EGYPTIAN JOURNAL OF AQUATIC RESEARCH **ISSN: 1687-4285**
VOL. 33 NO. 1, 2007: 59-84

SEDIMENTOLOGICAL AND ENVIRONMENTAL IMPACTS OF DEVELOPMENT PROJECTS ALONG THE COAST OF HURGHADA, RED SEA, EGYPT

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Keywords: Sedimentological, Environmental proplems, Tourism activities, Coast destruction, Red Sea, Hurghada.

ABSTRACT

The studies areas lay in Hurghada region include different aspects of coastal development. It represents different environmental problems and threats to the Red Sea ecosystem and geosystem. They include two tourist projects, a central marina for yachts and fishermen and a site for oil exploration and production. All sits have implemented Environmental Impact Assessment studies (EIA). Unfortunately, dredging and landfilling caused severe coast destruction and shoreline change in these areas. All sites have accurately surveyed and environmental problems cited, oceanographic parameters were measured, and 109 samples were collected from the beach and the tidal flat of four sits forming the study area. Grain size, carbonates and organic matter contents, major and trace elements were determined. Cluster analysis and correlations were carried out. The results reflect the impact of coast destruction and shoreline change. Grain size analysis indicated the predominance of coarse grained sediments close to the landfilled areas. Mixtures of terrigenous and biogenic fragments are the main components of these sediments. The distribution of carbonates supports this result where carbonates content is low in the beach area and gradually increases seaward. Fine sands and mud dominate the dredging areas and cover the nearby corals and bottom facies. Results of major and trace elements, total organic matter (TOM), organic carbon (OC), and carbonate contents were used to discuss the sediment characteristics and interpret the abundance of some parameters in the impacted areas. The findings of this study help decision makers to identify anthropogenic impacts and better assess of the needs for remediation.

1. INTRODUCTION

The coastal and marine resources of the Red Sea are contributed to the food, energy, oil exploration and production and touristic development of Egypt. These activities have the potential to conserve or enhance the marine environment. The quality and preservation of natural environments has become a leading concern in the last few years, especially in the coastal and marine realm where increasing population pressure and human activities stress a wide variety of natural systems. Generally, the environmental problems and threats to the Red Sea ecosystem and geosystem include recreation and tourism activities, land filling, dredging, water pollution, oil production, harbors and fishing practices (Piller and Mansour, 1990; El-Mamony, 1995; Mansour, 1995; Mohamed, 2000; Mansour *et al.*, 2000; and Mansour, 2003).

Studies of recent sediments in the beach and intertidal zone along the coast are very important in assessing potential environmental hazards resulting from unplanned human activities (Mansour *et al.*, 2000). Different types of development projects were constructed along the coast of Hurghada. Landfilling activities throughout the shoreline of Hurghada, were determined by the environmental office of Red Sea Governorate. Dredging also has been carried out to construct lagoons, boat channels, causeways and port facilities such as jetties in some parts of the present study areas. These activities negatively impacted the marine environments in the area. The present study aims to shed some light on these activates and their impact on the sediments and the environment.

1.1. Environmental Problems

The coastal area of Hurghada City consists mainly of fringing coral reefs living over the coralline limestone at the end of a narrow tidal flat. A series of barrier reefs extends parallel to the coast and ended at El Fanadir stony islands. The southern part of the marine area of Hurghada is characterized by a series of stony islands such as; Giftun El Kabir, Giftun El Saghir, Abu Minqar and Um Gawish. Reefal sediments and sea – marginal lagoon sediments are the most characteristic sedimentary deposits in the near shore area of the Red Sea (El-Sayed, 1984; Friedman and Krumbein, 1985). The high load of terrigenous deposits transported to the shore by wadis, and hence the high turbidity of sea water prevented the formation of the coral reefs and this gave rise to the formation of embayments (Behairy, *et al.*, 1992). Raised fossil coral reefs higher than current sea level are one of the most striking features of the Egyptian Red Sea coast line. The coastal and marine environments of the Egyptian Red Sea constitute a relatively distinctive set of habitats and species in both the intertidal and subtidal areas. In the intertidal habitat, mangrove swamps are conspicuous and important ecologically. In subtidal areas, coral reefs and seagrass are the important habitats.

The selected four study areas cover different development projects along the coast of Hurghada and represent different environmental problems and threats to the Red Sea ecosystem and geosystem. They include two tourist projects, central marina for yachts and fishermen and an oil exploration and production site (Fig. 1). These projects have implemented EIA (Environment Impact Assessment) study with violation the law no 4/94 for the environment. Coast destruction, shoreline change, dredging and landfilling are the main environmental problems in these areas. These problems will become increasingly common as further coastal development occurs.

1.2. The First Tourist Site

This site is a tourist village located about 14 km south Hurghada at 27° 05′ 48″ N and 33° 50′ 47″ E (Fig.1). It lies behind mangrove swamps that prevents most terrestrial materials to reach the sea and at the same time permits biogenic carbonates to accumulate. The owner company of this project has got permission from the Egyptian Environment Affairs Agency (EEAA) to dredge coastal lagoon and to construct a pillared jetty with some environmental guidelines must be taken during constructions. The original coastline of this area has been completely altered by dredging and landfilling operations (Fig. 2A, B & C). The total land filling is about 74014.3 m^2 (Fig. 3a).

1.3. The Second Tourist Site

This site is also a tourist village located about 8km south Hurghada at 27° 09′ 48″ N and 33° 49′ 24″ E. The owner company of the project has got permission from the EEAA to dredge a coastal lagoon behind the setback zone (30m from the shoreline) without any landfilling and to construct a pillared jetty. Unfortunately, fill operation has been carried out on the reef flat in front of the site using sediments transported from the land of this site and dredged a closed lagoon inside the landfilled area (Fig. 2D,E,F). The total land filling is about 89670.8 m^2 and the dredging is about 8422.3 m^2 (Fig. 3b).

Fig. 1. Location map of the selected sites.

Fig 2. The first (A, B, C) and second (D, E, F) tourist sites and their environmental problems.

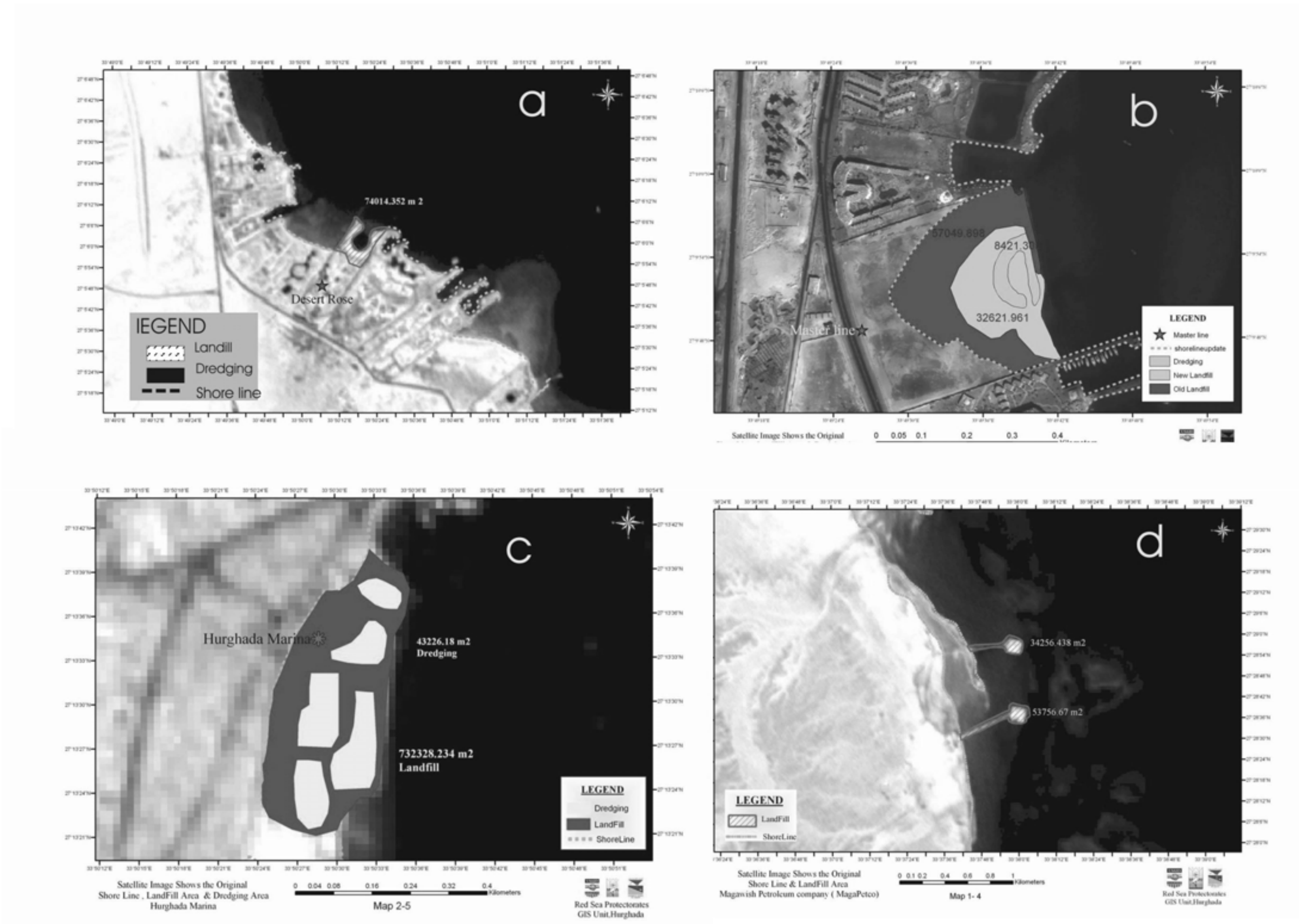


Fig.3. Satelite images after development shows the coast construction and change of shore line, landfill and dredging areas; the first toursit village (a), the secod toursit village (b), the central marina (c) and the site of oil exploration and producation (d).

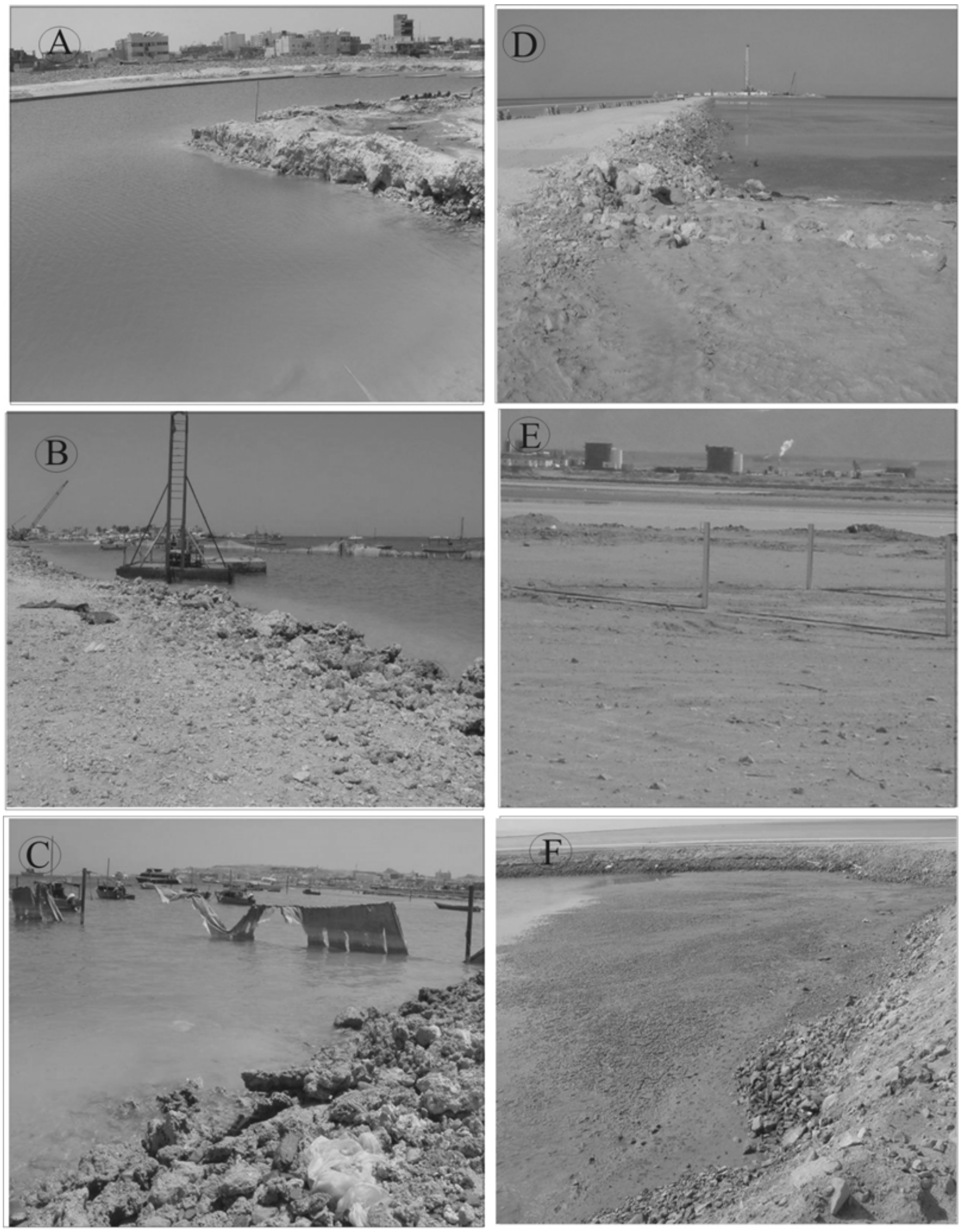


Fig 4. The central marina (A, B, C) and the site of oil exploration and production (D, E, F) tourist sites and their environmental problems.

1.4. The Yachts and Fishermen Marina

The marina is located in Sakkala area, about 5km south Hurghada at 27° 13′ 35″ N and 33° 50′ 28″E. This site was for fishermen boats and the contamination was massive. Plastic bottles, wood remains, sinking old boats, rubbish, cans and oil are the main wastes in the area. The fill operation has used sediments transported from the land outside the site and close to the mountain area (Fig. 4A,B & C). The total land filling is about 732328.2 m^2 and dredging is about 43226.18 m^2 (Fig. 3c). Coastline alteration by dredging and landfilling operations of shallow water areas and the excavating artificial lagoons are the main environmental problems causing massive destruction of the marine life in the area.

1.5. The Oil Exploration and production Site

The site is located in the northern limits of Hurghada. about 35 km north of the City at 27° 28′ 27″ N and 33° 37′ 31″ E. The area is used for oil exploration and production. Two landfilled tongues connected with two landfilled islands (Platforms) have been constructed in the intertidal zone for drilling oil wells and connecting pipelines. The total land filling in the area is about 88013.108 m^2 (Fig. 3d). There was a huge impact on marine environment during fill operations and drilling the oil wells (8-12 wells). Wastes of drilling are distributed at the southern side of the landfilled platforms. Unfortunately, most of the released sediments during construction were washed into the sea. Nevertheless, a huge amount of dust was blown offshore. The original coastline has been completely altered by filling operations (Fig. 4D,E & F). During drill operations of the oil wells some crude oil was flown out beside the two platforms and tongues.

2. MATERIALS AND METHODS

One hundred and nine samples were collected in 2002 (12 samples from the beach and 97 samples from the intertidal zone), until the breaker zone at coral reef crest, in front of the different four development projects. The samples were taken by pushing a plastic box about 10 cm deep into the sediment. Oceanographic parameters that control the coastal features of the Red Sea, such as salinity, temperature, pH and turbidity values were determined during samples collection. Moreover, most of these parameters, especially water temperature (Temp), pH, salinity (S), total dissolved salts (TDS), specific conductivity (Spec) (ms/cm is the selected unit from the unit list of the used instrument), dissolved oxygen (DO), and oxidation reduction potential (Eh) were measured in the summer 2002 (July-August) at different studied localities in the area by using hydrolab surveyor-4 model instruments of Inst. Oceanography and Fisheries, Hurghada (Table 1).

The grain-size distribution of desalted sediments was determined by wet sieving of sand and gravel and by pipette technique for silt and clay fractions (Folk, 1974). The analyses were carried out in Inst. Oceanography and Fisheries, Hurghada. All chemical analyses were carried out in duplicates and the average data was determined. The total organic matter content of all samples was determined by Allison method (1935) that depends on the back titration. The organic carbon content determined as follows: Total organic matter = organic carbon x 1.8. Carbonate content was determined by treating the samples with HCl acid. The insoluble residue was separated and the carbonate % was calculated. Concentrations of 13 major and trace elements (Fe, Mg, Ca, Na, Cd, Mn, Co, Cu, Ni, Pb, Sr, and Zn) were determined using a computerized flame Atomic Absorption Spectrophotometer (Varian model) of Inst.

Table (1): Oceanographic parameters measured during summer 2002 at the studied localities.

Station	DO (mg/l)	S%	pH	Eh(MV)	Temp.	TDS (g/l)	Spec (ms/cm)
Abu Shaar	5.31	40.52	8.61	351	30.3	38.3	59.56
Hurghada Area	5.44	40.3	8.65	333	27.8	38.1	59.69
Marine station	5.55	40.47	8.61	355	27.5	38.32	59.87

Oceanography and Fisheries, Hurghada. Samples collected from areas away from any expected contaminants were used as reference material for trace metals (Mansour, *et al.*, 2000).

Multivariate analysis (correlation and cluster analyses) of data was carried out to determine associations among elements, and to objectively find groupings of similar samples along the coast. Analyses are carried out on the data using the computer programs of the SPSS.

3. CLIMATE AND OCEANOGRAPHIC INFLUENCES

Generally, in the northern Red Sea Coast, the prevailing wind is mainly NNW all the year round (Morcos, 1970). The average air temperatures at Hurghada are fluctuated around 17.38°C in winter and vary between 27.5 and 30.6°C in summer (the Egyptian Meteorological Authority Reports). Humidity depends on the activity of the wind region over this area. At night landward winds tend to be dry but lower temperature raise the relative humidity, also in summer ES wind over saturated with water occasionally bellows over the Red Sea.

A close relationship is observed between air and sea surface temperatures. Water temperature clearly reflects seasonal changes (summer: 28-29°C, winter: 21-23°C). In extreme shallow areas higher values were measured due to solar radiation (Piller and Pervesler, 1989).

Water temperature varies from 27.5°C to 30.3°C, salinity (S) from 40.3‰ to 40.52‰, pH values between 8.61 and 8.65, dissolved oxygen (DO) from 5.31 to 5.55mg/L, total dissolved salts (TDS) from 38.1 to 38.32 g/L, oxidation reduction potential (Eh) between 333 and 335mv, and specific conductivity (Spec) from 59.56 to 59.87ms/cm. The water salinity is relatively high in semiclosed areas as bays and valley mouth (up to 44.5 ‰ in July; Piller and Pervesler, 1989). The tide is semidiurnal, max. peak every 12 h with a mean tidal range of ab. 0.80 m.

4. GRAIN SIZE DISTRIBUTION

The present study deals with grain size characteristic of the beach and intertidal sediments in order to shed some light on the physical properties, real distribution and the depositional environment. The grain size were done initially on siliceous clastic sediments, but in the last few years, it has been used for carbonate rocks (Flügel, 1982), and mixed carbonate-non carbonate sediments (Mansour, 1989; Piller and Mansour, 1990; Mansour, 1995; Mohamed, 2000; Madkour, 2004). Some authors are of the opinion that the reliability of grain size parameters of carbonate sediments for estimating depositional conditions may be questioned seriously, because the unequal hydrodynamic behavior of skeletal particles having extremely diverse morphology and because much carbonate sediments either remain in place or has undergone little transportation (Jindrich,1969). Other workers have determined these parameters and successfully related with the environment of deposition (Lewis, 1969; Taylor and Lewis, 1970).

Although most of the collected sediments are biogenic, beach and near shore samples contain high amounts of clastic sediments highly influenced by geological and sedimentation factors. Therefore, the grain size analysis is important and gives a good idea about the particles size and characteristics of sediments.

Cluster analysis (using Ward's method) includes gravel, sand and mud separating all samples (109) into 3 main clusters (Fig. 5). The first cluster represents 30.27% (33 samples) of the total samples and is characterized by the abundance of sand (73.31%) and gravel (25.12%) with low mud (1.57%). The second cluster represents 29.36 % (32 samples) of the total samples and is characterized by the abundance of sand (98.1%) with very low mud (1.23%) and gravel (0.67%). The third cluster represents 40.37% (44 samples) of the total samples and is characterized by high sand (91%), highest mud content (5.92%) and low gravel (3.08%) compared to the other clusters. The reason for this high mud content of cluster 3 is the landfill and dredging.

Distribution of gravel, sand and mud fractions is related to the type of source sediment, water depth and the distance from the shore. The result indicated that the predominant sediments are the coarse sands, with some exceptions at the second tourist site and the oil exploration site where the mud content is up to 17.05% and 12.24%, respectively (Tables 2,3). The main reason for this high mud content is the landfill in these sites. From the beach to about few hundred meters seaward fine sands and mud dominate most areas, whereas medium to coarse sands occur in the beach and close to the dredging areas. In some areas fine sand and mud dominate the dredging areas. This distribution of coarser sediment may reflect the abundance of terrigenous sediments at the beach, and carbonates around the dredging areas. The distribution of carbonates supports this result where carbonate content is low at the beach and gradually or abruptly increases seaward (Fig. 2). During dredging the winnowed material are transported in the nearshore zone and leave the coarser materials behind. The gravel fraction reaches to the highest percentage in the sediments of the first tourist site (from 0 to 32.29%) and the centeral Marina (from 0.00 to 42.89%) due to the abundance of materials transported from the excavation in these areas. Sand is the dominant fraction in the sediments of the study areas.

The distribution of mean grain size (Mz) depends mainly on the type of sediments and the water depth. Therefore, the increase of mean grain size is associated either with the higher carbonate content or with the effect of dredged or landfill processes. The investigated sediments of different environments range from very fine skewness to very coarse skewness and from very platykurtic to very leptokurtic category. This variation in character of sediments is produced in one side by diversity of skeletal grains and the effectiveness of currents and wave actions and in other side by types of flux of clastic sediments. Duane (1964) recorded that negative skewness is produced by winnowing action along the beach and tidal inlets, where erosion or non deposition and high energy conditions prevail, while positive skewness is found in sheltered areas where fine materials may accumulate. He attributed a mixture of positively and negatively skewed curves to type of flux of clastic sediments. Similar kurtosis values were obtained by El-Sayed and Hosny (1980) for sediments of the intertidal zone in the area surrounding the National Institute of Oceanography and Fisheries at Hurghada. Folk and Ward (1957) recorded the high and low values of kurtosis to a mixed population. They also suggested that if the environment of final deposition is not effective in sorting, the kurtosis will remain high and the opposite occur if the environment is effective. Nordstrom (1977) has related the variations observed in different areas due to the difference in the mode of wave energy causing variations in redistribution of the sediments. Moreover, there are two main sources of sediments supply biogenic fragments from the sea and terrigenous influx from the hinterland and mountains. Folk and Robles (1964) and Pilkey *et al.*, (1967) showed that the carbonate beach sands tend to be leptokurtic or excessively peaked. Generally, the values of all size parameters of the sediments in different areas vary from one sample to another and there is no tendency for general increase or decrease along each area or from south to north reflecting the variations in the nature of the area, the source of the sediments and the water depth.

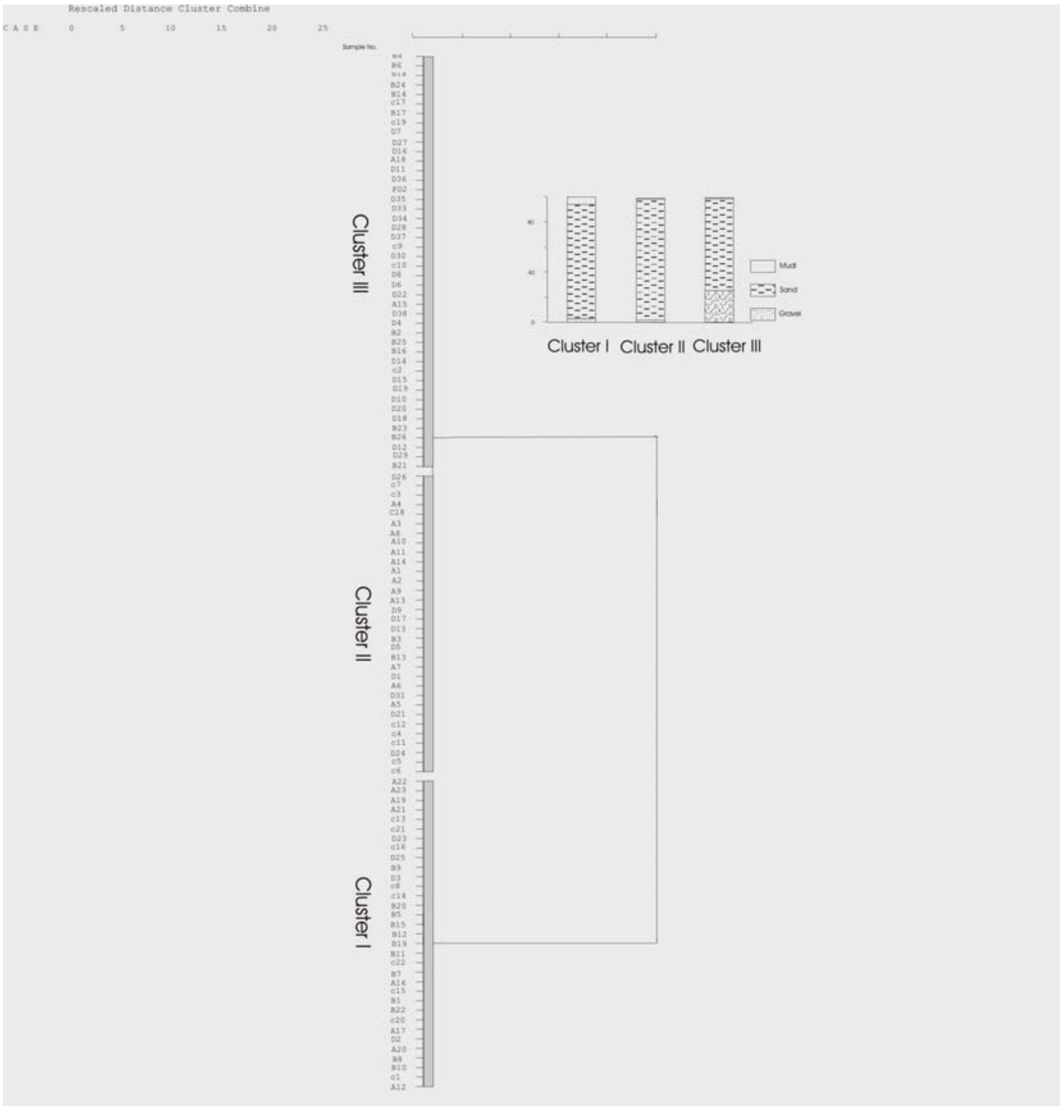
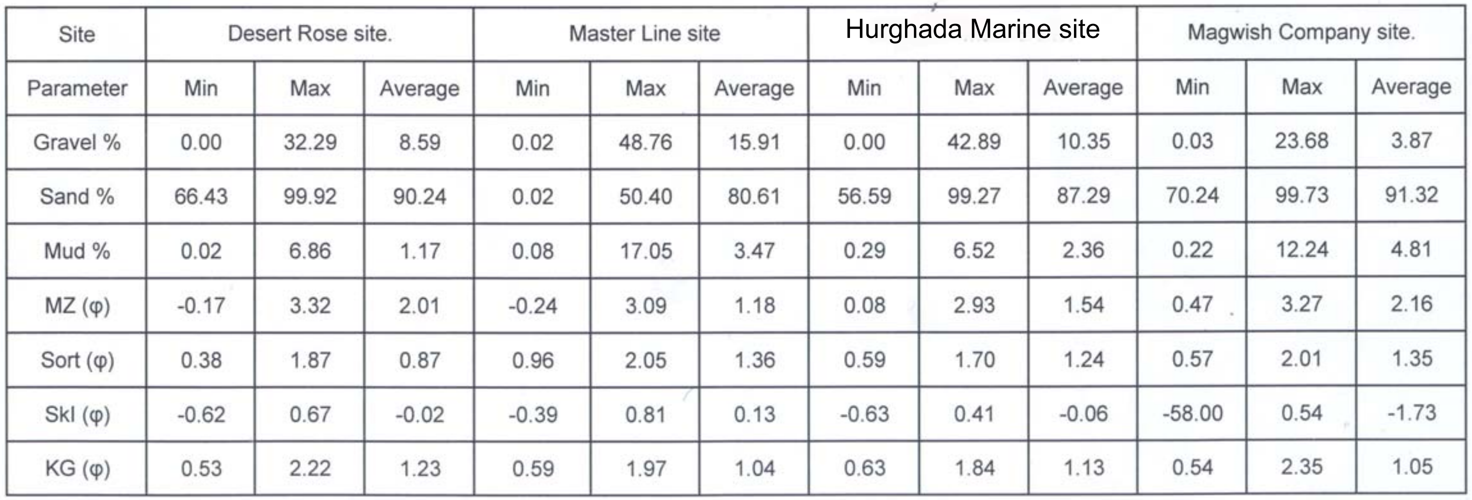


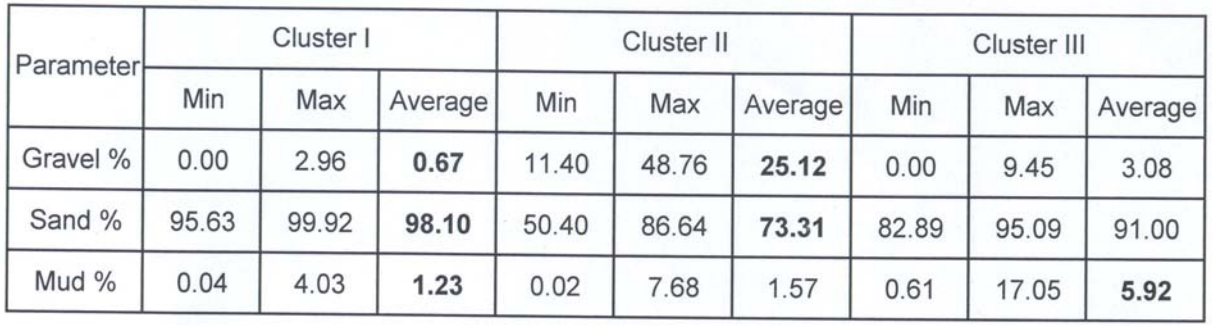
Fig. (5). Dendrogram from cluster analysis (Ward,s method) and histogram exhibiting cluster of grain sizetexture.

Table (2): Grain size parameters and textures of sediments of selected studied sites.



Site	Desert Rose site.			Master Line site			Hurghada Marine site			Magwish Company site.		
Parameter	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
Gravel %	0.00	32.29	8.59	0.02	48.76	15.91	0.00	42.89	10.35	0.03	23.68	3.87
Sand %	66.43	99.92	90.24	0.02	50.40	80.61	56.59	99.27	87.29	70.24	99.73	91.32
Mud %	0.02	6.86	1.17	0.08	17.05	3.47	0.29	6.52	2.36	0.22	12.24	4.81
MZ (φ)	-0.17	3.32	2.01	-0.24	3.09	1.18	0.08	2.93	1.54	0.47	3.27	2.16
Sort (φ)	0.38	1.87	0.87	0.96	2.05	1.36	0.59	1.70	1.24	0.57	2.01	1.35
Skl (φ)	-0.62	0.67	-0.02	-0.39	0.81	0.13	-0.63	0.41	-0.06	-58.00	0.54	-1.73
KG (φ)	0.53	2.22	1.23	0.59	1.97	1.04	0.63	1.84	1.13	0.54	2.35	1.05

Table (3): Grain size parameters and textures of sediments of different clusters.



Parameter	Cluster I			Cluster II			Cluster III		
	Min	Max	Average	Min	Max	Average	Min	Max	Average
Gravel %	0.00	2.96	**0.67**	11.40	48.76	**25.12**	0.00	9.45	3.08
Sand %	95.63	99.92	**98.10**	50.40	86.64	**73.31**	82.89	95.09	91.00
Mud %	0.04	4.03	**1.23**	0.02	7.68	1.57	0.61	17.05	**5.92**

In land filled areas; the beach sediments are coarse grained and poorly sorted. Grain size increases and sorting improves from low to high water mark due to the change of hydrodynamic conditions. In dredged areas, fine sediments are dominant. Generally, dredging and landfilling increase turbidity, change water circulation and sediment distribution patterns, and may destroy entire reef systems. Waves and current move turbid water further offshore to other places with living corals on the adjacent reef flat and reef slope. Corals and other organism mostly may be destroyed if such activities continue.

5. GEOCHEMICAL PARAMETERS

The chemical characteristics of the marine sediments and metals are released to the environment as a result of a variety of human activities such as sediments released through beach enhancement, coastal constructions, landfilling and dredging, heated and chemically treated effluent water from power and desalination plants and oil and hydrocarbons lost from drilling operations and pipeline. The distribution, movement and storage of contaminants in coastal seawater have a substantial influence of the marine ecology and environmental chemistry. The impact of release of industrial wastes in the sea depends on various factors, e.g., local meteorological conditions (the wind effect is important in controlling turbidity), hydrodynamic regime of water mass; and the amount of frequency of the discharge (Boughriet *et al.* 1994). The current research on the anthropogenic effects on the marine environment has been carried out on the coastal area, where the human impact may be increasingly affecting the oceanic realms (Omori and Norman, 1995)

Organic Carbon (OC) and Total Organic Matter (TOM)

The Hurghada Marina sediments have the highest total organic matter content that ranges from 1.22% to 4.72% with an average of 2.58. The sediments also have the highest organic carbon content which ranges from 0.68% to 2.62% with an average of 1.43% (Table 4). The total organic matter content of sediments of the second tourist project is high and ranges from 0.22% to 3.86% with an average of 2.28% and the organic carbon content ranges from 0.12% to 2.14% with an average of 1.27% (Table 4). Mansour (1999) has found that the terrestrial materials rich in organic matter and the high organic productivity are the two main reasons for the high content of organic matter in Sharm Abu Makhadeg area.

Cluster analysis; Based on total organic matter (TOM) and organic carbon (OC) three main clusters were obtained (Fig. 6). The first cluster includes 34 samples and is characterized by the highest values of TOM (2.57%), OC (1.43%) and carbonate (72.41%). This cluster includes all samples of the central marina (19 samples) and the second tourist site (15 samples). The main impact of these two areas is dredging the tidal flat that composed mainly of biogenic materials, and most landfill is from these materials. Cluster 3 (45 samples) has also high values of TOM (1.87%) and OC (1.04%). It includes most samples (34) of the oil exploration site. The second cluster is poor with TOM (1.07%), OC (0.59%) and carbonate (18.34%). It includes samples from the first tourist site, a few samples of the second tourist site and the central marina. Dredging is the reason for the high organic content in the central marina and the second tourist site whereas in the oil exploration site drilling mud, oil wells and oil extraction are the main reason. Dredging of the tidal flat reveals fine sediments and concentrates organic matter and trace metals in confined pools. Moreover, the shoreline change in these areas has produced semiclosed areas, artificial lagoons and quiet water areas where organic productivity increase. Contribution of the landfilling materials of terrigenous origin from the areas close to the high mountain of igneous and metamorphic rocks decreases the carbonate content in the first tourist site.

Table (4). Total organic matter, organic carbon and carbonates of all samples of studied areas.

Site	Desert Rose site.			Master Line site			Hurghada Marina site.			Magwish Company site.		
Parameter	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
TOM%	0.18	1.68	0.92	0.22	3.86	2.28	1.22	4.72	2.58	1.16	1.48	1.74
O.C.%	0.10	0.94	0.51	0.12	2.14	1.27	0.68	2.62	1.43	0.64	0.82	0.97
Carb.%	8.20	36.60	17.10	12.90	92.90	36.30	84.60	68.44	26.30	53.90	42.78	4.01

O.C. : Organic carbon TOM : Total orgainic matter Carb.: Carbonates

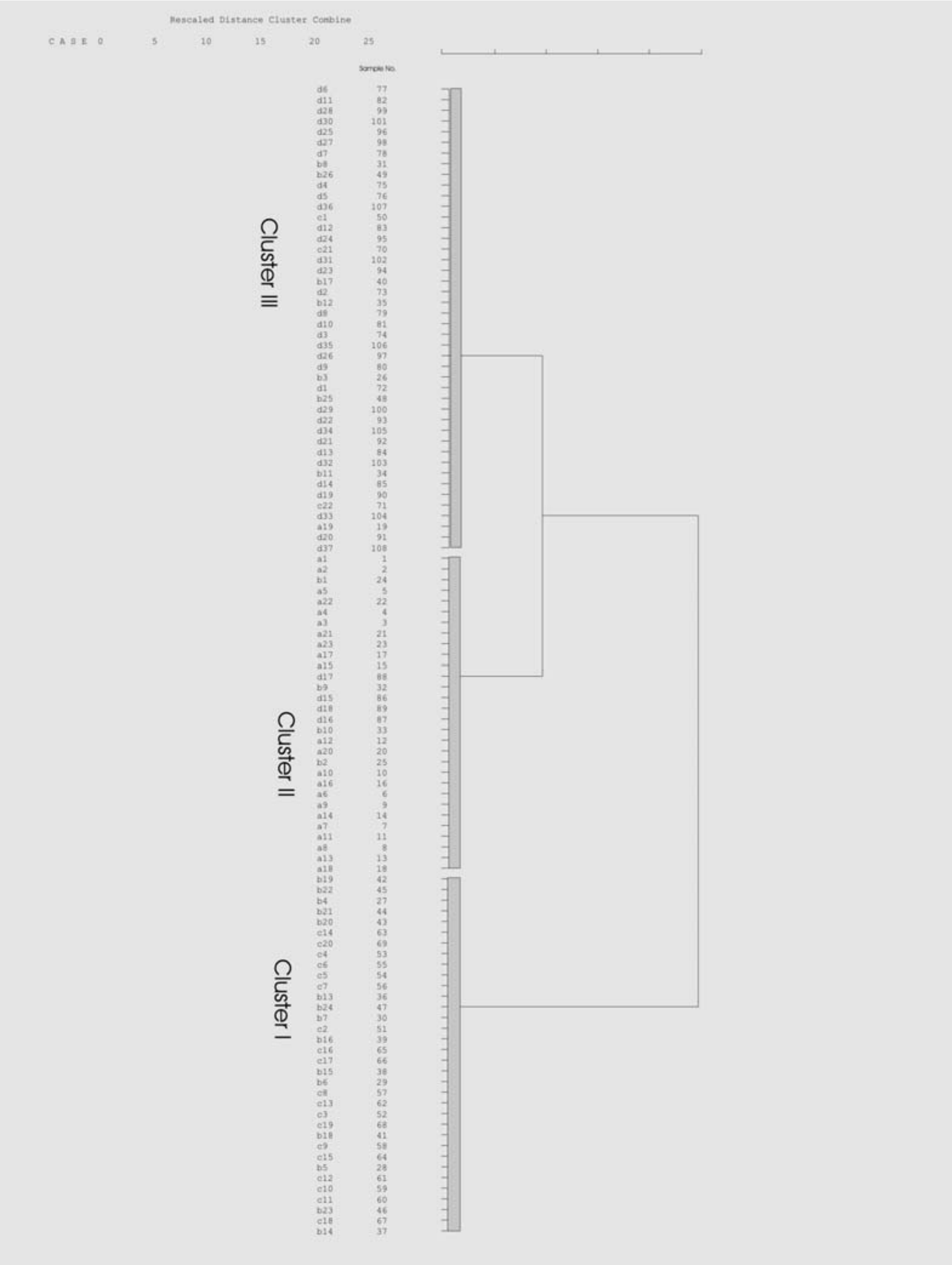


Fig. (6). Dendrogram of cluster analysis using Ward Method exhibiting cluster of total organic matter and carbonate.

Total Carbonates:

Carbonate sediments are composed largely of calcium carbonate. They are made up for the most part of the skeletal parts of marine organisms. Contributions from pre-existing limestone or from chemical precipitation are relatively insignificant in most marine environments.

Carbonate sediments are composed mainly of organic skeletons, their make-up and origin is, to a great extent, a biological problem. Composition of the sediments is strongly influenced by the same ecological conditions, which control the distributions of organisms.

El-Mamoney (1995) found that the carbonate contents of the marine sediment along a distance of 500 m in the sea of areas in front of wadi El Hamara, El Ash, Abu Shaar, El Jemal and Khasier varies from 21.75% to 98.29%. Mansour *et al*., (1997) found that the carbonate content varies from 19.38% to 100% with an average of 63.26% of the beach and intertidal sediments allover the coastal area from Gemsa to Marsa Alam.

Maxwell (1968) classified sediments according to carbonates contents to high carbonate (>80%), impure carbonate (80% – 60%), transitional (60% – 40%), terrigenous (40% – 20%) and high terrigenous (<20%). According to this classification, sediments of the first tourist site are high terrigenous to terrigenous, sediments of oil exploration site are mostly transitional with some terrigenous samples. Most sediments of the second tourist site are transitional with some samples of high carbonate content. Nearly all samples of the central marina are impure carbonate and high carbonates. The distribution of carbonates of all sediments in the different studied areas reflects their origin and the effect of dredging and landfilling processes. The sediments of the central marina and the second tourist site have high carbonate content of biogenic origin due to the dredging in coral reefs areas. The sediments of the first tourist site and the site of oil exploration have the lowest carbonate contents due to the landfilling by terrestrial sediment in the beach and intertidal area (Table 4).

Major Elements:

The major elements determined in this study include Ca, Na, K, Mg, Sr, Mn, and Fe. Most of these elements are derived mainly from the hinterland source rocks of the Basement complex. However Ca, Mg and Sr are mainly derived from the marine biogenic sources.

Calcium (Ca)

Calcium is one of the major constituents of the earth's crust and in the biogenic componants. Calcium occurrence in the fine fraction sediments may has some special emphases to the anthropogenic impacts mainly from construction residuals as concrete, cement materials and gypsum. El Askary *et al.* (1988) pointed that, there is a slight tendency for increasing of magnesium oxide as calcium oxide increasing in both beach and bottom sediments in the northern Red Sea. El-Sayed (1984) found that the calcium contents of the reefal sediments of Hurghada average 21.7%. Mansour *et al.* (2000) found that calcium contents of the marine sediment of thirteen areas along the Egyptian Red Sea coast from Hamata to Hurghada range from 6.41% to 73.9% with an average of 15.94%.

Calcium content of the investigated sediments ranges from 0.14% to 32.60% with an average of 15% (Table 5). The first tourist site has low Ca content ranges from 0.14% to 18.50% with an average of 5.11% (Table 5). Sediments of the second tourist site have high Ca content ranges from 2.87% to 28.41% with an average 17.55% (Table 6). Calcium content is also high in the central marina and ranges from 8.75% to 32.6% with an average of 22.34% (Table 5). This relatively high content of Ca is resulted from coral rock fragments of the dredging areas. Calcium content in the oil exploration site ranges from 6% to 21.36% with an average of 14.26% (Table 5). The general low content of Ca in sediments of the studied sites and especially, the first tourist site and the site of oil exploration is due to the terrigenous sediments of the landfilling materials.

Table (5).Major elements of sediments of selected studied sites.

Site	Desert Rose site.			Master Line site			Hurghada Marina site.			Magwish Company site.			Total samples		
Element	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
Ca %	0.14	18.50	5.11	2.87	28.41	17.55	8.75	32.60	22.34	6.00	21.36	14.26	0.14	32.60	15.00
Mg %	0.06	0.24	0.17	0.15	0.26	0.23	0.24	0.26	0.25	0.24	0.27	0.24	0.06	0.27	0.22
Sr %	0.001	0.10	0.03	0.03	0.15	0.10	0.06	0.17	0.13	0.03	0.13	0.09	0.001	0.17	0.14
Fe*	2337.76	3293.71	2920.09	179.91	3202.77	1551.97	75.78	2517.42	1213.80	1175.00	3176.16	2223.98	75.78	3293.71	1977.46
Mn*	79.42	536.51	272.40	5.23	334.81	112.24	12.73	219.05	77.00	125.43	1496.57	249.55	5.23	1496.57	177.80

(*) Concentration in µg/g

Table (6).Trace elements of sediments of selected studied sites.

Site	Desert Rose site.			Master Line site			Hurghada Marina site.			Magwish Company site.			Total samples		
Element	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
Cd*	0.30	1.94	0.77	0.08	1.88	0.52	0.21	0.98	0.45	0.04	1.17	0.32	0.04	1.94	0.51
Cu*	0.07	0.84	0.22	0.02	0.64	0.19	0.03	2.52	0.65	0.59	3.18	1.60	0.02	3.18	1.80
Zn*	3.01	9.71	5.51	0.50	10.06	3.65	1.25	13.03	5.48	0.24	23.18	4.01	0.24	23.18	4.70
Pb*	0.99	16.54	7.39	4.42	15.90	12.45	11.06	26.34	16.76	4.85	21.15	14.96	0.99	26.34	13.00
Ni*	0.11	3.33	1.43	0.04	4.17	1.17	0.40	2.38	1.26	0.08	6.50	3.76	0.04	6.50	1.91
Co*	0.70	1.58	1.05	0.80	1.61	1.11	0.62	1.77	1.23	1.04	2.46	1.71	0.62	2.46	1.30

(*) Concentration in µg/g

Magnesium (Mg)

Magnesium is associated with calcium in most recognized minerals such as pyroxenes, plagioclase, feldspars, amphiboles and carbonate minerals. It has its essential occurrence in dolomite mineral and also related to the carbonate occurrences in the marine sediments.

El-Sayed (1984) found that the magnesium contents of the reefal sediments of Hurghada average 5.01%. Mansour *et al.* (2000) found that, the Mg contents of marine sediments along the Red Sea coast from Hamata to Hurghada in Egypt range from 0.35 to 5.93% with an average of 1.55%. Mg content of the studied areas ranges from 0.06% to 0.27% with an average of 0.22% (Table 5). In the first tourist site it ranges from 0.06% to 0.24% with an average of 0.17% (Table 5) and from 0.15% to 0.26% with an average of 0.23% (Table 5) in the second tourist site. In the central marina Mg ranges from 0.24% to 0.26% with an average of 0.25% and from 0.24% to 0.27% with an average of 0.24% in the oil exploration site (Table 5). Low Mg values reflect the abundance of terrigenous materials from landfilling.

Strontium (Sr)

Carbonates contain a high proportional of strontium in marine sediments. El-Wakeel and Riley (1961) have pointed out that strontium is also associated with clay minerals either by ion-exchange or by incorporated in the clay minerals lattices. El-sayed (1984) found that the strontium contents of the reefal sediments of Hurghada average 0.82%. Most of strontium is biogeneous origin and the variations in the strontium content reflect variations in the Sr/Ca ratio in marine organisms (El-Wakeel and Riley, 1961). Mansour *et al.* (2000) reported that, Sr contents along the Egyptian Red Sea coast from Hamata to Hurghada range from 0.05 to 0.46%.

Strontium contents of the present study range from 0.001 to 0.17% with an average of 0.14% (Table 5). In the first tourist site Sr content ranges from 0.00 to 0.10% with an average of 0.03% (Table 5) and ranges between 0.03% and 0.15% with an average of 0.10% (Table 5) in the second tourist site. In the central marina Sr ranges from 0.06% to 0.17% with an average of **0.13**% (Table 5). In the oil exploration site it ranges from 0.03% to 0.13% with an average of 0.09% (Table 5). Similar to Ca and Mg the relative high content of Sr in the second tourist site and the central marina is because the dredged areas are tidal flat composed mainly of biogenic materials, and most landfill is from these materials.

Iron (Fe)

Riley and Skirrow (1965) pointed out that Fe may be incorporated directly in the hydrogenous phase of marine sediments. Iron is one of the most abundant elements in marine sediments of the Red Sea. It is also essential constituent of plants and has been considered as one of the substances that may limit the amount of plant production in the sea. Beltagy (1973) stated that precipitation with iron oxides is important for Mn and to lesser extent of Pb and Zn. Ostrofsky (1987) reported that iron content is highly correlated with phosphorus content of the sediments because of iron-bound phosphorus was large fraction of total inorganic phosphorus.

In Hurghada mixed sediments Fe is 0.19 – 0.60% (El-Sayed, 1984). El – Mamoney (1995) found that Fe content ranges from 0.03 to 2.17% in sediment from different areas along the Egyptian Red Sea coast. Mansour *et al.* (2000) found that Fe content ranges from 0.14 to 1.72% with an average of 0.59% in sediment from thirteen areas along the Egyptian Red Sea from Hamata to Hurghada.

Iron content of the present study ranges from 75.78 to 3293.71 µg/g with an average of 1977.46 µg/g (Table 5). Sediments of the first tourist site and the oil exploration site have high iron contents. They range from 2337.76 to 3293.71 with an average of 2920.09 µg/g in the first tourist site (Table 5) and from 11751 to 3176.16 with an average of 2223.98 µg/g (Table 5) in the oil exploration site. In the second tourist site Fe ranges from 179.907 to 3202.77 with an average of 1551.97 µg/g (Table 5) whereas in the central marine it ranges from 75.78 to 2517.42 with an average of 1213.8 µg/g (Table 5). This high iron content is related to the terrigenous materials of the landfilling and the presence of construction rubbish and pipelines rust. The mean concentration of Fe (1977.46 µg/g does not exceed the recommended values (41000.00 µg/g) of unpolluted sediments (GESAMP, 1982; Salomons and Froster, 1984; IAEA, 1989) (Table 7).

Table (7). Comparison of mean trace metal concentrations in marine sediments.

Locations / Element	Fe*	Mn*	Cd*	Cu*	Zn*	Pb*	Ni*	Co*	References
Hurghada, Red Sea	1270.90	105.00	0.51	1.80	4.70	13.00	1.91	1.30	present study
Knysna lagoon, South Africa	-------	-------	0.23	6.70	40.60	48.40	-------	-------	watling and watling, 1982a
Saint John, Harbor	-------	296.00	0.16	16.00	53.00	24.00	-------	-------	Ray *and Macknight*, 1989
Bay of Bengal, Chittagong, Bangladesh	5272.13	556.10	0.88	32.91	33.54	23.18	-------	-------	Azam Khan *et al.*, 2003
Red Sea, Egypt	970000.00	388.84	1.01	25.70	35.56	36.22	25.00	11.00	Mansour, *et al.*, 2000
Recommended values of unpolluted sediments	41000.00	770.00	0.11	33.00	95.00	19.00	-------	-------	Salomons and Froster, 1984

Manganese (Mn)

Manganese is relatively mobile in the sediments and its solubility is lowered when high redox potentials occur at sediment surface. The detrital Mn in the sediments is associated with biotite, chlorite and hornblende, where the relative abundance in the sediment component is related to silicates more than carbonates. Mn is an element of low toxicity having considerable biological significance. It is one of the more biogeochemical and active transition metals 'in aquatic environment (Evans *el al.,* 1977). Beltagy (1982) has shown that the concentration of Mn and Fe elements varies significantly, even over very short distance in the area of Hurghada. Mn concentration in the mixed sediments at Hurghada ranges from 0.012 to 0.036% with an average of 0.021% (El-Sayed, 1984). El Mamoney (1995) found that the manganese content ranges from 0.009 to 1.31% in the sediments of five areas in front of some wadis. Mansour *et al.* (2000) found that Mn concentration from thirteen areas along the Red Sea coast from Hamata to Hurghada averaging 0.38%.

In the study areas Mn ranges from 5.23 to 1496.57 with an average of 177.8 µg/g (Table 5). Sediments of the first tourist site have high Mn content ranging from 79.42 to 536.51 with an average of 272.4 µg/g (Table 5). Sediments of the central marina have low Mn content ranges from 12.73 to 219.05 with an average of 76.99 µg/g (Table 5). In the second tourist site Mn ranges from 5.23 to 334.81 with an average of 112.24 µg/g (Table 5). In the oil exploration site Mn ranges from 125.43 to 1496.57 with an average of 249.55 µg/g (Table 5). The high Fe and Mn concentration in the first tourist site and in the site of oil exploration is also regarded as a consequence of the contribution of the landfilling materials of terrigenous origin from the areas close to the high mountain of igneous and metamorphic rocks. The mean concentration of Mn (177.8 µg/g does exceed not the recommended values (770.00µg/g) of unpolluted sediments (Salomons and Froster, 1984) (Table 7).

Trace Elements:

Seven trace elements (Cu, Co, Zn, Pb, Cd, Ni and V) have been determined in the investigated sediments. These elements are important as polluted metals. Zn, Ni, Pb, Co and Cu are more abundant in deep-sea clays than in nearshore sediments (Riley and Skirrow 1965). These trace metals are introduced onto coastal waters by the intensive development of industries and urbanization. The trace metals are transported by physio-chemical processes, including scavenging by sinking particulate and organic matter. Trace elements, therefore, are initially supplied to the site of deposition from terrestrial sources via rivers, landfilling or the atmosphere from biological activity within the ocean and from ocean bottom waters. Beltagy (1982) attributed the variation in the metal content in Hurghada Red Sea water to; the selective utility of these elements by different marine organisms, decomposition of dead organic matter and air-borne material transported to the sea. The results of trace metal concentrations are shown in Table 6. The concentrations of different trace metals at all the stations are not uniform.

Copper (Cu)

Copper concentrations of the present study areas range from 0.02 to 3.18 µg/g with an average of 1.80 µg/g. Sediments of the oil exploration site have the highest copper concentration especially in the beach and intertidal samples due to the abundance of terrigenous sediments. This content ranges from 0.59 µg/g to 3.18 µg/g with an average of 1.60 µg/g (Table 6). Copper is usually concentrated in the soft parts of several marine organisms. High Cu concentrations are in samples of the beach at the central marina and the fishing port which involves the biggest shipyard in the region. This content ranges from 0.03 µg/g to 2.52 µg/g with an average of 0.65 µg/g (Table 6). El-Sayed (1984) found that the copper concentrations of sediments from Hurghada area range from 8.50 to 27.50 µg/g with an average of 21 µg/g. El-Mamoney (1995) found that the copper concentrations in the sediments of five areas in front of some selected wadis along the Red Sea coast in Egypt range from 1 to 59 µg/g. Mansour *et al.* (2000) found that the copper concentrations in sediments of thirteen areas along the Egyptian Red Sea coast from Hamata to Hurghada range from 6 to 249.90 µg.g-1. Cu concentration was lower than the recommended values (33.00 µg/g) of unpolluted sediments (GESAMP, 1982) (Table 7).

Cobalt (Co)

Cobalt is strongly concentrated in marine sediments relative to igneous rocks (El-Wakeel and Riley, 1961). Cobalt has arisen from two independent sources, namely detrital clay and dissolved material fed into the oceans by rivers (Riley and Skirrow, 1965). Cobalt concentrations of the studied areas range from 0.62 to 2.46 µg/g with an average of 1.3 µg/g. Sediments of the oil exploration site have the highest cobalt values range from 1.04 to 2.46 µg/g with an average of 1.71 µg/g (Table 6). Beltagy (1984) pointed that the average cobalt concentration in the sediments of the northern Red Sea is 48 µg/g. Mansour *et al.* (2000) found that, the cobalt concentrations along the Red Sea of Egypt from Hamata to Hurghada range from 0.01 to 27.10 µg/g with an average of 11 µg/g.

Zinc (Zn)

Zinc concentration of the investigated sediments ranges from 0.24 to 23.18 µg/g with an average of 4.7 µg/g. Sediments of the oil exploration site and the central marina have the highest zinc concentrations in the beach and tidal flat sediments due to the terrigenous materials. These contents range from 0.24 to 23.18 µg/g with an average of 4.01 µg/g (Table 6). El-Sayed *et al.* (1984) found that, zinc concentrations of the sediments from Hurghada areas ranges from 11 to 90 µg/g with an average of 31 µg/g. Mansour *et al.* (2000) found that, the zinc concentrations of sediments in front of thirteen areas along the Egyptian Red Sea coast from Hamata to Hurghada range from 8 to 164.4 µg/g. Zn concentration was lower than the recommended values (95.00 µg/g) of unpolluted sediments (Salomons and Froster, 1984) (Table 7).

Lead (Pb)

Lead was extensively used in marine paints as a spreading and sealing agent. About two-thirds of Pb in all Pleistocene sediments has been chemically precipitated from sea water solution and the remainder has been transported in detrital particle (Riley & Skirrow, 1965). Lead concentrations of the study areas range from 0.99 to 26.34 µg/g with an average of 13 µg/g. Sediments of the oil exploration site and the central marina have the highest lead concentrations. They range from 4.85 to 21.15 µg/g with an average of 14.96 µg/g (Table 6). El-Mamoney (1995) found that, the lead concentrations of sediments from different areas along the Egyptian coast range from 26 to 101 µg/g. Mansour *et al.* (2000) found that, the lead concentrations in front of thirteen areas from Hamata to Hurghada range from 0 .50 to 127 µg.g-1. However, in aquatic systems, lead tends to accumulate in aquatic organisms through the food-chain and by direct uptake (Kruus, 1991). In all sites Pb concentrations in many samples espesially in oil exploration and the central marina sites exceeded the recommended values (19.00 µg/g) of unpolluted sediments (Salomons and Froster, 1984) (Table 7).

Nickel (Ni)

Nickel concentrations of the investigated sediments range from 0.04 to 6.5 µg/g with an average of 1.91 µg/g. Sediments of the oil exploration site have the highest nickel concentrations ranging from 0.08 to 6.5 µg/g with an average of 3.76 µg/g (Table 6). The high concentration of nickel was observed in the beach samples of this area due to terrigenous origin. El-Mamoney (1995) found that, the Ni concentrations of sediments from different five areas in front of wadi El Hamara, Abu Shaar, El Gemal and Khasier range from 1 to 149 µg/g. Mansour *et al.*

(2000) reported that, the Ni concentration from different thirteen areas along the Red Sea range from 0.10 to 111.50 µg/g with an average of 25 µg/g.

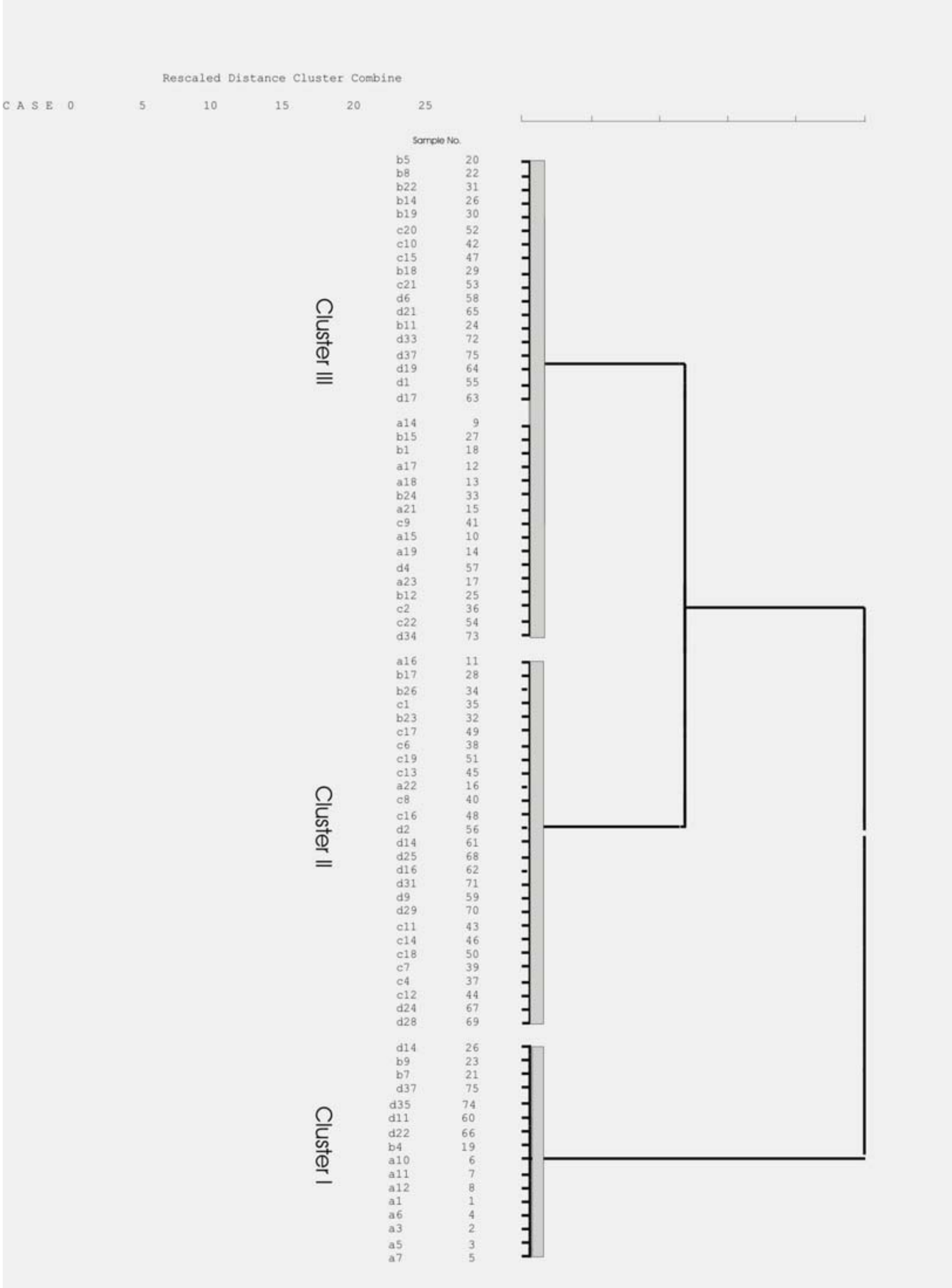


Fig. (7). Dendrogram of cluster analysis using Ward Method exhibiting cluster of trace metal.

Cadmium (Cd)

Cadmium concentrations of the investigated sediments range from 0.04 to 1.94 µg/g with an average of 0.51 µg/g. Sediments of the two tourist sites have the high cadmium concentrations due to the terrigenous origin and the increase of human activities in the regions. These contents range from 0.30 µg/g to 1.94 µg/g with an average of 0.77 µg/g in the first tourist site (Table 6) and from 0.08 µg/g to 1.88 µg/g with an average of 0.52 µg/g in the second tourist site (Table 6). El-Mamoney (1995) found that, the cadmium concentrations of sediments from different investigated regions along the Egyptian Red Sea coast range from 0.001 to 2.787 µg/g. Mansour *et al.* (2000) reported that, the Cd concentrations in different thirteen areas range from 0.0 to 3.10 µg/g. However, at the low redox potential with the presence of organic-bound metal, cadmium release from the underlying sediment layer to the water. The concentration of Cd was always higher in all the stations compared to the other metals. The mean value of Cd concentration was recorded as 0.51 µg/g which is about 5 times higher than the recommended value (0.11µg/g) of unpolluted marine sediments (GESAMP, 1982; Salomons and Froster, 1984; IAEA, 1989) (Table 7).

Cluster analysis; Based on metals (Cd, Co, Ni, Zn, Pb, V, Cu, Fe and Mn) concentration, 3 main clusters were obtained. The first cluster (33 samples) shows the lowest concentration of metals (Cd, Ni, Zn, Pb, V, and Cu) (fig. 7). This cluster includes 11 samples of the second tourist site, 9 samples of the oil exploration site, 7 samples of the central marina and 6 samples of the first tourist site. The third cluster (Fe & Mn cluster) includes 16 samples of the two tourist sites and the oil exploration site indicating that most of Fe and Mn are related to terrigenous origin due to the landfilling in the beach and intertidal area and to the pipelines rust. Cluster 2 includes 26 samples, 12 sample from the central marina, 9 samples from the oil exploration site, two samples from the second tourist site and 3 samples from the first tourist site. The highest concentration of Pb, Co, Zn, and Ni characterizes this cluster. This is probably related to the nearby harbor. The second cluster includes some samples in semi-enclosed areas which are sensitive to the anthropogenic activities. The shore of the study areas is occupied by harbor, tourist villages and oil Company. Oil production and heavy oil tankers in the Gulf of Suez and the NE-SW wave motion and southward currents are probably the reason for the increasing rate of Pb. Motor boats are the largest source of Pb enrichments in sediments. It originates from the combustion and aeolian distribution of the tetraethyl lead added to automobile gasoline since 1945 (Chow *et al.*, 1973). Concentration of Pb in the dredged parts of some sites is associated with fine sediments.

Toxicity criteria for sediments can be determined by exposing biota to varying levels of contaminants in sediments and comparing responses. However, unpolluted sediments can occasionally have metal (ex. Ni, Co) concentrations greater than or equal to the lowest recommended toxicity thresholds. Adverse effects in organisms may also depend on factors other than concentrations. The findings of this study are useful to establish natural variations in background levels of potentially toxic metals and organic contaminants, as well as sediment properties.

6. CONCLUSIONS AND RECOMMENDATIONS

The study area includes different aspects of coastal development such as tourist villages, constructing marinas, and oil exploration and production. Although all projects has executed an Environmental Impact Assessment study (EIA) all sites were subjected to severe coast destruction and shoreline change from landfilling and dredging of the beach and the tidal flat. Such activities increase turbidity and change sediment distribution patterns, and may destroy entire reef systems.

Sediment characteristics such as grain size, major and trace elements, total organic matter (TOM), organic carbon (OC), and carbonates are important in detecting the hazards of development activates along the Red Sea coast. Therefore, the obtained information helps managers to identify anthropogenic impacts and better asses of the needs for remediation.

The landfilling and dredging are the most significant environmental problems related to the existing coastal uses and human activities in Hurghada city. Such activities may increase turbidity, after water circulation and sediment distribution patterns, and may destroy entire reef systems. Two sources for the artificial land filling; 1) resulted from the beach and neighbor areas enhancement by removing the sand hills and sand piles from the areas of investment and 2) resulted from the near sand quarries.

Landfiling and dredging in Hurghada coastal areas have physical, chemical and biological impacts on the marine environment; therefore, the following recommendations should be taken in consideration:

1- Landfilling and other destructive activities throughout the Red Sea coastal Zone should be prohibited.

2- The coastal areas of Hurghada must by investigated continuously by numbers of environmental inspectors.

3- A regular monitoring program includes organic contaminants and toxicity tests, to detect environmental changes throughout the Red Sea coastal zone should be established.

4- Using the satellite images every year and the degree of change in the coastal areas, especially the shore line change should be examined.

5-Hurghada coastal zone requires integrated planning and management to achieve ecologically sustainable use of coastal resources and conservation of coral reefs.

6-Continuation of a comprehensive research and monitoring program is necessary to study the impact of the increased human activities.

7. Chemical and biologic measurements should be made to determine whether metal concentrations sufficiently high to cause toxic effects in test organisms.

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