-Taher and Madkour, 2011; Mansour *et al.*, 2011; Mohamed *et al.*, 2011; El-Taher *et al.*, 2004; El-Taher, 2007). However, investigations including the impact of development activities along the Red Sea coast are still rare.

This study represents baseline information of the anthropogenic impacts on El-Hamrawein area. Hence, it could be useful for the management and sustainable development of the area.

MATERIALS AND METHODS

Study area: El-Hamrawein harbour is considered as one of the old phosphate harbours on the Egyptian Red Sea coast. It is located about 20 km north of Quseir City. The study area lies between latitudes 26° 15'02''N and 26° 15'17''N and longitudes 34° 12'07"E and 34° 12' 00"E (Fig. 1). This harbour lies at the mouth of Wadi Hamrawein. Terrigenous sediments have been transported to the marine environment through this wadi. Vegetated coastal dunes and sabkhas occupy the lowland areas at its mouth. The supratidal area represents sabkha area while the shoreline occupied by fine to medium beach sands. The tidal flat is very narrow and extents smoothly and slopes gently seaward. Most sediment samples have brown color, due to phosphate shipment operations (Fig. 2a-d). The system of the malaise of marine environment deterioration at El-Hamrawein area includes the spread of dense seagrasses, algal blooms, coral bleaching and declining of productivity (Fig. 2). This observation needs more investigations.

Materials: In the year 2005, twenty-two samples have been collected from El-Hamrawein harbour. Surface sediment samples represent four different environmental features; supratidal

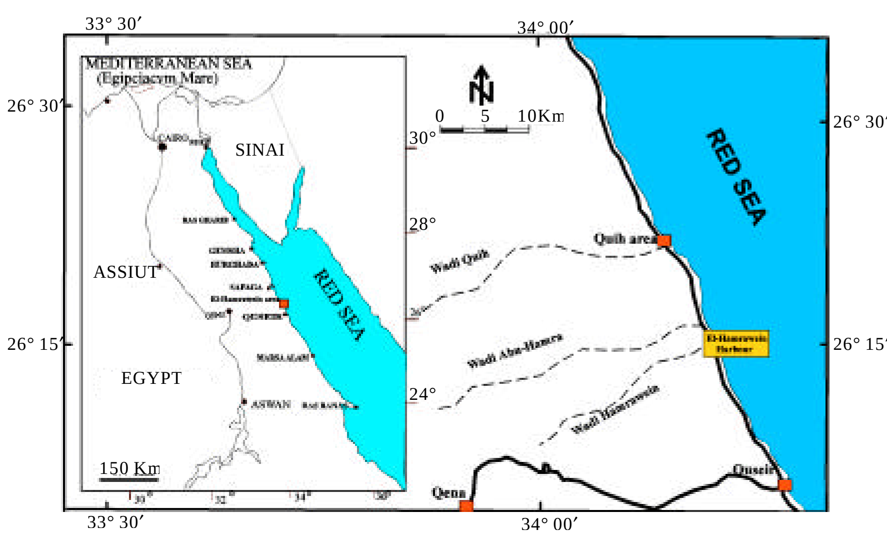

Fig. 1: Location map of El-Hamrawein harbour

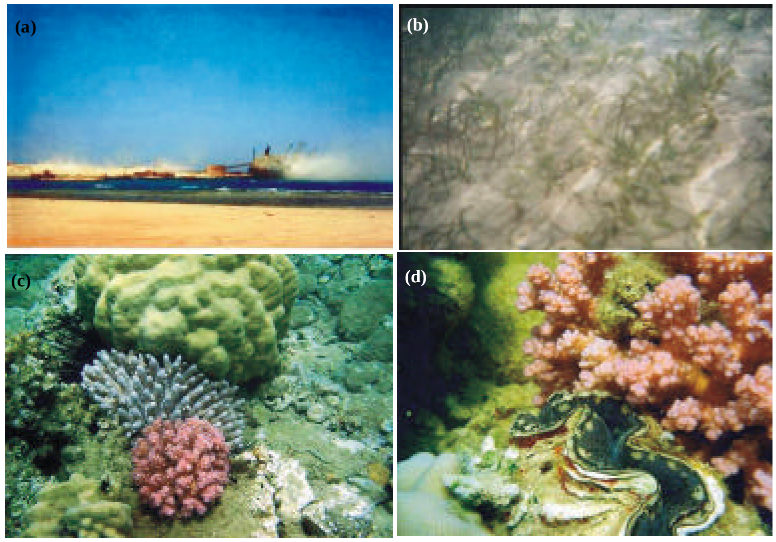

Fig. 2(a-d): (a): Phosphate shipment operations, (b): Dense of seagrasses and algae affected by the phosphate dusts, (c) and (d): Patches of high diversity of some species of corals and bivalve species (*Tridacna* sp.) at El-Hamrawein harbor

zone, beach, intertidal zone and offshore zone. The study area was divided into three transects H1, H2 and H3 from south to north. Transect H1 was taken in the southern part in front of Wadi Hamerawein. Transect H3 was taken under platform of phosphate shipment, while transect H2 was taken between H1 and H3, which covering the harbour area. The samples were collected by hand and SCUBA diving with depth from zero to 20 m below sea level. The collected samples (22 samples) were placed in labeled plastic bags and returned to the laboratory.

Methods: Grain size analysis provides basic information for the geochemical investigations of marine sediments. The analysis was performed using the sieving technique according to Folk and Ward (1957). All geochemical analyses were carried out in duplicates and the average data were considered. The total carbonate content was determined by treating the samples with one normal hydrochloric acid (1N HCL acid). The insoluble residue remaining after acid washing was determined and the carbonate percentage was calculated. Determination of organic matter was made by sequential weight loss at 550°C (Dean, 1974; Flannery *et al.*, 1982; Brenner and Binford, 1988; El-Saeid *et al.*, 2011; Uzoije and Egwuonwu, 2011). Determination of total phosphorus was made according to APHA (1995). Concentrations of the metals; Fe, Mn, Zn, Cu, Pb, Ni and Cd were determined according to Oregioni and Aston (1984). About 0.5 g of the prepared ground sample was completely digested in a Teflon cup by using a mixture of conc. nitric, perchloric and hydrofluoric acids, with the ratio 3:2:1, respectively. Acids were slowly added to the dried sample and left overnight before heating. Samples were heated for two hours on hot plate at temperature of approximately 200°C, then left to cool and filtered to get rid of the nondigested parts. The solution was justified to volume of 25 mL, then the concentration of the elements was determined by Atomic Absorption Spectrophotometry (AAS) (GBC-932 Ver. 1.1). The analyses were carried out in National Institute of Oceanography and fisheries, Red Sea branch.

Correlations and cluster analyses were carried out to determine associations among elements and to objectively find groupings of similar samples in the study area.

RESULTS AND DISCUSSION

Grain size distribution: Grain size helps in determining the textural and depositional characteristics of the environment. The granulometric fractionation of the coastal marine sediments in El-Hamrawein harbour showed drastic difference in admixtures of sand, mud and gravel fractions. The contents of sand vary from 40.6 to 99.9% (avg. 90.5%), mud from 0.1 to 53.6% (avg. 7.2%) and gravel from 0.0 to 11.3% (avg. 2.3%). The sediment nomenclature, according to Folk and Ward (1957) is shown in Table 1. The sand fraction is dominant and constitutes more than 90% of the total samples weight. The observed texture of the samples reflects a highly varied energy regime with strong ebbing and flooding intervened substantially by terrigenous flux from the opposite wadi.

Table 1: The results of grain size and geochemical analysis of marine sediments of El-Hamrawein harbor

	Sediment types			Grain size parameters (Folk and Ward, 1957)														
								Carb.	OC	TOM	P	Fe	Mn	Zn	Cu	Pb	Ni	Cd
S. No.	Gravel	Sand	Mud	Mz	6I	SkI	KG	(%)			(ppm)							
H1-1	4.1	95.8	0.1	2.1	1.0	-0.3	1.8	34	1.1	2.0	4332	1954	356	66	18	30	25	1.7
H1-2	8.0	91.3	0.7	0.5	1.1	0.1	1.0	74	2.5	4.5	4196	1209	158	26	12	30	32	1.7
H1-3	11.3	87.7	1.0	0.3	1.1	0.1	0.9	86	2.9	5.2	4040	728	90	23	10	35	43	2.3
H2-4	5.5	69.5	25.0	3.0	2.5	0.1	1.5	59	2.2	3.9	5366	1816	467	157	29	33	53	3.2
H2-5	0.7	98.1	1.2	3.1	0.5	-0.1	1.0	45	1.6	2.9	5092	1834	362	67	14	28	43	2.0
H2-6	0.0	97.3	2.7	3.3	0.5	-0.1	1.4	41	1.9	3.5	4950	1956	415	67	17	32	45	2.1
H2-7	0.3	72.2	27.4	3.9	1.3	0.5	2.4	54	2.5	4.5	6036	1840	409	95	19	33	42	2.8
H2-8	0.3	87.2	12.5	2.9	1.3	0.0	1.9	51	1.2	2.1	4996	1913	409	76	19	33	34	2.2
H2-9	1.9	86.0	12.0	2.3	1.6	0.0	1.3	53	1.6	2.9	5128	1834	374	65	16	35	43	2.5
H2-10	0.2	94.9	4.9	2.1	1.1	0.1	1.0	61	2.0	3.6	4010	1528	251	42	11	39	41	2.2
H2-11	0.1	98.0	1.9	2.8	0.6	0.0	1.2	57	1.9	3.5	4706	1566	292	40	17	39	36	2.0
H2-12	0.1	99.2	0.7	2.3	0.6	0.0	1.4	71	1.5	2.7	5418	1309	198	31	13	43	40	2.4
H2-13	0.1	92.3	7.6	3.3	0.7	0.2	2.2	58	1.8	3.2	5742	1643	309	66	16	49	43	2.4
H2-14	5.9	93.0	1.1	0.8	1.2	0.0	0.9	79	3.4	6.1	6954	1730	543	174	22	37	41	3.7
H3-15	5.7	40.6	53.6	3.9	3.1	-0.1	1.2	31	4.3	7.7	5430	2159	782	153	32	38	48	2.7
H3-16	0.1	99.6	0.3	2.5	0.6	-0.1	1.4	39	4.3	7.7	4578	2219	952	81	23	37	45	1.7
H3-17	0.5	99.4	0.1	2.9	0.5	0.1	1.0	25	1.1	1.9	4826	2100	1413	67	18	32	46	1.7
H3-18	1.6	98.1	0.3	2.9	0.6	0.1	1.0	27	1.7	3.0	4468	2120	1471	69	19	42	45	2.1
H3-19	0.0	99.9	0.1	1.7	0.7	-0.1	1.2	31	1.2	2.1	4710	2069	1098	57	17	35	44	2.0
H3-20	0.2	96.5	3.3	3.2	0.5	0.0	1.7	35	2.3	4.1	4868	2045	887	76	17	56	44	2.3
H3-21	0.0	98.1	1.9	3.2	0.5	-0.1	1.9	23	1.9	3.4	5280	2092	1208	67	17	46	47	1.9
H3-22	2.8	96.9	0.3	1.0	1.1	0.1	1.2	55	1.7	3.1	5108	1856	584	47	15	66	46	2.4
St. dev	3.2	13.9	13.0	1.0	0.7	0.2	0.4	18	0.9	1.6	680	357	408	40	5	9	6	0.5
Std.er.	0.7	3.0	2.8	0.2	0.1	0.0	0.1	4	0.2	0.3	145	76	87	9	1	2	1	0.1
Min.	0.0	40.6	0.1	0.3	0.5	-0.3	0.9	23	1.1	1.9	4010	728	90	23	10	28	25	1.7
Max.	11.3	99.9	53.6	3.9	3.1	0.5	2.4	86	4.3	7.7	6954	2219	1471	174	32	66	53	3.7
Avg.	2.3	90.5	7.2	2.5	1.0	0.0	1.4	49	2.1	3.8	5011	1796	592	73	18	39	42	2.3

Mz: Mean size, 6I: Sorting, SKI: Skewness, KG: Kurtosis, Carb.: Carbonate content, OC: Organic carbon, TOM: Total organic matter, St. dev.: Standard deviation, Std. er.: Standard error, Min.: Minimum, Max.: Maximum, Avg.: Average

Table 2: Correlation coefficients between grain size analysis, carbonate content, total organic matter Phosphorus and heavy metals of marine sediments of El-Hamrawein harbour

	Gravel	Sand	Mud	Mz	Carb.%	TOM%	P	Fe	Mn	Zn	Cu	Pb	Ni	Cd
Gravel	1													
Sand	-0.39	1												
Mud	0.18	-0.97	1											
Mz	-0.62	-0.33	0.50	1										
Carb.%	0.54	-0.03	-0.09	-0.62	1									
TOM%	0.40	-0.50	0.44	-0.04	0.20	1								
P	-0.10	-0.29	0.33	0.24	0.15	0.21	1							
Fe	-0.56	-0.07	0.21	0.61	-0.87	-0.01	0.21	1						
Mn	-0.33	0.13	-0.06	0.30	-0.79	-0.03	0.00	0.73	1					
Zn	0.16	-0.60	0.60	0.31	-0.10	0.47	0.68	0.44	0.20	1				
Cu	0.08	-0.68	0.71	0.47	-0.35	0.47	0.42	0.59	0.35	0.86	1			
Pb	-0.21	0.16	-0.13	-0.03	-0.06	0.00	0.13	0.11	0.20	-0.13	-0.10	1		
Ni	-0.09	-0.28	0.32	0.31	-0.22	0.26	0.26	0.28	0.44	0.37	0.39	0.30	1	
Cd	0.28	-0.49	0.46	-0.01	0.44	0.33	0.77	-0.08	-0.20	0.74	0.44	0.09	0.35	1

Mz: Mean size, 6I: Sorting, SKI: Skewness, KG: Kurtosis, Carb.: Carbonate content, OC: Organic carbon, TOM: Total organic matter, St. dev.: Standard deviation, Std. er.: Standard error, Min.: Minimum, Max.: Maximum, Avg.: Average

The statistical parameters of grain size distribution are presented in Table 1. More than 77% of the sediment samples of El-Hamrawein harbour are within the fine-to-very fine category of the sand class and have mean grain size between 0.3 and 3.9 Φ averaging 2.5 Φ. The remaining samples are rich with the coarse sand fraction. More than 54% of the sediment samples are moderatly to well sorted. The dominance of mud fraction is responsible for the poor sorting in the remaining samples. The skewness and kurtosis values are indicative of an enrichment of finer grained sediments with respect to mean size.

Geochemistry

Carbonates: Sediment sampled from El-Hamerwein harbour have carbonate contents range from 23.5 to 85.7%, averaging 49.55. The sediments have low carbonate content due to the terrestrial inputs from Wadi Hamrawein. Moreover, El-Hamrawein harbour is the big harbour for shipment of phosphate rock products. In addition, negative correlation has been observed between carbonate contents and most metals in the sediments (Table 2). Most of the analyzed heavy metals, the decrease is particularly strong for Fe, Mn and Cu (r = -0.87, -0.79 and -0.35, respectively). Generally, the carbonate content increase seaward (Table 1).

Organic matter: The total organic matter content of samples of El-Hamrawein harbour changes from 1.9 to 7.7%, averaging 3.8%, while organic carbon content varies from 1.1 to 4.3%, averaging 2.1% (Table 1). In comparison, Madkour 2004 found that the average distribution of total organic matter in the marine sediments varies from 2.1% at Quseir harbour to 3.39% at Safaga harbour. This value in Safaga harbour is similar to that of the present work. Biological productivity in the surface water, chemistry of the water column and sedimentation rate are the most important factors controlling the geographical variation of organic matter content (Cho *et al*., 1999).

A positive correlation is observed between organic matter and gravel and mud fractions while it shows negative correlation with sand fraction (Table 2). The coarse fractions are mainly of biogenic origin. The weak positive correlation (r = 0.2) between organic matter and carbonate and phosphorus probably suggests another source of organic matter (terrigenous flux from the wadi).

Generally, the total organic matter content in the coastal marine sediments of El-Hamrawein harbour seems to be controlled primarily by variations in terrigenous and biogenic admixtures of the sediments.

Phosphorus: Phosphorus is an essential and often limiting nutrient in marine ecosystem, yet its oversupplying of concern in many environments due to its role in eutrophication. In El-Hamrawein harbour, phosphorus content varies from 4010 to 6954 ppm, averaging 5010 ppm. The average contents of phosphorus in the marine sediments are 6303 ppm at Quseir harbour and 5125 ppm at Safaga harbour (Madkour, 2004). The average phosphorus contents in El-Hamrawein harbour are similar to those in Safaga harbour but lower than that of Quseir harbour.

In general, the P content of the coastal sediments in El-Hamrawein harbour may reach abnormally high values near the phosphate-loading berth. The P content decreases with increasing distance from the berth. The addition of phosphate dust accelerates nutrient level, creating algae development and possible eutrophication to the detriment of corals and other life forms. The high diversity of corals includes only some species such as *Pocillopora* sp., *Acropora* sp. and *Porites* sp. and bivalve species (*Tridacna* sp.) (Fig. 2 and Field observations by SCUBA diving). Besides causing an increase in food productivity, phosphate dust can cause water turbidity, which reduces light penetration and direct smothering and interference with feeding and respiratory processes.

There currently exists a certain amount of disagreement on the impact of phosphate dust on the ecology of the Red Sea water, but there is still a urgent need to expand the research area and to co-ordinate the efforts.

Metals concentration: Heavy metals concentration and their distribution in the coastal sediments of El-Hamrawein harbour show remarkable variability. The obtained data of heavy metals (Table 1) show rapid lateral variation among the selected samples within the study area. The variations are due to the grain size of sediments; organic matter contents; distance and location of the sampling site from the source of pollution. The concentrations of these metals range from 728 to 2219 ppm for Fe, 90 to 1471 ppm for Mn, 23 to 173 ppm for Zn, 10.3 to 32.3 ppm for Cu, 28.3 to 65.8 ppm for Pb, 24.6 to 53.3 ppm for Ni and 1.7 to 3.7 ppm for Cd. Table 1 shows the range, average, standard deviation and standard errors of variation of the total metals. The average distribution of heavy metals concentrations recorded high values especially for Cd, Zn, Cu and Pb compared to that of Quseir and Safaga harbours by (Madkour, 2004). Moreover, the samples were collected blow the platform of phosphate shipment has high values, with a general decrease with increasing distance from the berth. This indicates that the high concentration of heavy metals is mainly localized in vicinity of the loading berth although its influence may be detected in other areas along the coast. According to Abu-Hilal *et al.* (1988) a thick phosphate dust layer covers the original sediments of Aqaba harbour and the freshly deposited raw phosphate powder contains high level of heavy metals (ppm, dry wet) of Cd (<4-9), Cr (50-105), Cu (19-48), Mn (>77) Ni (>20) and Zn (190-490) (Jordan Phosphate Mines Company). Accordingly, this layer is considered as potential sources for many metals (Abu-Hilal, 1987). McMurtry *et al.* (1995), Al-Shuely *et al.* (2010), Al-Sheikh and Fathi (2010), Hosseini and Hosseini (2011) found that rock phosphate contains large amounts of zinc and cadmium as impurities. All metals of El-Hamrawein harbour display positive correlations with phosphorus (Table 2). High positive correlation was recorded between Cd and P ($r = 0.77$) and Zn and P ($r = 0.68$). The results reflect that these metals are in association with phosphate ore deposits in the marine sediments of the study area.

Another factor that helps in increasing the heavy metals content in the sediments of El-Hamrawein harbour is the influence of terrigenous inputs from Wadi Hamrawein, which faces the study area. Generally, the metals content of sediments depends on their chemical and mineralogical compositions (Horrowitz, 1991; Al-Othman, 2011; Dekhil *et al.*, 2011).

The comparison of metal concentrations in coastal sediments of this study area with other marine sediments of the former studies on the Egyptian Red Sea coast is presented in Table 3. All metals in the present work, except iron and manganese, show high values compared to that of Quseir and Safaga harbours by Madkour (2004). Also Zn and Cd concentrations record high values compared with the former studies of the Egyptian Red Sea coast (Table 3), while Zn concentrations are high values in Wadi El-Gemal are by Madkour (2005). Generally, the high concentration of metals in El-Hamrawein harbour relative to other studies of the Egyptian Red Sea coast suggests possible pollution.

Cluster analysis, applying, Ward method, four main clusters were distinguished, based on 7 variables of heavy metals (Fig. 3). The first cluster (9 samples) includes most samples in transect H2. This cluster shows high concentrations of cadmium, zinc and copper. The second cluster represent 27% of the total samples. All samples fall in transect H2 except one sample in transect H1. This cluster shows the lowest concentrations of metals (Fe, Mn, Zn, Cu and Ni) and can be used as background level of metals. The third and fourth clusters include all samples in transect H3 and is characterized by high concentrations of all metals. The samples of clusters 3 and 4 were collected blow the shipment platform. This reflects high metals concentration due to shipment operations of phosphate. Also, this indicates that the source of metals in the study area is phosphate ore deposits and the high concentrations in transect H3 support this result. Rock phosphate contains large amounts of Cd, Zn, Co, Ni, Pb and Cu should be considered in metal transport assessment,

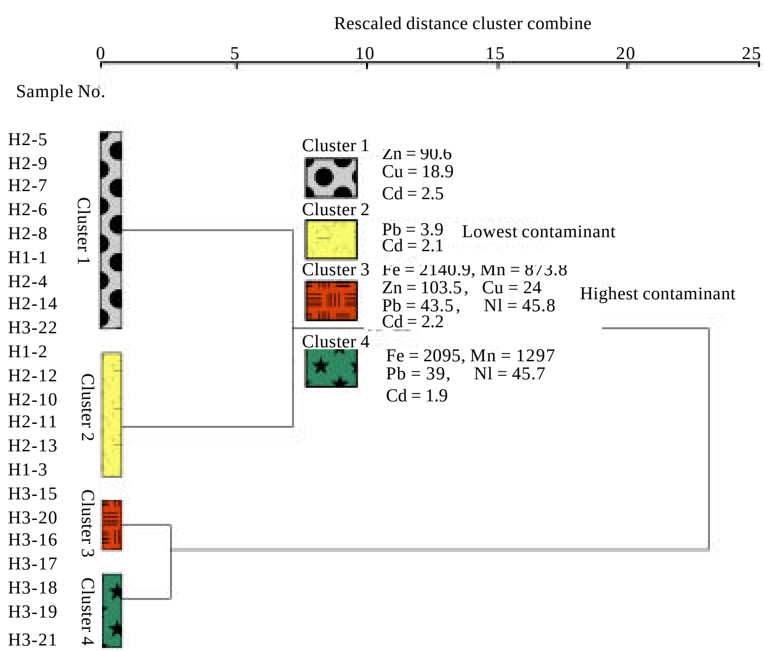

Fig. 3: Cluster analysis dendrogram (Ward's method) of heavy metals of sediment samples throughout El-Hamrawein harbour

Table 3: Comparison of the metal concentrations (ppm) in the studied marine sediments and published datd on the Egyptian Red Sea coast

Heavy metals		Other studies of the Egyptian red sea coast													
		El-Sayed (1984)	Beltagy (1984)	El-Mamoney (1995)				Nawar *et al.* (1997)	Mansour *et al.* (2000)	Dar (2002)	Madkour (2004)				Madkour (2005)	The present work
		Al-Ghardqa	North Red Sea	Wadi El-Hamra	Wad El-Esh	Wa Abu Shaar	Wadi Khashir	Hurghada area	Red Sea coast	Hurghad area	Quseir harbour	Safag harbour	Hurghada harbour	El-Esh area	Wadi El-Gemal	
Fe	Range	1900- 6000	95-4990	~~~~	~~~~	~~~~	~~~~		~~~~	~~~~	~~~~	~~~~	~~~~	~~~~	2266-3306	728-2219
	Avg.	3800	1322	10600	4900	4800	6000	6700	14000	12000	10000	7000	2916	1796		
Mn	Range	120-360	2-418	118-316	9-190	93-176	135-339	~~~~	127-609	~~~~	414-1458	66-1747	22-421	32-1557	162-968	90-147
	Avg.	210	55	236	107	125	180	205	902	1145	112	153	536	529		
Zn	Range	11.1-90	10-330	10-19.1	8-20.1	8-81.1	8-27.1	10.5-30.3	13.6-73.5	8.8-245	7.9-44	3.5-47.3	0.6-93.4	4.8-114.7	18-283	23-173
	Avg.	31	70.7	15	26	15	12	17.59	21.35	15.39	9.05	14.46	79	73.4		
Cu	Range	8.5-27.5	3-79.2	9-19.1	2-16.1	1-9.1	2-17.1	5.6-30.6	11.7-57.8	2.5-95.3	1.15-10	1.8-142.8	0.5-43.2	1.4-366	5.2-453	10.3-32.3
	Avg.	21	16	13	14	6	7	14.02	4.12	9.07	4.09	76.74	36.22	17.9		
Pb	Range	~~~~	10-110	40-60	60-101	44-78	66-91	54.5-108	14.4-71	9.9-114.4	0.2-27.5	0.5-118.7	3.1-128.9	0.03-187	12.7-96	28.3-65.8
	Avg.	75	49	57	56	81	19.81	10.47	21.56	19.54	11.28	41.7	38.5			
Ni	Range	~~~~	~~~~	15-149	11-70.1	29-69	7-49.1	17.1-51.4	4.6-57.8	9.9-613.1	14.3-38.3	13.8-82.1	3.9-16.9	1.2-33.4	11-156.3	24.6-53.5
	Avg.	44	43	45	19	23.48	26.52	38.37	8.86	9.78	51.39	42.2				
Cd	Range	~~~~	~~~~	0.1-1.51	0.1-2.8	0.4-1.2	0.001-1.9	~~~~	0.1-1.71	1-5.25	0.04-3.4	0.2-4.1	0.1-0.5	0.03-2.4	0.02-0.2	1.7-3.7
	Avg.			0.48	0.532	0.894	0.935		0.96		1.01	1.33	0.34	0.5	0.078	2.3

ecosystem studies and environmental assessments (Kpomblekou and Tabatabai, 1994; Mahjoobi *et al*., 2010; Rajaganapathy *et al*., 2011; Omanayi *et al*., 2011; Al-Farraj *et al*., 2011; Jayashree *et al*., 2011).

The pollution of El-Hamrawein area has attracted the attention of environmentalists and other concerned with environmental hazards. Such information may be necessary when needed for the share in environmental pollution monitoring program in the Egyptian Red Sea coast. On the other hand, the present data can be used as a database to monitor the success of strategies for the conservation of the Red Sea environment.

CONCLUSIONS AND RECOMMENDATIONS

The marine environment of the El-Hamrawein harbour and its surroundings is influenced by phosphorus pollution from shipping and processing of phosphorite ore.

The sand fraction is dominate and constitutes more than 90% of the total samples. Texture of sediments reflects a highly varied energy regime with strong ebbing and flooding intervened substantially by terrigenous flux from the opposite wadi. The carbonate content in the study area is low due to the terrestrial inputs from Wadi Hamrawein and the phosphate ore from the harbour. Generally, the variation in the heavy metals content of sediments reflects primarily the changes in sediment texture and carbonate contents. The total organic matter content in the coastal sediments of El-Hamrawein harbour is controlled primarily by variations in terrigenous and biogenic admixtures of the sediments.

Abnormally high phosphorus values of El-Hamrawein harbour have been recorded near the phosphate-loading berth. The currently exists a certain amount of disagreement on the impact of phosphate dust on the ecology of the Red Sea waters, but there is still a definite need to expand the research and co-ordinate the efforts.

The present geochemical study supports the concept that phosphate loading operations effluents have a great influence on the concentration and distribution of heavy metals in the studied marine sediments. Shipment activities are associated with the higher concentration of heavy metals such as Cd, Zn, Ni, Pb and Cu in the sediments. The concentration of metals in the sediments of the El-Hamrawein harbour are higher those quoted in former studies for the Egyptian Red Sea coast. This suggests that El-Hamrawein area is relatively contaminated.

More researches need to establish the toxicological effects of these polluted marine sediments on various life forms found in the marine environment. These results can be used as database for future investigations dealing with the effects of phosphate shipment operations in El-Hamrawein and the bioavailability of sediment-bound heavy metals.

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