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GEOCHEMICAL AND ENVIRONMENTAL STUDIES OF RECENT MARINE SEDIMENTS AND SOME HARD CORALS OF WADI EL-GEMAL AREA OF THE RED SEA, EGYPT

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ABSTRACT

The distribution of (Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd) concentrations were determined in surface marine sediments and coral reefs at Wadi El-Gemal in the Red Sea area. There were significant differences in concentrations of heavy metals in the marine sediments relative to the coral reefs. Some heavy metal concentrations in sediments and coral reefs in the study area are high compared to that in the impact areas of the Egyptian Red Sea coast. The results indicate that the high concentrations of heavy metals in marine sediments and coral reefs are particularly affected by the high contribution of terrigenous materials through the stream of Wadi El-Gemal. Generally, heavy metals concentration in the sediments decreased with increasing distance from the shoreline with the exception of Pb, which increased with increasing distance from the shoreline. On the other hand, Pb concentration in coral reefs is high compared to that in some sediment samples at Wadi El-Gemal area.

The grain size, carbonate, organic matter, phosphorus and heavy metals distribution reflect marked changes in lithology, biological activities in the sea and land geology of the study area. Carbonate content mainly of biogenic origin varies from 5.7 –69.5% of the sediments. Organic matter contents of the sediments (1.7 to 6.5%) and phosphorus content (110 to 5097ppm) usually reflect significant terrigenous influences. On the other hand, heavy metals show an increasing tendency in the mud fraction of Wadi El-Gemal area.

The present work reflects how much the marine sediments and coral reefs are influenced by natural impacts from this wadi. The collected data will be useful in management and suitable development of the area, beside being helpful as database in the future.

INTRODUCTION

Wadi El-Gemal area is declared as a protected area in November 2002. It is a valuable watershed area with wildlife habitat, containing unique plants and animals. In addition to its fascinating geologic history, the area is notable for its history of human activity, with a variety of ancient mining settlement of archeological value (Mansour, 2003). Active development of Wadi El-Gemal area affected most of the coastal area. Environmental pressures could spread to the hinterland mountainous region. Diversity and beauty of this natural environment attract for tourist and worth to be preserved for the national interest. Present tourist activities do not appear to have adverse impact the terrestrial resources of the area. Yet, little environmental degradation is noticed at some parts of the coast, and lesser environmental problems at some other sites in the Wadi, but most of these problems are not caused by tourism (Mansour, 2003). The Egyptian Environmental Affairs Agency (EEAA) rangers have started controlling this area, but considerable work still to be done to make this more effective and purposeful, starting with management plans.

The erosion of the coast by stream water has resulted in the removal of vast amount of sediments, especially silts and clays. Therefore, bottom sediments reflect the past and present environmental conditions of this area. Due to the high contribution of the terrigenous materials by the wadi, heavy metal concentrations of sediments and coral reefs recorded significant levels as compared to impacted areas on the Egyptian Red Sea coast. Moreover, differentiation between the natural and anthropogenic sources of trace metals can often be complicated by the large natural variability of trace metal concentrations in sediments arising from differences in lithology, mineralogy, grain size, and organic matter content. Carbonate sediments, for example, are well known to exhibit lower trace metal contents than Fe- and clay- rich sediments (Turekian and Wedepohl, 1961).

Several investigations on recent sediments and human impacts were carried out on the Egyptian Red Sea coast (eg. Madkour, 2004 with references). On the other hand, there is some published information on the levels of heavy metals in coral reefs of the Red Sea coast such as those presented by (Rinkevich and Loya, 1977, 1979; Loya and Rinkevich, 1980, 1987; Hanna, 1990; Abd El-Salam, 1993; Jameson et al., 1999; Mohammed 2002, Mohamed and El-Sorogy, 2003, Mohammed 2003, Dar, 2004 and Madkour, 2004). Generally, information on the geochemistry of recent sediments and coral reefs in the southern Red Sea of Egypt still needs more investigations.

The aim of this work is to assess the effect of natural impact on the recent sediment and coral reefs in Wadi El-Gemal area. For this purpose, geochemical investigations have been conducted on 25 samples of surface sediments collected from the backshore, foreshore and offshore (Fig.1). Some specimens of coral reefs have also been analyzed with a view to assess the release of heavy metals from the natural impact into the sea. Being these reefs are bioaccumulator considered as good biomonitor of heavy metals. Such information may be used as a database for management and development of the area.

Environmental conditions and geology of the study area

Wadi El-Gemal is one of the famous Red Sea wadis for tourism. The area is located about 50km south of Marsa Alam, between latitude 24° 39\ N and longitude 35° 05\E (Fig. 1). Wadi El-Gemal is characterized by an arid climate and dominated by hot, rainless summer and mild winter. Most of the precipitation occurs as heavy showers with short duration resulting in flash floods during the winter season between October and February. A huge amount of rainwater can be percolated and replenish the groundwater reservoir if the runoff is controlled (Mansour, 2003). Rainfall quantities of Wadi El-Gemal was estimated by Ahmed (2001). During collecting the samples, oceanographic parameters were measured at different depths using Hydrolab Instrument (Surveyor [(4)] 1997) as shown in (Table 1).

Table (1).The measured hydrographic parameters of water mass in Wadi El-Gemal area.

Depth (m)	pH	Salinity o/oo	Temp. °C	DO Mg\L	Eh	TDS g\L	SPC ms\cm
Surface	8.1	39.9	29.0	4.6	336	37.9	59.9
5	8.2	39.9	24.1	4.9	346	37.8	59.7
Surface	8.1	39.9	24.0	4.7	345	37.9	59.7
10	8.2	40.0	23.8	5.3	352	37.9	59.8
Surface	8.2	39.9	23.9	5.9	357	37.8	59.4
20	8.2	40.0	23.3	6.4	363	37.8	59.7

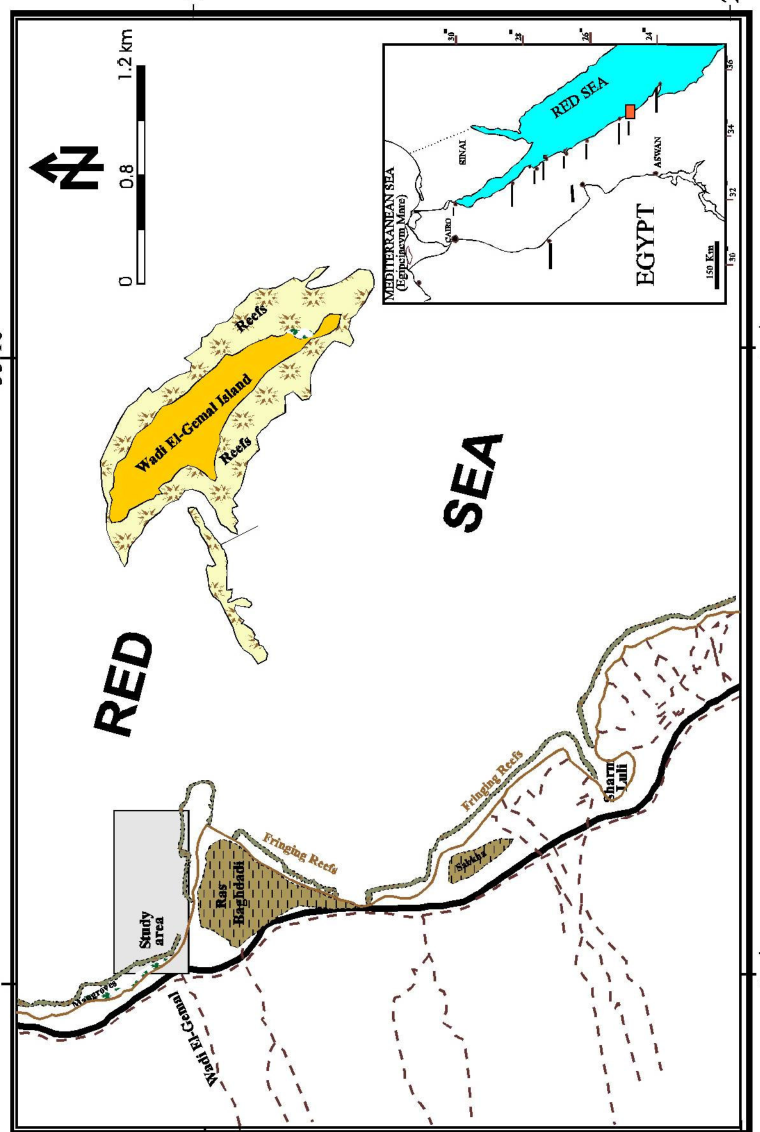

Fig. 1. Location map of Wadi El-Gemal area along the Red Sea coast, Egypt.

The source rocks of Wadi El-Gemal are composed of a complex of granites, diorites and green breccia (El-Mamoney, 1995) with the sediments along this wadi have relatively large cuttings resulting from the effect of the violent drive water during heavy torrents. Two prominent items; the palm trees and mangroves (Figs. 2 &3) distinguish the shore area of this wadi. The rocky beach ends abruptly into deep water. Wadi El-Gemal Island located in the front of the mouth of the wadi, far from Ras Bagdadi by a distance of about 5km to the east. This area is covered by seagrass and biogenic sand (Figs. 2 &3). Most sediment samples have gray to dark gray color. Fringing reefs characterize the area in front of the northern part at the mouth of the wadi (Fig.1). The most common and widely distributed coral species in this area are *Porites sp.*

Material and Methods

The material used in this study were collected during spring and autumn of 2004. The area was divided into two transects G1 and G2 from south to north (Fig. 2). Transect G1 was taken in front of the mouth of the wadi, while transect G2 was taken in the northern part at the mouth of the wadi. Twenty-five sediment samples were collected by hand, grab samples and Scuba diving along these transects at depths ranging from zero to 35m below sea level, and distributed along a distance of 2310m from the shoreline (Fig. 3). Surface sediment samples represent four different environmental features, namely supratidal zone, beach, intertidal and offshore zones. Coral reef species were collected by Scuba diving in front of the mouth of the wadi. Nine species of corals, which include seven species of branching (elkorn) coral (*Stylophora wellesi*, *Acropora humilis*, *Acropora hemprichii*, *Acropora hyacinthus*, *Pocillopora damicornis*, *Millepora complanata* and *Millepora dichotoma*) and two species of massive coral (*Porites lutea*, and *Porites compressa*), are considered as the most common species of this area. The samples were placed in labeled plastic bags and returned to the laboratory. Coral reef specimens were soaked in water for 15-30 minutes in order to kill any clinging algae then left to dry in air.

Granulometric analysis of marine sediments was performed using the sieving technique after Folk and Ward (1957), whereas the geochemical analyses were carried out for all marine sediments and coral reef species. The total carbonate content was determined by treating the samples with hydrochloric 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^{o}C (Dean, 1974; Flannery et al., 1982; Brenner and Binford, 1988) while determination of the total phosphorus was made according to (American Public Health Association "APHA" 1995). Concentrations of the metals; (Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd) were determined for recent sediments and coral reefs (Oregioni and Aston 1984). About 0.5g of the prepared ground sample were 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 ^{o}C, then left to cool and filtered to get rid of the nondigested parts. The solution was justified to volume of 25ml, then the concentration of the elements was determined by AAS (GBC-932 Ver. 1.1) of the National Institute of Oceanography and Fisheries, Red Sea branch.

Fig. (2): A general view of Wadi El-Gemal Delta (upper picture {left}), erosion of coastal area (upper picture {right}), coral reef community at 6m depth (lower picture {left}) and high dense of seagrasses at 15m depth.

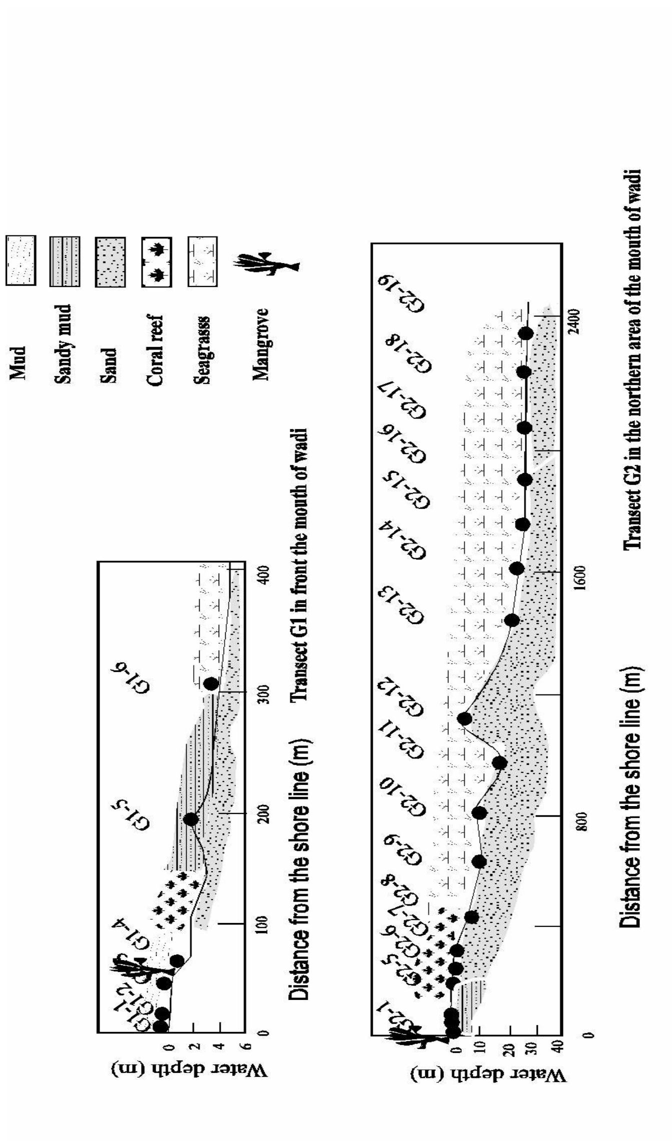

Fig. 3: Transects show sample depth (solid line with solid circles) and bottom facies at Wadi El-Gemal area.

RESULTS AND DISCUSSION

Distribution of surface sediments

Sediments in Wadi El-Gemal area are composed of a mixture of terrigenous and biogenic materials. However, terrigenous activity is regarded as the major source of sediments to the area. 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 area are mainly composed of sand (36 to 99.5%). Mud constitutes 0.06 to 63.9% and gravel is very rare (0.0 to 8.1%) (Table 2; Fig. 4). The supratidal (sabkha) and beach areas record the highest values of mud fraction compared to the intertidal and offshore sediments. Generally, the mud contents seem to be decrease with increasing water depth and distance from the shoreline. The domination of fine texture of Wadi El-Gemal sediments can be explained by the strong influence of terrigenous inputs by this wadi. The mean size generally decreases and the sediment type changes from coarse sand to muddy sand and sandy mud. The sorting is generally poor and the skewness values generally change from strongly coarse skewed to fine skewed. The kurtosis values are of platykurtic to very leptokurtic category, with an average of leptokurtic nature (Table 2). This variation in the character of sediments result from types of flux of clastic sediments, diversity of biogenic grains and the effectiveness of wave actions and currents.

Cluster analysis (using Ward's method) includes gravel, sand and mud content separates all samples (25 samples) of Wadi El-Gemal area into four main clusters according to the abundance of size fraction (Fig. 5). Of these clusters only two have a high number of samples. Clusters 1 and 2 constitute 84% of the total samples and are characterized by very high sand fraction (95.85%) and (82.54%) respectively. Most samples of clusters 1 and 2 fall in intertidal zone and offshore area (Fig. 5). Cluster 3 and 4 represent 16% of the total samples and are distinguished by the highest content of mud (39.65%) and (58.48%) respectively. Sediment samples of clusters 3 and 4 are belonging to the suprtidal and beach areas and some samples from offshore area (Fig. 5). Fine grains are transported by sea waves to the offshore. According to Mansour (1995) 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. Generally, the sediments of Wadi El-Gemal are characterized by a fine texture.

Geochemical parameters

Carbonates, organic matter and Phosphorus

The carbonate content in surface sediments of Wadi El-Gemal area ranges between 5.66% and 69.5% with an average of 31.54% (Table 2; Fig. 6). The carbonate content is a little suppressed by the over supply of terrigenous materials. It show negative correlation with mean size and mud fraction (r=-0.54 and –0.37 respectively; Table 3). A weak positive correlation is obtained between carbonate and sand fraction (r=0.33) and gravel (r=0.26) probably suggesting the predominance of carbonates in the coarse-grained sediment fractions. On the other hand, carbonates show positive correlation with the distance from the shoreline (r= 0.48) (Table 3). This indicate that carbonate content generally increase seaward.

The total organic matter of sediment samples is relatively high varying from 1.67% to 6.47% with an average of 3.8% (Table 2; Fig. 6). There are two main reasons for high the organic matter in this area. The terrigenous flux is the main reason and the green rug covering of dense seagrasses represent the second reason. Mansour (1999) and Mansour et al., (2000b) attributed the higher content of the organic matter in tidal flat sediments to the terrigenous flux. The organic carbon content increase as particle size decreases.

Phosphorus of marine sediments in Wadi El-Gemal varies from 110 ppm to 5097 ppm, averaging 1618 ppm (Table 2; Fig. 6). It decreases with increasing distance from the shoreline while the supratidal zone and beach areas recorded the highest values. This indicates that phosphorus might be derived from the terrestrial sediments. Phosphorus content in the sediments from natural sources is small compared to anthropogenic inputs in Quseir and Safaga Harbours as estimated by Madkour (2004). Moreover, phosphorus correlates directly with Fe and Mn while correlates reversally with carbonate, organic matter, depth and distance from the shoreline (Table 3). This clarifies that the phosphorus content of the investigated sediments are derived from the basement complex source materials and not as abound element in the marine carbonate sediments.

Heavy metals distribution

In sediments

The results of heavy metals are shown in (Table 2). The eight heavy metals (Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd) showed a wide range of concentrations.

Fe concentration of marine sediments varies between 2266ppm and 3306ppm, averaging 2916ppm. While Mn level ranges from 162.9ppm to 968.4ppm with an average of 536.6ppm. The association of iron and manganese is well known; Jeffery (1975) reported that in the igneous silicate rocks, Mn is present in divalent state associated with ferromagnesium and accessory iron minerals. There are many sources for iron and manganese transfer to the marine environment. In the present work Fe and Mn transfer to the marine environment naturally by Wadi El-Gemal.

Zinc concentration changes from 18.2ppm to 383.03ppm, averaging 79.12ppm. The increase in Zn content in supratidal, beach and tidal flat sediments is due to the influence of terrigenous fragments rich in this element and principally derived from volcanic and metamorphic rocks. El-Mamoney (1995) stated that Zn in the residual sediments may be present as primary component of illuminate and magnetite, the common constituents of black sands, which may contain from one to several thousand ppm of Zn. The concentration of copper is varying from 5.2ppm to 453.6ppm with an average of 36.2ppm. The supratidal zone and beach area recorded the highest values of Cu. Therefore, the Cu concentrations follow a decreasing trend toward shoreline and consequently seaward. The previous trend reveals that the general behavior of some elements, which have smaller content in the marine sediments than in parent rock materials, reflects the effects of weathering and leaching processes. The concentrations of the heavy metals in marine sediments of the present work are small compared to that estimated by El-Mamoney (1995) in terrestrial materials in Wadi El-Gemal area.

Lead, which is found in relatively higher concentration, ranges from 12.75ppm to 96.3ppm, averaging 41.7ppm. It shows a relative higher concentration in the offshore zone in comparison with the nearshore sediments (Table 2). However, the general trends of lead contents are more or less hardly increasing offshore direction, but those segments representing the land sediments have an opposite direction slightly decreasing towards the shoreline. Nickel is found in higher concentrations of the sediments. It varies from 11.19ppm to 156.3ppm with an average of 51.4ppm.

Nickel content show general expected trends, (Table 2) illustrating a decrease in seaward direction. Madkour (2004) reported that Ni concentration in the marine sediment not display trends indicative of large anthropogenic contribution to these sediments. Therefor, the main source is due to the contribution of terrigenous fractions.

Cobalt is found in relatively lower concentrations and ranging between 0.2ppm and 3.93ppm, averaging 1.7ppm. Mansour (1999) stated that, Co and Ni elements are principally derived from ultramafic rocks.

Several factors such as grain size, organic matter, pH and redox control the cobalt accumulation (Smith, 1992). Cadmium is one of the most rare elements recorded in the marine sediments. It varies from 0.02ppm to 0.16ppm, averaging 0.08ppm. El-Mamoney (1995) found relative higher cadmium contents in the marine sediments than those in terrestrial ones. This relative higher content is surely contained in the biogenic carbonates of the marine sediments of Wadi El-Gemal area. Generally, the concentrations of Co and Cd of the sediments in Wadi El-Gemal area are low compared with that of marine sediments in former studies of the Egyptian Red Sea coast (Table 4).

The relationships showed that Fe and Mn are negatively correlated with carbonate, depth and distance from the shoreline and positively correlated with zinc, nickel, cobalt, phosphorus and mean size (Table 3). Also, the correlation matrix shows positive correlation between Zn and Cu, Ni and Co while Zn shows negative correlation with carbonate, depth and distance from the shoreline. Pb are positively correlated with organic matter, carbonate content and distance from the shoreline. In the same manner, the results of the correlation coefficients show generally that the high concentrations of heavy metals (Fe, Mn, Zn, Pb, Ni and Cu) in Wadi El-Gemal sediments are due to the high contribution of terrigenous fragments. Wadi El-Gemal has the highest values of maximum runoff compared with other wadis of the Eastern Desert of Egypt (Mansour 2003).

In comparison, the results show that most heavy metal concentrations of marine sediments in Wadi El-Gemal area recorded relatively high values compared to other studies of the Egyptian Red Sea coast (Table 4). For example, Fe and Mn concentrations recorded high values in the present work compared to the former studies except in Quseir and Safaga Harbours (Madkour, 2004). Also, Zn and Ni concentrations recorded the highest values in the marine sediments compared with the former studies of the Egyptian Red Sea coast (Table 4). While Cu concentrations are high in El-Esh area (Madkour, 2004) and in Abu-Makhadaeg area (Mansour, 1999) compared to that in the present work (Table 4). In the same manner, Beltagy (1984), El-Mamoney (1995) and Nawar et al., (1997) each found that high concentrations of lead in marine sediments compared to the lead concentration in Wadi El-Gemal sediments. On the other hand, Co and Cd concentrations recorded the lowest values in Wadi El-Gemal sediments compared to their concentrations in the other studies of the Egyptian Red Sea coast (Table 4).

The behavior of heavy metals in Wadi El-Gemal marine sediments is complex due to seasonal and geographic variations in the terrigenous fluxes by this wadi.

Table (2). The results of grain size and geochemical analysis of marine sediments of Wadi El-Gemal area.

Sa.	Sediment types			Grain size parameters (Folk&Ward,1957)				Carb.%	OC%	TOM%	P*	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*	Depth	D.Sh
No.	Gravel	Sand	Mud	Mz	6I	SkI	KG													(m)	(m)
G1-1	7.30	39.76	52.95	4.22	3.48	0.01	1.06	11.92	2.99	5.38	4068	3306	968.4	216.8	70.9	96.3	124.2	3.9	0.14	0	0
G1-2	0.20	85.95	13.86	3.08	1.14	0.18	2	5.66	1.05	1.89	3499	3166	808.4	160.2	28.4	15.6	77.1	2.6	0.03	0.2	20
G1-3	3.79	80.38	15.83	3.04	1.48	0.03	2.57	11.51	2.44	4.39	839	3146	796.8	283.0	453.6	46.9	69.2	2.1	0.06	1	50
G1-4	3.45	96.39	0.17	1.79	1.33	-0.06	0.95	40.26	2.49	4.48	684	3217	926.2	247.8	72.0	40.3	156.3	3.4	0.02	beach	150
G1-5	0.47	99.47	0.06	2.61	0.8	-0.15	0.82	19.92	1.44	2.59	1038	2915	561.2	69.3	24.5	42.6	60.2	0.8	0.03	2	250
G1-6	0.16	93.77	6.07	3.02	0.73	0.05	1.36	10.74	0.94	1.69	3362	3168	799.7	133.2	29.9	39.6	73.2	2.1	0.14	7	350
G2-1	0.00	74.29	25.71	3.33	1.21	-0.18	1.57	8.72	0.93	1.67	4269	2932	552.5	45.4	15.5	12.9	32.2	1.2	0.11	0	beach
G2-2	0.00	36.03	63.98	4.17	1.33	-0.29	1.67	9.34	2.16	3.88	1554	3030	567.1	63.9	26.2	13.8	44.6	1.1	0.08	1	150
G2-3	0.00	99.14	0.86	2.41	0.41	0.16	1.32	12.36	2.37	4.27	1645	3045	754.6	70.4	29.2	13.5	51.2	2.1	0.11	0.5	310
G2-4	0.52	98.40	1.08	2.3	0.71	-0.02	1.55	55.36	2.43	4.38	231	2674	317.0	28.4	8.3	12.8	23.1	0.7	0.12	1.5	330
G2-5	6.13	91.88	1.99	1.34	1.49	-0.09	0.83	58.97	2.09	3.77	1187	2539	301.0	21.0	7.1	34.2	13.5	0.2	0.07	2.5	530
G2-6	0.10	82.67	17.23	2.63	1.85	-0.2	1.14	14.19	0.93	1.68	3132	3043	719.7	58.9	16.2	12.8	39.2	1.8	0.11	2.5	770
G2-7	0.17	98.67	1.15	2.28	0.51	0.06	1.59	46.67	1.38	2.48	3773	2969	610.7	50.6	7.6	14.3	32.8	1.2	0.09	1.5	1100
G2-8	8.07	91.79	0.14	0.78	0.94	-0.42	1.15	69.5	2.28	4.11	374	2266	162.9	18.2	5.2	68.7	11.2	0.2	0.06	3	1130
G2-9	0.49	89.51	10.00	2.63	1.35	-0.44	1.09	31.32	2.14	3.86	5097	2920	491.5	50.5	8.9	48.8	40.5	1.0	0.02	9	1240
G2-10	0.06	93.87	6.08	2.23	1.43	-0.33	0.78	33.63	1.48	2.67	2005	2952	517.6	50.1	10.7	55.9	49.0	0.2	0.04	6	1280
G2-11	0.63	86.80	12.57	3.32	0.82	-0.13	2.33	21.83	1.97	3.55	761	2922	424.6	51.2	10.1	33.7	50.3	2.7	0.08	10	1320
G2-12	0.05	77.02	22.94	2.94	1.72	-0.19	1.23	36.44	2.83	5.09	598	2890	383.9	55.9	9.5	73.1	41.9	2.1	0.09	7	1370
G2-13	0.03	76.73	23.24	3.54	1.16	0.04	2.55	64.97	2.76	4.96	171	2654	273.4	29.6	7.4	75.1	18.9	1.2	0.02	13	1410
G2-14	0.22	63.86	35.92	3.88	1.03	0.16	2.16	26.24	1.83	3.3	960	2979	459.5	57.5	14.9	46.7	56.5	2.2	0.16	15	1480
G2-15	0.34	56.29	43.38	4.15	1.67	0.19	1.8	35.1	3.59	6.47	487	2942	458.7	61.2	15.6	60.6	48.0	2.8	0.02	17	1610
G2-16	0.33	83.28	16.39	2.86	1.3	-0.13	1.2	51.04	3.30	5.94	110	2790	395.5	43.6	11.5	57.2	45.4	2.2	0.09	22	1810
G2-17	0.09	96.29	3.62	2.38	0.88	0.04	1.1	38.58	1.72	3.09	260	2829	398.4	39.6	8.5	53.9	51.4	2.1	0.09	25	2050
G2-18	0.32	94.68	5.00	2.49	0.91	0.02	1.06	42.66	3.26	5.87	164	2728	330.1	29.6	6.6	16.2	32.0	1.7	0.14	30	2230
G2-19	0.06	88.74	11.20	2.67	1.08	0	1.19	31.45	2.08	3.74	171	2871	434.8	42.4	7.3	57.5	43.0	2.3	0.03	35	2310
Stdev	2.42	17.45	17.29	0.837	0.596	0.177	0.528	18.94	0.76	1.38	1557	226	213.4	71.8	88.7	23.6	31.9	1.0	0.04	10	741
Std.er.	0.48	3.49	3.46	0.17	0.12	0.04	0.11	3.79	0.15	0.28	311	45	42.7	14.4	17.7	4.7	6.4	0.2	0.01	2	151
Min.	0.00	36.03	0.06	0.78	0.41	-0.44	0.78	5.66	0.93	1.67	110	2266	162.9	18.2	5.2	12.8	11.2	0.2	0.02	0	0
Max.	8.07	99.47	63.98	4.22	3.48	0.19	2.57	69.50	3.59	6.47	5097	3306	968.4	283.0	453.6	96.3	156.3	3.9	0.16	35	2310
Avg.	1.32	83.03	15.66	2.80	1.23	-0.07	1.44	31.54	2.12	3.81	1618	2916	536.6	79.1	36.2	41.7	51.4	1.8	0.08	9	969

Mz = mean size *6I* = sorting SK*I* = skewness *KG* = kurtosis Carb. = carbonate content * = values ppm OC = organic carbon TOM =total organic carbon

Stdev =standard deviation Std.er = standard error Min =minimum Max. =maximum Avg =average

Table (3). Correlation coefficients between grain size analysis, carbonate content, total organic matter, phosphours and heavy metals of marine sediments of Wadi El-Gemal area.

	Gravel	Sand	Mud	Mz	Carb.%	TOM%	P*	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*	Depth(m	D.Sh(m)
Gravel	1																
Sand	-0.13	1															
Mud	0.00	**-0.99**	1														
Mz	-0.35	**-0.78**	**0.84**	1													
Carb.%	0.26	0.33	-0.37	**-0.54**	1												
TOM%	0.23	-0.29	0.26	0.16	0.43	1											
P*	-0.02	-0.13	0.14	0.17	**-0.52**	**-0.54**	1										
Fe*	-0.22	-0.30	0.34	**0.54**	**-0.81**	-0.22	**0.48**	1									
Mn*	0.06	-0.17	0.17	0.28	**-0.73**	-0.27	**0.53**	**0.92**	1								
Zn*	0.34	-0.18	0.14	0.19	**-0.47**	0.03	0.20	**0.72**	**0.82**	1							
Cu*	0.28	-0.09	0.05	0.10	-0.30	0.10	-0.05	0.34	0.41	**0.73**	1						
Pb*	0.41	-0.30	0.24	0.14	0.29	**0.46**	-0.21	-0.10	-0.13	0.14	0.08	1					
Ni*	0.21	-0.18	0.15	0.22	-0.43	0.04	0.18	**0.77**	**0.81**	**0.83**	0.30	0.20	1				
Co*	0.02	-0.34	0.35	**0.50**	-0.42	0.28	0.02	**0.67**	**0.59**	**0.61**	0.20	0.25	**0.75**	1			
Cd*	-0.02	-0.15	0.16	0.18	-0.20	-0.07	0.13	0.12	0.09	-0.06	-0.05	-0.22	-0.03	0.13	1		
Depth(m)	-0.32	0.08	-0.04	0.08	0.28	0.35	**-0.48**	-0.27	**-0.46**	-0.38	-0.23	0.24	-0.22	0.16	-0.01	1	
D.Sh(m)	-0.29	0.16	-0.12	-0.07	**0.48**	0.35	**-0.46**	-0.44	**-0.63**	**-0.56**	-0.35	0.30	-0.40	-0.02	-0.05	**0.89**	1

* = values ppm

Table (4). Comparison of the metal concentrations (ppm) in marine sediments between the present work and the other studies of the Egyptian Red Sea coast.

Heavy metas		Other studies of the Egyptian Red Sea coast															The present work
		El - Sayed {1984}	Beltagy {1984}	Nawar & Shata {1989}	El - Mamony {1995}				Nawar et al., {1997}	Mansour {1999}	Mansour et al., {2000b}	Dar {2002}	Madkour {2004}				
		Al Ghardqa	North Red Sea	Mersa El-At	Wadi El Hamra	Wadi El Esh	Wadi Abu Shaar	Wadi Khashir	Hurghada area	Sharm Abu Makhadeg	Red Sea coast	Hurghada area	Quseir Harbour	Safaga Harbour	Hurghada Harbour	El-Esh area	
Fe	range	1900- 6000	95 - 4990	~~~~	~~~~	~~~~	~~~~	~~~~	80 - 1820	~~~~	~~~~	~~~~	~~~~	~~~~	~~~~	~~~~	2266-3306
	avg.	3800	1322		10600	4900	4800	6000	145	14500	6700		14000	12000	10000	7000	2916
Mn	range	120-360	2 - 418	1.4 -66.3	118 - 316	9 - 190	93 - 176	135 - 339	~~~~	285 - 1087	127 - 609	~~~~	414-1458	66-1747	22 - 421	32 - 1557	162-968
	avg.	210	55		236	107	125	180		610	205		902	1145	112	153	536
Zn	range	11.1 - 90	10 - 330	4.2 - 44.5	10 - 19.1	8 - 20.1	8 - 81.1	8 - 27.1	10.5-30.3	29.6-104	13.6-73.5	8.8 - 245	7.9 - 44	3.5 - 47.3	0.6 - 93.4	4.8-114.7	18 - 283
	avg.	31	70.7		15	26	15	12	21.75	63	17.59		21.35	15.39	9.05	14.46	79
Cu	range	8.5 - 27.5	3 - 79.2	4.7 - 11.3	9 - 19.1	2 - 16.1	1 - 9.1	2 - 17.1	5.6-30.6	18.7 - 65	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
	avg.	21	16		13	14	6	7	11.1	40	14.02		4.12	9.07	4.09	76.74	36.22
Pb	range	~~~~	10 - 110	13.2-26.5	40 - 60	60 - 101	44 - 78	66 - 91	54.5-108	0.5 - 64	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
	avg.		75		49	57	56	81	90.9	39.6	19.81		10.47	21.56	19.54	11.28	41.7
Ni	range	~~~~	~~~~	~~~~	15 - 149	11 - 70.1	29 - 69	7 - 49.1	17.1-51.4	26 - 44.2	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
	avg.				44	43	45	19	37.13	34	23.48		26.52	38.37	8.86	9.78	51.39
Co	range	~~~~	29 - 65	~~~~	~~~~	~~~~	~~~~	~~~~	5.7 - 17.1	1.9 - 10.8	4.7 - 18.9	0.99-12.8	1.5-10.9	0.5 - 13.6	0.9 - 11.1	0.6 - 26.7	0.2 - 3.9
	avg.		48						11	7	9.64		5.73	6.84	3.96	3.59	1.76
Cd	range	~~~~	~~~~	~~~~	0.1 - 1.51	0.1 - 2.8	0.4 - 1.2	0.001-1.9	~~~~	0.3 - 1.3	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
	avg.				0.48	0.532	0.894	0.935		0.93	0.96		1.01	1.33	0.34	0.5	0.078

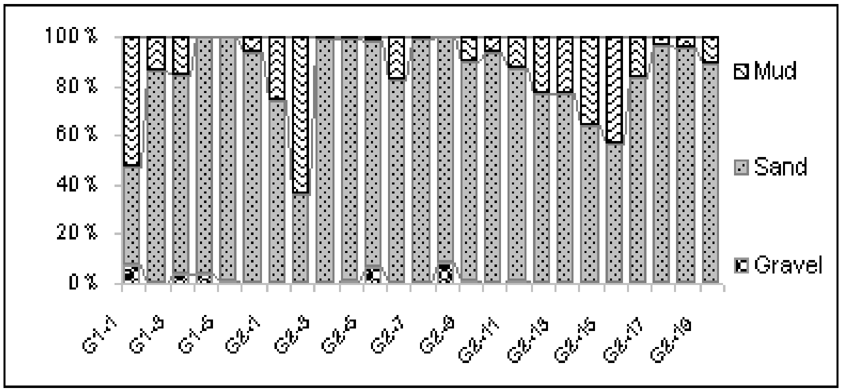

Fig. (4). Distribution of gravel, sand and mud fractions of marine sediments of Wadi El-Gemal area.

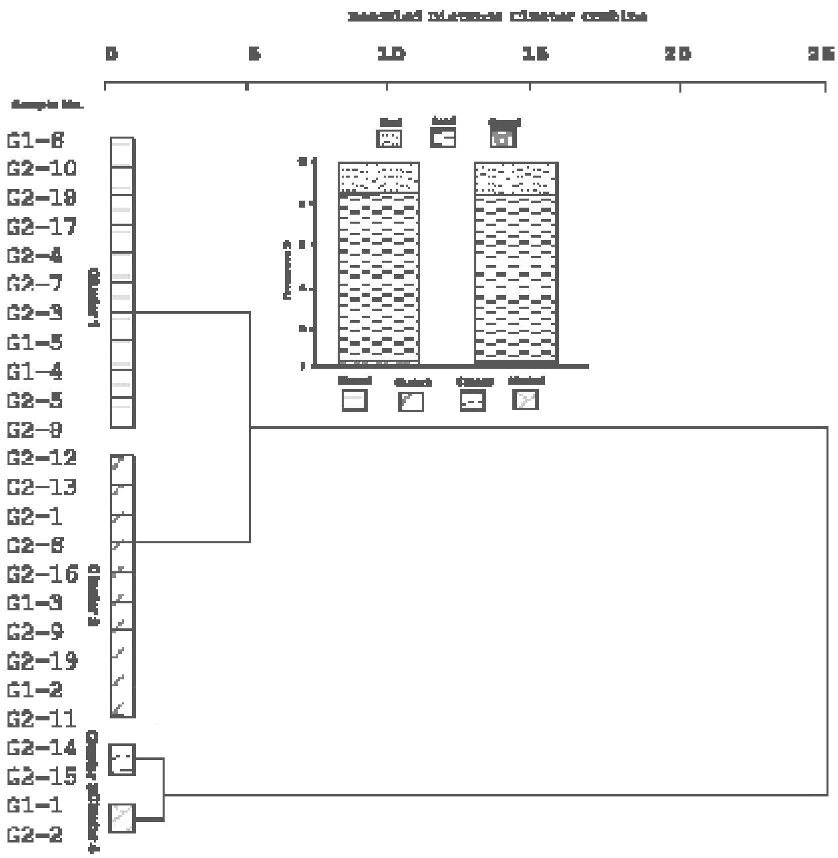

Fig. (5). Dendrogrm from cluster analysis (ward's method) and histogram exhibiting cluster of component constituents.

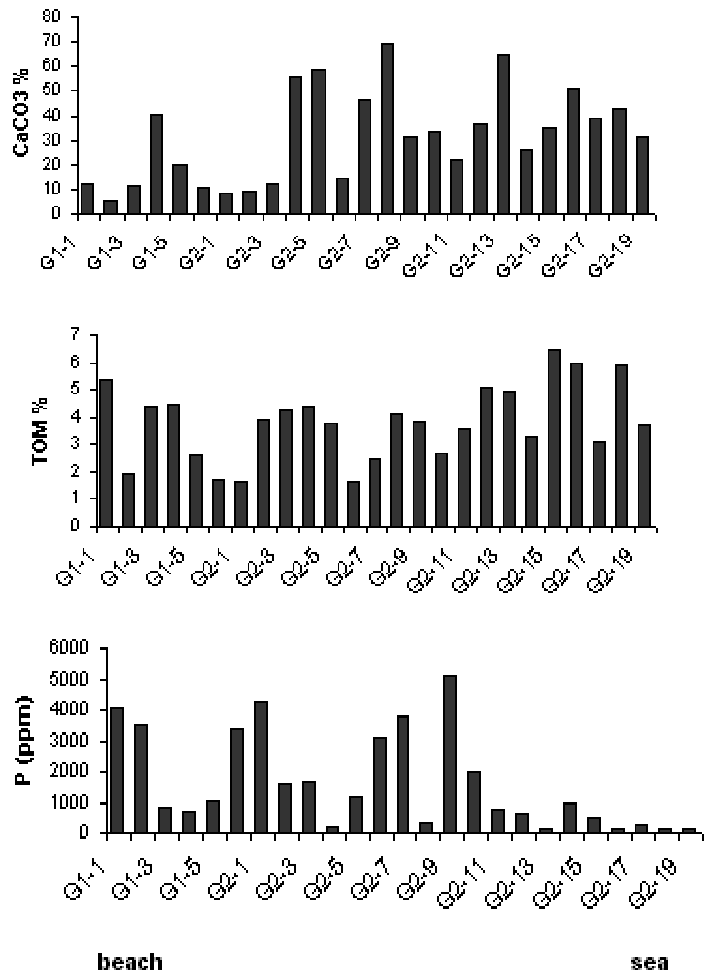

Fig. (6). Distribution of carbonate content, total organic matter and phosphorus of marine sediments of Wadi El-Gemal area.

Cluster analysis (using Ward's method includes heavy metals; Fe, Mn, Zn, Cu, Pb, Co, Cd concentrations) separates sediment samples into 5 main clusters (Fig. 7; Table 5). Cluster 1 contain 4 samples, is characterized by high concentrations of Fe (X= 3105ppm, S= 70.9ppm); Mn (X= 770.6ppm, S= 41.3ppm), Zn (X= 105.7ppm, S= 48.9ppm) and Ni (X= 60.2ppm, S= 18.1ppm). Cluster 1 distributes in tidal flat area and supratidal zone. Cluster 2 includes three samples represent the highest concentrations of Fe, Mn, Zn, Cu, Ni and Pb compared to the other clusters. All samples of cluster 2 fall in supratidal zone and beach area. The 5 samples of cluster 3 are separated by high concentrations of Pb (X= 55.1ppm, S= 14.1ppm). Samples of this cluster are only from offshore area. This indicates that, the general trends of lead contents are increasing offshore. Cluster 4 includes 8 samples (32% of the total samples), and is characterized by moderate to high concentrations of Fe, Mn, Zn, Pb and Ni. This cluster contains mixture of beach, tidal flat and offshore samples. Cluster 5 consisting of 5 samples (20% of the total samples). This cluster has the lowest concentration of heavy metals except Pb compared to the other clusters. Most samples of this cluster are from the offshore area.

In hard corals

Coral reefs extremely disappeared at the mouth of some wadis as result of sediment accumulation during floods. Coral reef species were selected from the northern area of the mouth of the wadi. Results of the heavy metal concentrations in coral reefs are shown in (Table 6; Fig. 8).

The highest concentration of Fe in coral reefs is recorded in *Acropora hyacinthus* (250.7ppm), while the lowest one is in *Stylohora wellesi* (33.6ppm). Mn in coral reef ranges from 2.03ppm in *Stylophora wellesi* to 13.09ppm in *Porites comporessa*. This can be attributed to their detrital origin which mostly contain terrigenous alumino-silicate and ferromanganic oxides in the study area. Apparently the nature of the detritus often reflects the local environment. Generally, Fe and Mn concentrations in coral reefs are relatively high but these values are low compared to those determined by Mohammed (2002), Mohammed (2003) and Madkour (2004) (Table 7).

Zinc level in coral reefs varies from 2.03ppm in *Pocillopora damicornis* to15.8ppm in *Acropora hyacinthus*. Because Zn is an essential element, it will be accumulated by organisms, therefore the bioaccumulation factor will be greater if the availability of zinc is low (Madkour, 2004). The concentration of zinc in coral species is high in Wadi El-Gemal area compared to that of the other studies on the Egyptian Red Sea coast except in Mohammed (2002) (Table 7). The Cu concentration in coral reefs ranges between 0.55ppm in *Stylophora wellesi* and 4.18ppm in *Millepora dichotoma*. Copper is an essential and potentially toxic element (Merian, 1991). The primary source of Cu may be terrigenous origin. The concentrations of copper in coral reefs in the present work are similar to the Cu values in coral reefs reported in previous works with the exception of that made by Mohammed (2002), Mohammed (2003) and Madkour (2004) (Table 7).

The highest concentration of Pb in coral reefs is in *Millepora complanata* (35.67ppm), while the lowest one is in *Acropora humilis* (14.01ppm). The Pb level in coral reefs in Wad El-Gemal is very high compared with that of the previous works (Table 7). In the same manner, the concentration of Pb in coral reefs in Wadi El-Gemal is high compared with their concentrations in some sediment samples in the same area. Hanna (1990) reported that, trace metals have been directly replaced calcium with the skeletal aragonite framework or as suspended particulate matter introduced into the carbonate skeleton during the biosynthesis.

The Ni content in coral reefs varies from 0.38ppm in *Porites compressa* to 4.36ppm in *Acropora humilis*. The Ni concentration in coral reefs is low compared to that by Mohammed (2003) and Madkour (2004) (Table 7). Coral reefs in Wadi El-Gemal have low concentrations of cobalt. Also, sediment samples have low concentrations of cobalt. The Cd concentration in coral reefs is high compared to that in sediments at Wadi El-Gemal area. It ranges from 0.04ppm in *Acropora hyacinthus* to 0.2ppm in *Millepora complanata*. On the other hand, the concentration of Cd in coral reefs is low in the present work compared to those in Safaga and Hurghada Harbours (Madkour, 2004). This is indicating that the main source of Cd is of anthropogenic origin. Generally, the variation in the studied species of the present work, indicate that bioaccumulation of these metals is different from species to another.

Table (5). The heavy metals of the clusters computed by (Ward's method) Cluster analysis based on 8 variables of heavy metals.

	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*
Cluster 1 (4 samples)								
S	71	41.3	48.9	6.5	12.9	18.1	0.4	0.05
Min.	3042.7	719.7	58.9	16.2	12.8	39.2	1.8	0.03
Max.	3168	808.4	160.2	29.9	39.6	77.1	2.6	0.14
X	3105.3	770.6	105.7	25.9	20.4	60.2	2.1	0.1
Cluster 2 (3 samples)								
S	80	89.4	33.2	220.7	30.6	44.1	0.9	0.06
Min.	3145.9	796.8	216.8	70.9	40.3	69.2	2.1	0.02
Max.	3305.6	968.4	283	453.6	96.3	156.3	3.9	0.14
X	3222.9	897.1	249.2	198.8	61.2	116.6	3.1	0.08
Cluster 3 (5 samples)								
S	52.1	21.3	6.8	1.6	14.1	4.3	0.2	0.03
Min.	2789.5	383.9	39.6	7.3	33.7	41.9	2.1	0.03
Max.	2922.2	434.8	55.9	11.5	73.1	51.4	2.7	0.09
X	2860.3	407.4	46.5	9.4	55.1	46.4	2.3	0.08
Cluster 4 (8 samples)								
S	37.8	54.8	8.2	6.8	20.1	10.1	0.8	0.05
Min.	2914.9	458.7	45.4	7.6	12.9	32.2	0.2	0.02
Max.	3030.4	610.7	69.3	26.2	60.6	60.2	2.8	0.16
X	2954.8	527.3	56.1	15.5	36.9	45.5	1.3	0.07
Cluster 5 (5 samples)								
S	184.6	67.2	5.4	1.1	29.1	8.3	0.6	0.05
Min.	2266	162.9	18.2	5.2	12.8	11.2	0.2	0.02
Max.	2728.1	330.1	29.6	8.3	75.1	32	1.7	0.14
X	2572.2	276.9	25.3	6.9	41.4	19.7	0.8	0.08

* = values ppm S= standard deviation X= average

Table (6). The results of geochemical analysis of coral reef species at Wadi El- Gemal area.

Species name	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*
Stylophora wellesi	33.6	2.5	6.5	0.6	21.2	2.0	0.5	0.1
Acropora humilis	49.0	2.9	8.5	3.7	14.0	4.4	0.5	0.2
Acropora hemprichii	72.6	2.9	7.3	0.7	16.5	0.4	0.7	0.1
Acropora hyacinthus	250.7	7.0	15.8	0.8	26.8	0.5	0.5	0.0
Pocillopora damicornis	51.0	7.6	2.0	2.4	31.1	0.6	0.4	0.2
Porites lutea	179.2	3.7	7.5	3.1	32.0	0.6	0.2	0.2
Porites compressa	62.4	13.1	3.5	4.2	30.8	0.4	0.3	0.2
Millepora complanata	50.4	3.2	4.0	1.2	35.7	1.9	0.6	0.3
Millepora dichotoma	60.9	2.6	4.1	4.1	35.2	1.2	0.6	0.2

*= values ppm

Table (7). Comparison of the heavy metal concentrations (ppm) in coral reefs from the present work and others areas of the Egyptian Red Sea coasts.

Location	Heavy metals								Author
	Fe	Mn	Zn	Cu	Pb	Ni	Co	Cd	
Al-Ghardaqa area	~~~~	3.8 - 8.8	0.33 - 18.8	0.59 - 4.2	3.48 - 55	0.09 - 0.38	~~~~	0.003 - 0.06	Hanna {1990}
South Hurghada Abu Soma Bay	1380-4280	~~~~	5.9 - 56	18 - 88.9	0.01 - 4.9	1.4 - 6.7	0.01 - 0.9	0.01 - 0.05	Mohammed 2002
Hurghada area	~~~~	0.33 - 7.78	1.49 - 9.14	0.8 - 3.23	0.75 - 4.22	0.12 - 1.26	0.03 - 1.8	~~~~	Mohammed and El - Sorogy {2003}
North Hurghada area	100 - 377.5	~~~~	~~~~	2.92 - 6.95	10 - 18.84	11.5 - 19.4	~~~~	0 - 2.00	Mohammed {2003}
Quseir Harbour	871 - 2576	17.5 - 33.5	2.96 - 8.9	0.71 - 0.97	0.05 - 7.15	13.1 - 17.7	1.66 - 1.82	0.08 - 0.22	Madkour {2004}
Safaga Harbour	1529 - 3640	17.12 - 26.9	2.2 - 3.71	1.03 - 1.28	0.26 - 0.7	12.9 - 14.43	0.5 - 2.48	0.63 - 0.95	
Hurghada Harbour	788 - 962	7.33 - 7.64	2.42 - 6.58	1.08 - 3.59	11.49 - 13.2	3.5 - 15.21	2.73 - 2.91	1.25 - 1.55	
El-Esh area	932 - 1754	8.55 - 11.06	5.81 - 9.06	14.7 - 31.2	1.26 - 3.04	14.6 - 17.45	1.1 - 1.77	0.09 - 0.14	
Wadi El-Gemal area	33.6 - 250.7	2.53 - 13.1	2.03 - 15.81	0.55 - 4.18	14.01 - 35.7	0.38 - 4.36	0.19 - 0.68	0.04 - 0.26	The present work

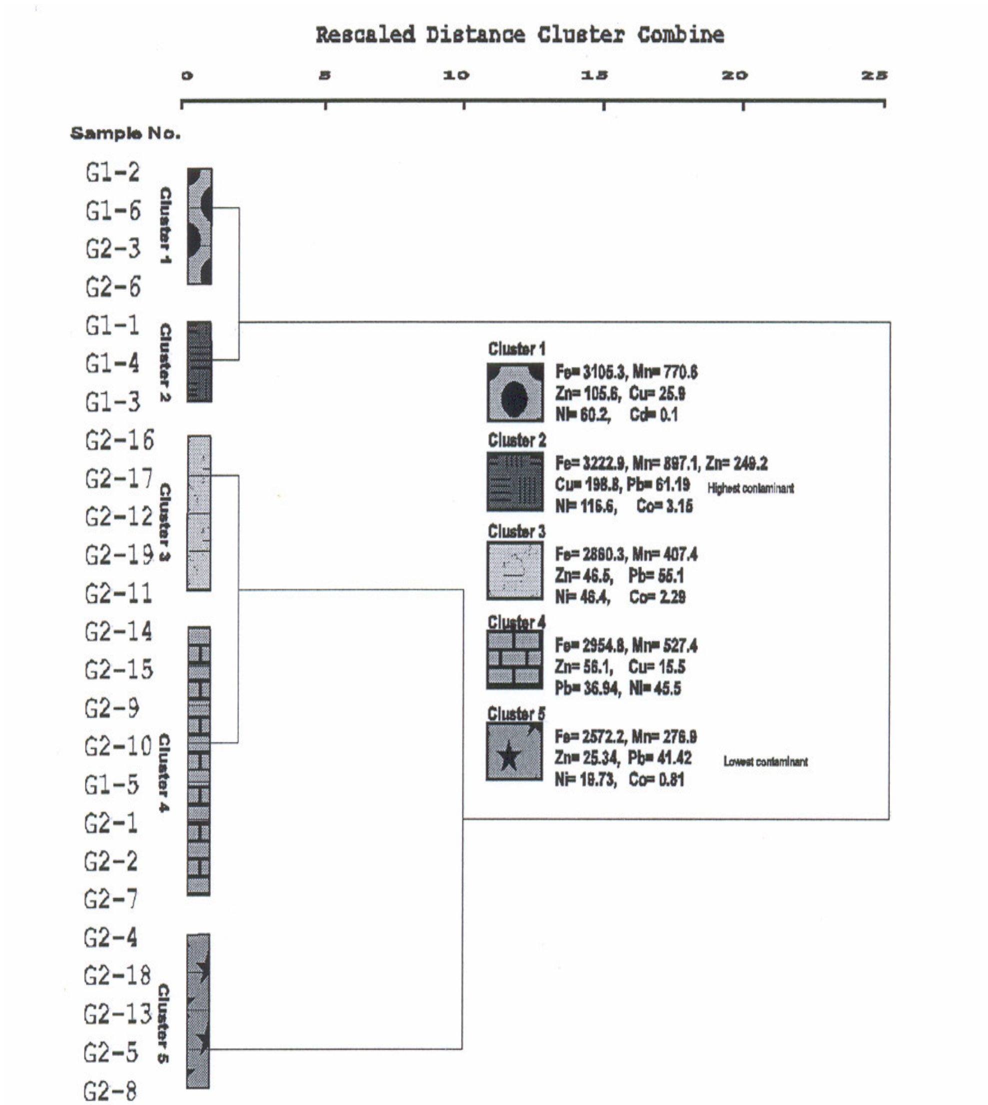

Fig. (7). Dendrogram from cluster analysis (ward's method) of heavy metals of sediment samples throughout Wadi El-Gemal area.

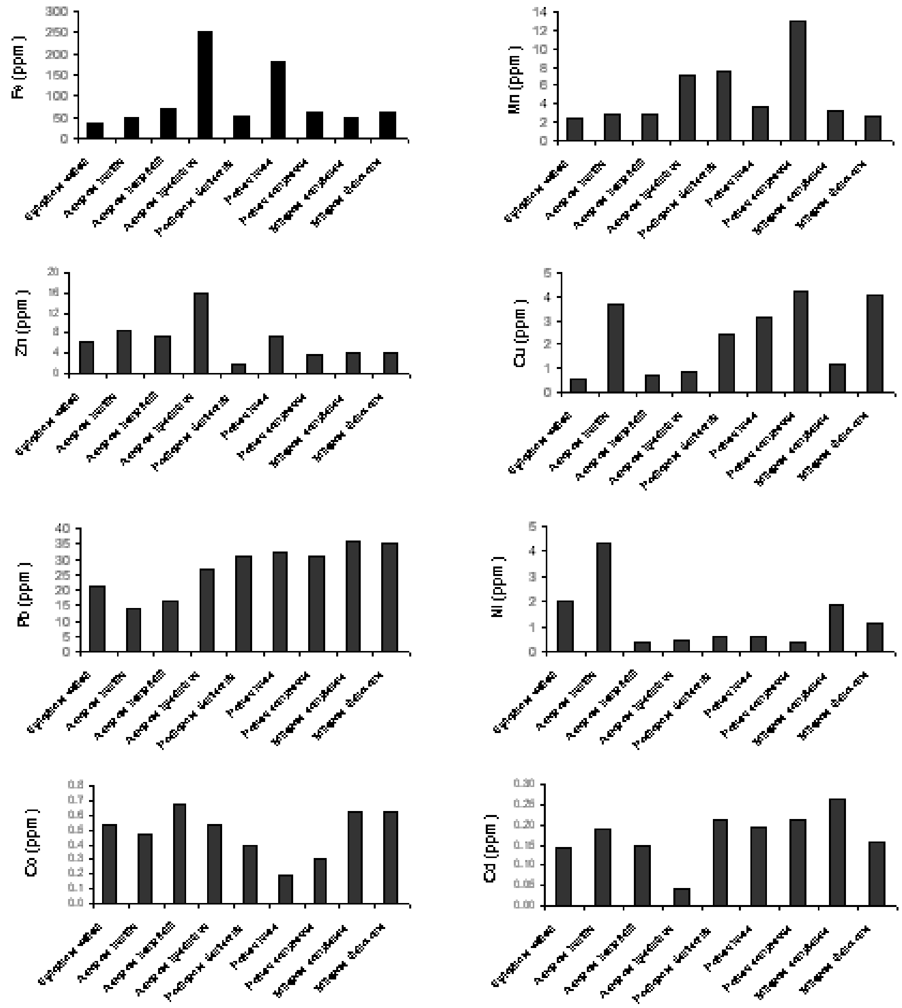

Fig. (8). Iron, manganese, zinc, copper, lead, nickel, cobalt, cadmium concentrations of coral reefs of Wadi El-Gemal area.

CONCLUSIONS AND RECOMMENDATIONS

Wadi El-Gemal area is very rich with natural resources in the land or in the sea and its preservation is a national interest. Therefore, a co-operation with the EEAA is very important in order to centralize decisions and responsibilities.

Terrestrial environment acts for the dominance of terrigenous material mostly in the beach and nearshore sediments. On the other hand, grain size characteristics reflect a mixed detrital and biogenic origin of the offshore sediments. The domination of fine sediment in Wadi El-Gemal can be explained by the strong influence of terrigenous activities. So, sediments of this area are rich in organic matter, phosphorus and heavy metals.

The sediments are carbonate – poor while the offshore ones contain higher amounts of carbonate. Skeletal materials are the main source of carbonate production. The distribution of organic matter in the sediments is dependent upon the organic material supply and the hydrodynamic energy of the basin. The main source of phosphorus content is derived from terrestrial materials and the second source may be due to phosphatization of calcareous skeletons.

The behavior of heavy metals in Wadi El-Gemal area is complex, and the natural impact on the coastal environment is clearly reflected by their concentrations. In comparison with the concentrations of some metals in sediments and coral reefs, the studied area recorded high concentrations of some heavy metals than that of the anthropogenic activities of the Egyptian Red Sea coast. The high concentration of heavy metals in the sediments and the studied species of coral reefs can be attributed to the natural impact resulting from the high contribution of terrigenous inputs through this wadi.

The difference between Pb concentrations in corals and sediments indicted that Pb concentration in coral reefs recorded high values compared to that in some sediment samples at the study area.

The environmental effects of heavy metals on the coral reefs species such as; lead, zinc, iron, copper and cadmium are naturally absorbed by these organisms. High concentrations of these metals may reach levels that cause harm to marine organisms like corals. Therefore, the concentration of these metals in marine sediments and coral reefs can be used to monitor the natural impact of this wadi and to assess any changes or bias from the existing level due to different activities.

Wadi El-Gemal zone requires integrated planning and management to achieve ecologically sustainable use of coastal resources and conservation of this virgin area. These findings will help the EEAA and the developers to assess the risk to the region resources, besides addressing land-management and policy issues in this area.

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