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Research Article
Observation of Changes in Sediment Nature by Environmental Impacts of Abu-Makhadeg Area, Red Sea, Egypt

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Abstract

Background and Objectives: More than 15 tourist projects occupy the Red Sea coast of the Sharm Abu-Makhadeg area (Makadai area) Red Sea, Egypt. During the 90's, landscape destruction, landfills, shoreline change, dredging rocky tidal flat and brine water discharge were the main environmental impacts in Abu-Makhadeg area. The scope of the present work were monitoring of changes of sediment nature by environmental impacts of Sharm Abu-Makhadeg area and record all developmental activities during the past 20 years. **Materials and Methods:** Grain size and geochemical analyses had been carried out on 32 surface marine sediment samples collected from Sharm Abu-Makhadeg area along the Egyptian Red Sea coast. **Results:** The sediments were characterized by the abundance of sand with minor amounts of mud and gravel. Generally, sand fraction is the main category among the three constituents. Geochemically, the factor controlling the carbonate content of studied sediments includes material supply of biogenic and terrigenous components. Organic matter recorded high values in some samples with increase depth. The high organic matter in surface marine sediments is primarily due to the high supply from primary productivity, terrestrial and reworked sediments. Texture was the main controlling factor for the organic matter enrichment. **Conclusion:** Grain size distribution and geochemical aspects of surface marine sediments of Sharm Abu-Makhadeg area using some statistical methods revealed the dominance of muddy sediments of most samples with high values of organic matter than background areas reflected the negative impact of the biogenic life and humans.

Key words: Monitoring, observation sediments, sand fraction, impacts, Sharm Abu-Makhadeg area, Red sea, Egypt, grain size distribution and geochemical aspects

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sharm Abu-Makhadeg between Hurghada and Safaga along the Egyptian Red Sea coast occupies a small area with a beach about 4.5 km. Sharm Abu-Makhadeg area and its surrounding regions are a major recreational area sea bird and marine-mammal rookery and important commercial fishing ground[1]. Now several of hotels and tourist villages are being built around the sharm. This tourism projects including what is working and the ones under construction and tourism projects total area of Sharm Abu-Makhadeg more than 50 tourist projects.

The rest of the beach is already sold for developers and destruction clearly appears in the land and offshore. For example because the rocky tidal flat surrounds the sharm, the needs for swimming pools or marinas entail dredging zones in-front of resorts during the nineties[1].

In the present work, 32 samples were collected of surface marine sediments from Sharm Abu Makhadeg area and to follow up on those natural variations sedimentary environmental influences after the passage of more than 15 years of study by Mansour[1].

Several investigations on the surface marine sediments were carried out on the Egyptian Red Sea coast[2-20]. However, investigations including the impact of development activities along the Egyptian Red Sea coast are rare. The scope of the present work was observation of changes of sediment nature by environmental impacts of Sharm Abu-Makhadeg area and record all development activities during the past 20 years. The impact of development activities in Sharm Abu-Makhadeg area was measured by surveying and by analyzing the surface marine sediment[21-27]. In the same manner, this paper deals with the changes that have occurred in marine sediments as a result of these activities through the mechanical analysis of sediment samples and the study of the geochemistry of these sediments.

MATERIALS AND METHODS

Study area: Sharm Abu Makhadeg area, the famous Egyptian coast of the Red Sea tourist areas and are called Madinat Makadi Tourist. Sharm Abu Makhadeg has a small and very narrow fringing reef occupying its northern border, a wide and fascinating coral reef covers its southern part (Fig. 1, 2). South of the Sharm, a crescent tidal flat area with a maximum width of 800 m is developed' decreasing southward to reach to ab. 75 m at Sharm El-Arab, with a few pools (lagoons) (Fig. 3a, b). The inland geomorphology of Wadi Abu-Makhadeg and its accumulations of alluvial fans north and south, which Quaternary coral reef terraces occur. Vegetated coastal dunes and sabkhas occupy the lowland areas at the wadi mouth (Fig. 1, 2). Westwards, Miocene and younger sediments extend to the high Basement rocks mountains. Wadi Abu Makhadeg fan-out down slope of hills, being dry most of the time and is characterized by sporadic and abrupt fluvial activity. Quaternary sand and gravels cover the study area. Some Pliocene marine outcrops formed of inter-bedded sandstone, marls and clayey rocks, while the outcropping Miocene rocks are formed of clastic base with gypsum and carbonate beds[1]. The majority of the area westward is covered by high rugged outcropping basement rocks, which mainly composed of granitoid rocks, volcanics and metavolcanics and gabbroic basic rocks. Generally, these outcropping basement rocks is traversed by N-E and N-W trending faults and fractures. Along these faults, the basement rocks are brecciated, sheared and milonitized.

Field works: In this study, 32 surface marine sediment samples have been collected from Sharm Abu-Makhadeg area (Fig. 1, 2), the location, depth and description of bottom characteristics of the collected samples are given in Table 1 and Fig. 2 and 3. Surface marine sediments samples collected from the study area represent three different environmental feature; beach, intertidal zone and offshore zone until 25 m water depth. The sampling was carried out by a grab sampler and Scuba diving. The later was used in areas rich with corals where grab sampler failed to collect samples. After anchoring the boat at each station, the sampler was lowered to the sea floor and left a few seconds before being pulled back to the surface. The sediment caught in the sampler or collected by Scuba diving was placed in labeled plastic bags and returned to the laboratory.

Laboratory methods and treatment of data: All samples were washed several times to remove soluble salts. Grain size analysis were performed using the sieving technique according to Folk and Ward[28]. The resulting data were processed on a personal computer using the "BASIC" program "SEDPAK"[21]. The carbonate content and the organic matter of all sediment samples were determined in the National Institute of Oceanography and Fisheries, Red Sea Branch. All geochemical analyses were carried out in duplicates and the average of data was determined. Carbonate content was determined by treating the samples with (1 N HCL acid). The

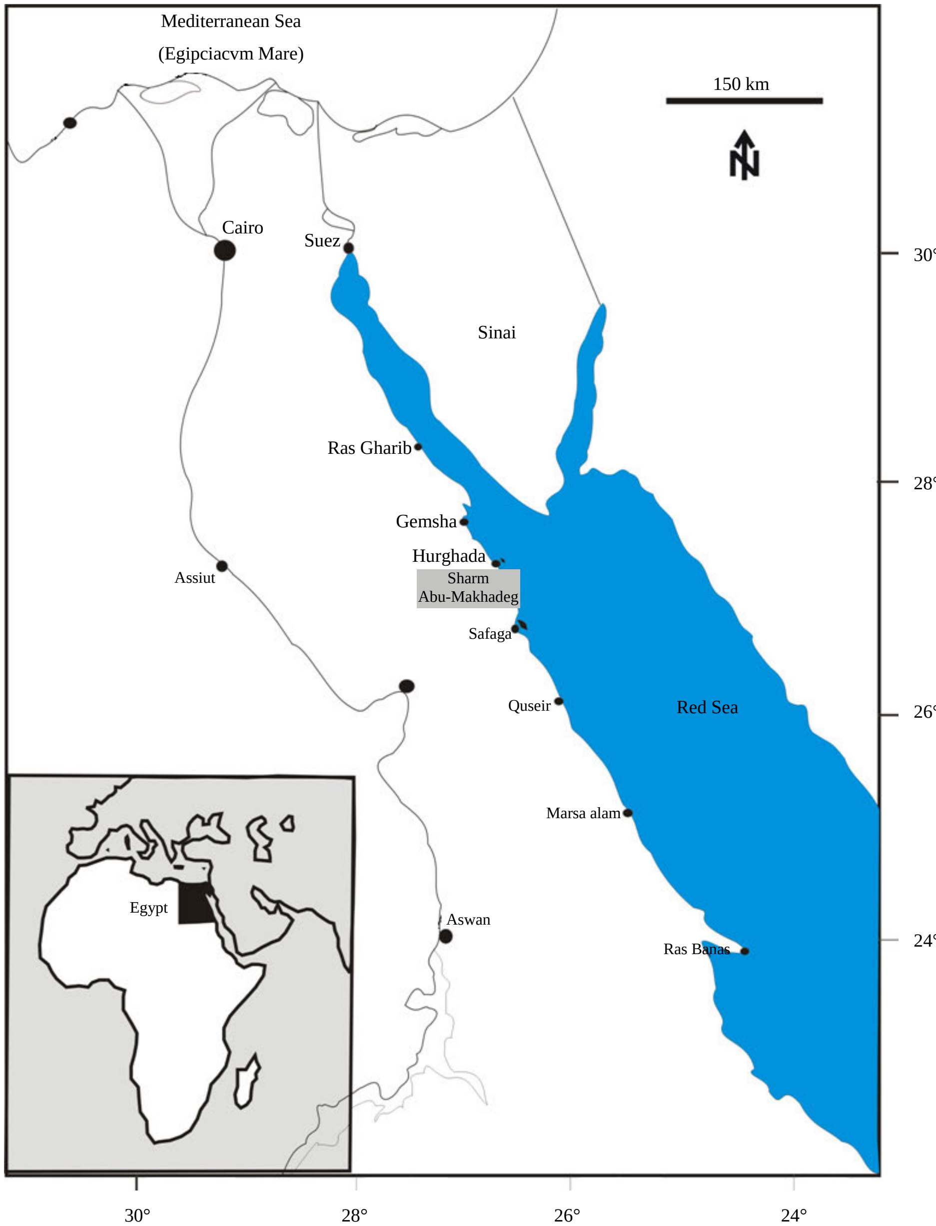

Fig. 1: Study area along the Red Sea coast, Egypt (After authors)

insoluble residue remaining after acid washing was determined and the carbonate percentage was calculated. Determination of organic matter was made by sequential weight loss[29] at 550°C. All analysis of the sediment samples carried out of the laboratories of the National Institute of Oceanography and Fisheries, Red Sea Branch, Egypt in the period between March and August, 2018.

The obtained data of the granulometric and geochemical analyses were dealt statistically in order to exclude the characteristic parameters. The statistical treatment includes the average, correlation coefficient and cluster analysis. Analyses are carried out on the data using the computer programs of the SPSS system available in National Institute of Oceanography and Fisheries, Red Sea Branch, Egypt.

RESULTS

Grain size analysis: The marine sediments in the study area were mainly composed of sand (68.85-96.8% with average 84.13%), mud constitutes (0.001-30.24% with average 10.97%) and gravel was very rare (0.14-30.11% with average 4.9%) (Table 2). Generally, the correlation coefficients between

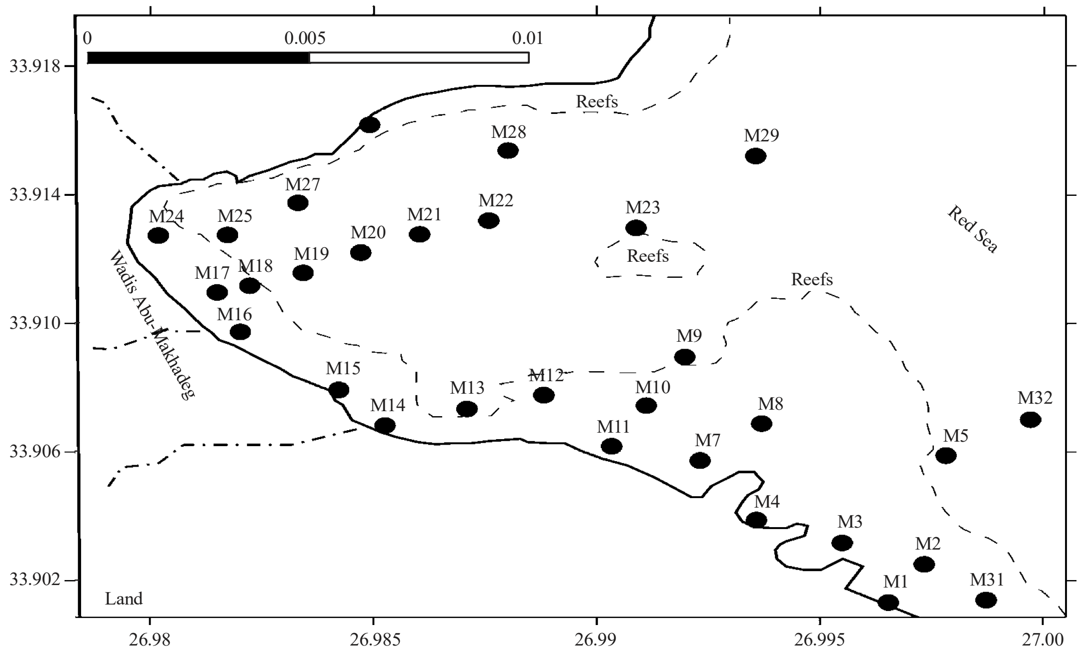

Fig. 2: Distribution of surface marine sediment samples at Sharm Abu-Makhadeg area (After authors)

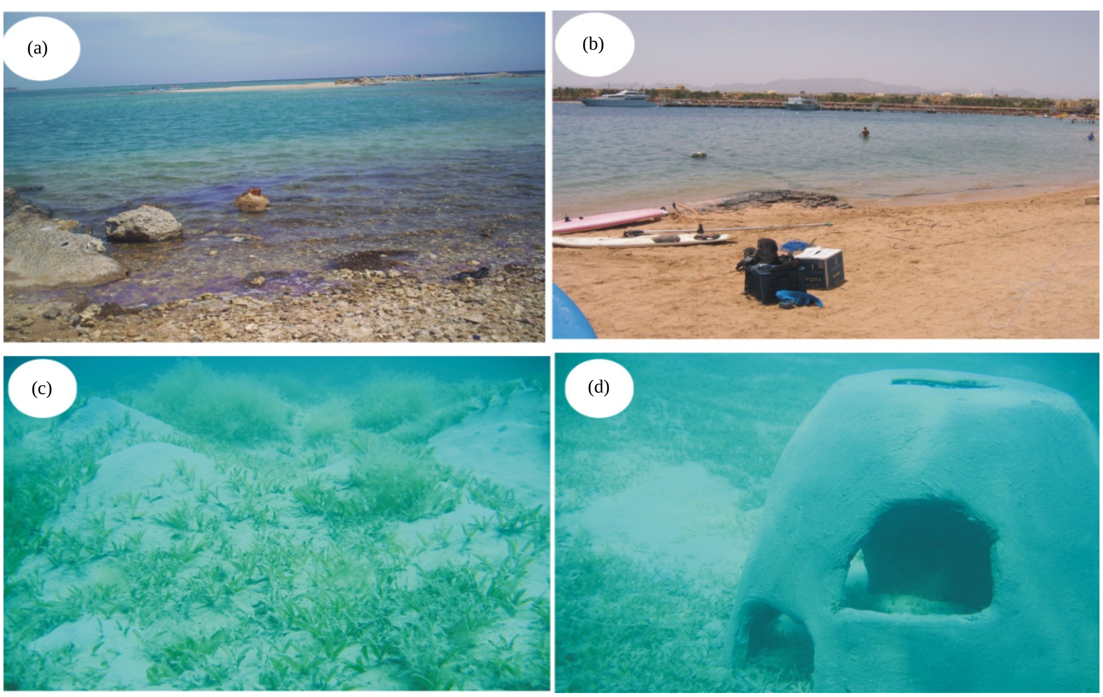

Fig. 3(a-d): General view of Abu-Makhadeg Bay: (a-b) Southern part of beach and intertidal area of Abu-Makhadeg area, (c) Nature of bottom sediments near the beach of the northern part of Abu-Makhadeg Bay and (d) Rehabilitation operation of coral reefs and marine organisms of Abu-Makhadeg Bay by this project (After authors)

sediments types, grain size parameters, carbonate content and total organic matter was weak (Table 3). With the exception of these relations gravel with Mean Size (MZ) (r = -0.82), gravel with carbonate content (r = - 0.52), sand with mud (r = -0.7), sand with skewness (Sk_I) (r = -0.56), mud with mean size (MZ) (r = 0.77), mud with sorting (6_I) (r = 0.51), mud

Table 1: Sample location, depth and bottom facies at Sharm Abu-Makhadeg area

	Position			
	Latitude	Longitude		
Sa. No.	o / // N	o / // E	Depth (m)	Bottom facies
M1	26 59 02	33 54 53	Beach	Coarse sand
M2	26 59 04	33 54 53	4	Muddy sand with seagrass
M3	26 59 03	33 54 53	4	Biogenic sand with seagrass
M4	26 59 02	33 54 48	Beach	Muddy sand
M5	26 59 02	33 54 50	2	Sandy gravel
M6	26 59 02	33 54 50	2.2	Sand with seagrasses
M7	26 59 09	33 54 53	1.5	Sand with seagrasses
M8	26 59 13	33 54 53	2.2	Muddy sand with seagrass
M9	26 59 16	33 54 54	2.9	Muddy sand with seagrass
M10	26 59 17	33 54 53	1.4	Biogenic sand
M11	26 59 11	33 54 48	2.6	Muddy sand
M12	26 59 08	33 54 47	2.1	Muddy sand
M13	26 59 07	33 54 46	2.1	Sand
M14	26 59 06	33 54 45	Beach	Coarse sand
M15	26 59 09	33 54 42	Beach	Coarse sand
M16	26 59 13	33 54 45	1.25	Sandy mud with seagrasses
M17	26 59 17	33 54 43	2.4	Muddy sand with seagrass
M18	26 59 20	33 54 41	1.2	Biogenic sand
M19	26 59 24	33 54 40	9	Biogenic sand
M20	26 59 25	33 54 39	17	Very fine sand
M21	26 59 27	33 54 31	19	Very fine sand
M22	26 59 27	33 54 22	21	Sandy mud with seagrasses
M23	26 59 27	33 54 15	8	Very fine sand with seagrasses
M24	26 59 27	33 54 13	3.5	Very fine sand with seagrasses
M25	26 59 25	33 54 11	2.5	Sandy mud with seagrasses
M26	26 59 21	33 54 10	3.2	Sandy mud with seagrasses
M27	26 59 28	33 54 09	Beach	Sandy gravel
M28	26 59 33	33 54 09	10	Muddy sand with seagrasses
M29	26 59 38	33 54 07	17	Biogenic sand
M30	26 59 39	33 54 05	10	Muddy sand with seagrasses
M31	26 59 42	33 54 03	6	Muddy sand with seagrasses
M32	26 59 38	33 54 00	25	Muddy sand with seagrasses

with skewness (Sk_I) (r = 0.55), mud with total organic matter (TOM) (r = 0.47), Mean Size (MZ) with kurtosis (K_G) (r = 0.58), Mean Size (MZ) with TOM (r = 0.47), carbonate content with total organic matter (TOM) (r = 0.52) (Table 3). The marine sediments collected from the study area had mean size (Mz) values ranging from -0.32-4.06Φ, averaging 2.6Φ (Table 2). Sorting (6_I) of sediments varies between 0.65 and 1.95Φ averaging 1.28Φ (Table 2). The inclusive graphic skewness (SK_I) of the collected sediments ranges from -0.54 to 0.5Φ, averaging -0.06Φ (Table 2). The graphic kurtosis (KG) of sediments sampled from Sharm Abu-Makhadeg area ranges from 0.68-5.09Φ, averaging 2.13Φ (Table 2).

Cluster analysis (using Ward's method) includes gravel, sand and mud content separates all samples (32 samples) of Sharm Abu-Makhadeg area into 6 main clusters according to the abundance of size fraction (Fig. 4). Of these clusters only three had a high number of samples. Clusters 1, 2 and 6 constitute 72% of the total samples and are characterized by very high sand fraction 88.3, 94.4 and 79.9%, respectively. Most samples of clusters 1, 2 and 6 fall in shallow marine environment and offshore area (Fig. 2). Cluster 3, 4 and 5 represented 28% of the total samples and were distinguished by the lowest content of mud except cluster 5. Sediment samples of clusters 3 and 4 were belonging to the supratidal and beach areas and some samples from offshore area (Fig. 2). On the other hand, cluster 5 recorded the highest content of mud compared with the other clusters. Sediment samples of clusters 5 were belonging offshore area (Fig. 4).

Geochemistry

Carbonate content: In general, the total carbonate in the Sharm sediments was between 2.94 and 84.17% with an average 43.18% (Table 2).

Table 2: Results of grain size and geochemical analysis of surface marine sediments at Sharm Abu-Makhadeg area

	Sediment types			Grain size parameters				Geochmical analysis			
Sa. No.	Gravel	Sand	Mud	Mz	6_I	Sk_I	K_G	Carb. (%)	OC (%)	TOM (%)	Depth (m)
M1	12.80	86.20	1.00	1.53	1.68	-0.37	0.77	27.71	1.22	1.53	Beach
M2	1.61	86.42	11.97	3.24	1.02	0.05	2.84	44.90	2.66	3.33	4
M3	4.85	90.20	4.96	2.53	1.35	-0.54	1.90	43.78	1.78	2.22	4
M4	5.73	81.05	13.22	3.11	1.57	-0.22	3.69	55.05	1.85	2.31	Beach
M5	30.11	69.89	0.002	-0.32	0.79	0.12	0.89	2.94	0.54	0.67	2
M6	4.58	85.42	10.00	3.10	1.38	-0.16	3.33	37.47	2.14	2.68	2.2
M7	1.64	89.32	9.05	3.15	1.20	-0.16	3.43	25.00	2.02	2.52	1.5
M8	2.92	81.08	16.00	3.36	1.31	0.04	4.38	51.55	1.56	1.95	2.2
M9	3.43	79.05	17.53	2.93	1.82	-0.13	1.93	69.17	4.98	6.22	2.9
M10	0.14	96.80	3.06	2.06	1.18	-0.06	0.85	84.17	2.20	2.75	1.4
M11	4.14	77.54	18.32	3.69	1.46	-0.02	5.09	37.91	3.02	3.78	2.6
M12	6.62	79.95	13.44	2.78	1.79	-0.31	3.32	54.22	2.66	3.33	2.1
M13	6.10	86.51	7.39	2.84	1.47	-0.41	3.51	45.99	1.66	2.08	2.1
M14	12.61	87.34	0.05	-0.20	0.65	-0.05	1.09	3.68	0.15	0.19	Beach
M15	11.50	87.97	0.53	0.54	1.42	0.43	0.68	28.98	1.80	2.25	Beach
M16	0.54	69.77	29.69	3.84	1.51	0.50	1.24	17.31	1.20	1.50	1.25
M17	6.56	75.49	17.95	2.95	1.95	-0.20	2.56	59.32	2.92	3.65	2.4
M18	0.96	96.08	2.97	1.94	1.33	-0.13	0.87	79.64	3.06	3.82	1.2
M19	1.21	96.70	2.09	2.23	1.14	-0.33	1.27	56.64	2.22	2.78	9
M20	0.78	90.34	8.89	2.91	0.86	-0.21	1.47	66.73	2.12	2.65	17
M21	0.73	90.86	8.41	3.04	1.07	-0.11	2.23	72.72	2.75	3.44	19
M22	1.80	70.03	28.17	3.79	1.70	0.08	3.01	58.68	2.79	3.49	21
M23	0.70	94.30	5.00	3.04	0.75	-0.31	1.36	20.09	0.98	1.23	8
M24	2.11	94.50	3.39	2.71	0.83	-0.20	1.81	26.20	1.37	1.71	3.5
M25	0.92	68.85	30.24	4.06	1.39	0.44	1.78	37.36	4.17	5.21	2.5
M26	1.16	70.26	28.58	3.94	1.44	0.43	1.80	22.47	3.76	4.70	3.2
M27	24.35	75.56	0.09	-0.31	0.69	-0.10	0.72	17.94	2.20	2.75	Beach
M28	2.59	83.21	14.20	2.68	1.72	-0.19	1.64	46.69	3.83	4.79	10
M29	1.32	92.54	6.14	2.57	1.24	-0.25	1.33	62.45	4.34	5.42	17
M30	1.80	89.84	8.36	2.91	1.19	-0.14	1.82	53.86	3.44	4.30	10
M31	0.23	87.40	12.36	3.17	1.13	0.05	2.53	42.50	3.48	4.35	6
M32	0.21	81.72	18.07	3.62	1.03	0.39	3.10	28.57	2.90	3.62	25
Min.	0.14	68.85	0.001	-0.32	0.65	-0.54	0.68	2.94	0.15	0.19	0.00
Max.	30.11	96.80	30.24	4.06	1.95	0.50	5.09	84.17	4.98	6.22	25.00
Avg.	4.90	84.13	10.97	2.61	1.28	-0.06	2.13	43.18	2.43	3.04	5.72

Mz: mean size, 6_I: Sorting, SK_I: Skewness, K_G: Kurtosis, Carb.: Carbonate content, *Values ppm, OC: Organic carbon. Source: Folk and Ward[28]

Table 3: Correlation coefficients between sediment types, grain size parameters, carbonate content, total organic matter, depth of surface marine sediments at Sharm Abu-Makhadeg area

Parameters	Gravel	Sand	Mud	Mz	6_I	Sk_I	K_G	Carb. (%)	TOM (%)	Depth
Gravel	1									
Sand	-0.33	1								
Mud	-0.45	-0.70	1							
Mz	-0.82	-0.15	0.77	1						
6I	-0.23	-0.35	0.51	0.42	1					
SkI	-0.02	-0.56	0.55	0.15	-0.03	1				
KG	-0.29	-0.21	0.42	0.58	0.31	-0.06	1			
Carb.%	-0.52	0.36	0.05	0.33	0.38	-0.33	0.12	1		
TOM%	-0.44	-0.14	0.47	0.47	0.44	0.14	0.12	0.52	1	
Depth	-0.38	0.11	0.19	0.33	-0.13	0.04	0.06	0.29	0.31	1

Organic Carbon (OC) and Total Organic Matter (TOM): In general, the sediments had values of organic Carbon 0.15-4.98% with average 2.43% and total organic matter content varying from 0.19-6.22% with average 3.04% (Table 2). The results of correlation coefficient illustrated in Table 3, weak positive correlation between TOM and depth and high positive correlation coefficient between TOM and carbonate (Table 3).

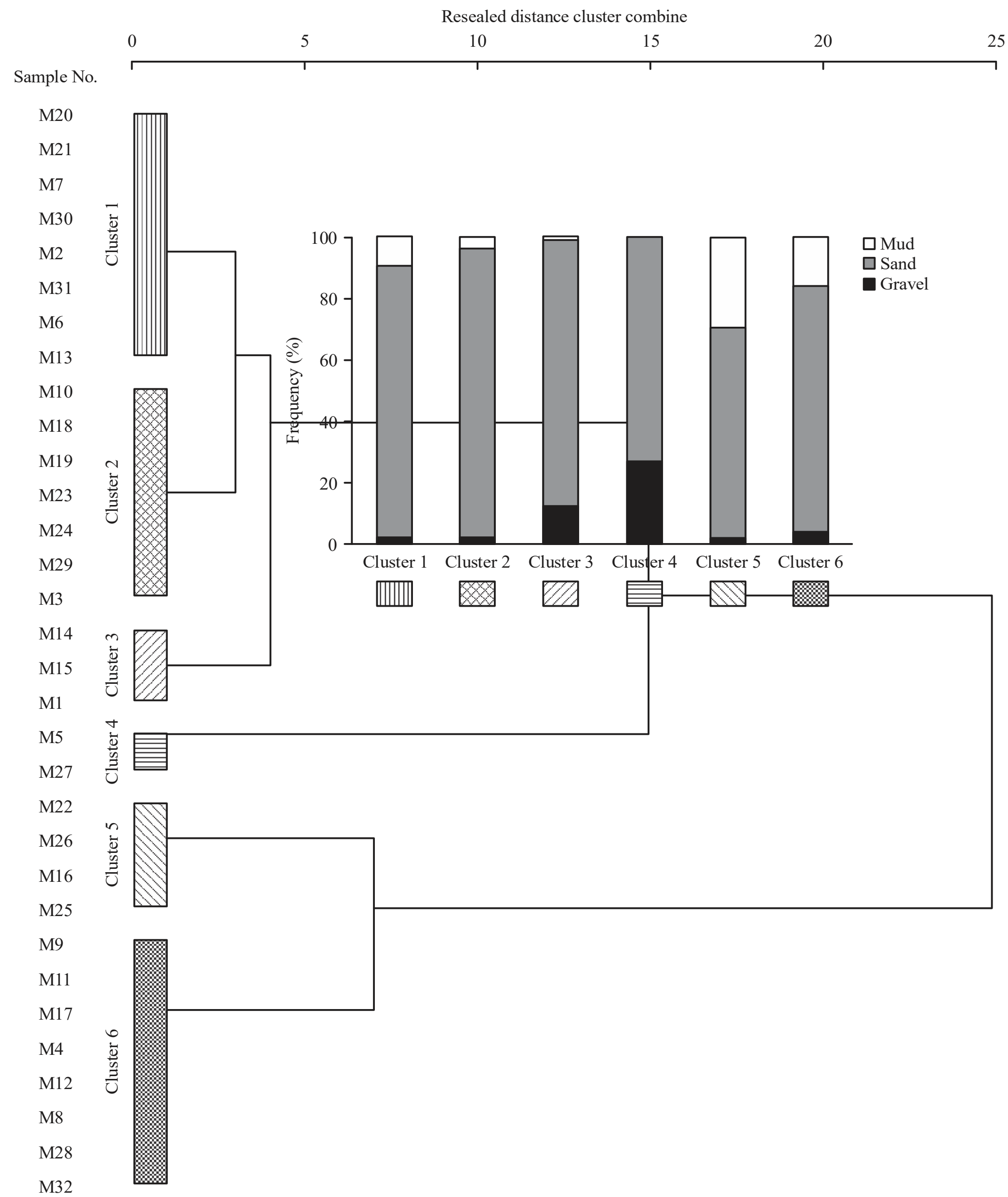

Fig. 4: Dendrogram from cluster analysis (ward's method) and histogram exhibiting cluster of grain size texture

DISCUSSION

Sediments in Sharm Abu-Makhadeg as well as in the beach, intertidal and lagoons are composed of a mixture of carbonates and siliciclastics. However, biogenic activity is regarded as the major source of sediments few meters away from the wadi mouth. Intertidal sediments are mainly sands compared to beach sediments, gravel content is low and mud is a little higher. Sediments of lagoons are finer than those of beach and intertidal area. Generally, the sediments of the investigated area were found to consist of a wide variety of texture classes, from coarse sand to sandy mud. The marine sediments in the study area are mainly composed of sand. Generally, the mud contents seem to be increase with increasing water depth and distance from the shoreline. The reason for this high mud content is due to the landfill operation in the past.

Cluster analysis (using Ward's method) includes gravel, sand and mud content separates all samples (32 samples) of Sharm Abu-Makhadeg area into 6 main clusters. According to cluster analysis fine grains are transported by sea waves to the offshore. According to Mansour[1] waves and currents redistribute terrigenous debris carried into the sea either via wadi or NW winds on the tidal flat and most likely also sweep some of the fine terrigenous sediments from the submarine slopes into the deeps. The distribution of the coaser sediments my reflect the abundance of terrigenous sediments in the beach and biogenic fragments in the reef areas. Generally, the sediments of Sharm Abu-Makhadeg are characterized by a fine texture. Sand is the main category among the three constituents as showed (Fig. 4).

The distribution of mean grain size (MZ) is included here for comparison with those of the various geochemical parameters. The influence of these sources is more or less localized resulting in a particular textural and compositional distribution, especially in the nearshore area. The marine sediments collected from the study area have mean size (Mz) values fine sands. Sorting (6_I) of sediments are poorly sorted. The sediments in the study area show change from strongly coarse skewed and fine skewed near the beaches to nearly symmetrical and coarse skewed distribution with increasing water depth. The kurtosis (KG) values of this area do not show any trend for increase or decrease with water depth.

Most samples of beach and intertidal have low carbonates content resulted from very high landfilling and dredging, as a result of human activities carried out in the coastal region during the 1990s. High carbonate content is recorded in samples away from offshore areas. The biogenic constituents are relatively high in the seaward sediments less influenced by terrigenous constituent. Mansour *et al.*[24] found that the carbonate content of shallow marine sediments between Hamata and Gemsha along the Egyptian Red sea coast varies from 39.98-84.40% with an average of 77.56. This average value is higher than that recorded in Sharm Abu-Makhadeg. This is attributed to the increasing in landfilling and dredging income to the tidal flat in Sharm Abu-Makhadeg area.

The investigated area is subjected to occasional torrents rich with fine sediments with high organic content. Therefore, sediments with darkish gray color cover most area. However, samples with high organic content occur mainly in the Sharm itself and in the dredged areas of tidal flat in the past. In general, the average organic carbon and total organic matter contents of the sediments are relatively higher than those of other areas in the Red sea[30]. This is probably due to this high organic productivity. The terrestrial input of organic matter by wadi might be very high compared with that from the plant debris and animals inhabiting its waters and living on its bottom. The high content of organic matter is probably responsible for metal enrichment.

Sharm Abu Makhadeg is a small embayment and construction marinas in front of each hotel will close the Sharm and destroy the environment of the area, a practice that has been widespread in Hurghada and Safaga. The other problem is that the construction of private embankments used as jetties should be halted and jetties should only be allowed if they are floating or constructed on pillars, which allow the natural flow of sedimentation. Human activities may increase turbidity, alter water circulation and sediment distribution patterns and may destroy entire reef systems. The unnatural obstruction in the water disrupted tidal flows and the natural deposit of sediments, so that after a certain time hundreds of m^2 of land were ebbed away from the property, ruining the plans an architect had designed for land. The fine grained sediment resulting from the development activity increases the water turbidity and now the visibility of water is very poor.

CONCLUSION

Abu Makhadeg area are rich with organic matter. Fortunately, sediments on both sides of the sharm are covered with rocky limestone o tidal flat. Dredging of this rocky cover reveals fine sediments and concentrate organic matter and trace metals in confined pools. The contribution of land-derived materials is significant high in bottom sediments of Sharm Abu-Makhadeg. Cooperation between the investors and the EEAA is very important in order to centralize decisions and responsibilities. Sharing the developers of the area in constructing new marina, cornish in front of their resorts and round road behind their properties will be very faithful and decrease the environmental problems.

SIGNIFICANCE STATEMENT

The scope of the present work are monitoring of changes of sediment nature by environmental impacts of Sharm Abu-Makhadeg area and record all development activities during the past 20 years. The impact of development activities in Sharm Abu-Makhadeg area was measured by surveying and by analyzing the surface marine sediment. These study Reasonable recommendations have been outlined to offer guidelines to mitigate the impact on the marine environment. These recommendations are something of a compromise between the economic interests and environmental concerns in the area.

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