Assessment of heavy metals concentrations resulting natural inputs in Wadi El-Gemal surface sediments, Red Sea coast

Hashem Abbas Madkour [2] Mohamed Anwar K abdelhalim [1] and A. El-Taher [3,4]

[1]Department of Physics and Astronomy, College of Science, King Saud University, Saudi Arabia
[2]National Institute of Oceanography and Fisheries, Red Sea Branch, Hurghada 84511, Egypt
[3]Physics Department, Faculty of Science, Qassim University, 51452 Buraydah, KSA
[4]Physics Department, Faculty of Science, Al-Azher University, Assuit 71452, Egypt
mabdulhleem@ksu.edu.sa

Abstract: This paper deals with increased heavy metals concentrations in the marine sediments in-front of the mouth of Wadi El-Gemal area due to high natural inputs from the wadi. Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd concentrations were determined in surface marine sediments at Wadi El-Gemal along the Egyptian Red Sea. heavy metal concentrations in sediments of 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 are particularly affected by the high contribution of terrigenous materials through the stream of Wadi El-Gemal. Heavy metals concentrations in the sediments decreased with increasing distance from the shoreline with the exception of Pb, which increased with increasing distance from the shoreline. Nature of sediments and heavy metals distribution reflect marked changes in lithology, biological activities in the sea and land geology of the study area. 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 are influenced by natural inputs 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.
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2. Introduction

Wadi El-Gemal area is declared 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, differentiating 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 rocks were carried out along the Egyptian Red Sea coast (eg. Mansour, 2011; El-Taher, et al 2003, El-Taher, 2007; El-Taher et al., 2004; El-Taher, 2010, El-Taher and Madkour 2011and El-Taher and Madkour 2013).

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, heavy metals concentrations have been conducted on 25 samples of surface sediments collected from the backshore, foreshore and offshore (Fig.1).

1.1. 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). Oceanographic parameters were measured at different depths using Hydrolab Instrument (Surveyor [(4)] 1997) as shown in (Table 1) by (Madkour 2005).

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) 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 seagrasses and biogenic sand (Figs. 2). 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*. I depend on (Madkour 2005) in description of the study area.

2. Materials and Methods:

The area was divided into two transects WG1 and WG2 from south to north (Fig. 2). Transect WG1 was taken in front of the mouth of the wadi, while transect WG2 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 40m below sea level, and distributed along a distance of 2400m from the shoreline (Fig. 2). Surface sediment samples represent four different environmental features, namely supratidal zone, beach, intertidal and offshore zones

According to Folk and Ward (1957), grain size analysis of marine sediments was performed using the sieving technique. 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°C (Dean, 1974; Flannery *et al.,* 1982; Brenner and Binford, 1988). The sediment samples were gently washed several times by distilled water to remove soluble salts, then spread on glass sheets and left to dry in air. About ten grams of sediments were ground to a powder using an agate mortar (Retsch Mortar), passed through a 80 mesh sieve and kept in dry, clean bag waiting for analysis. 0.5 gram of the prepared ground sample was completely digested in a Teflon cup by using a mixture of conc. Nitric (HNO_3), perchloric ($HClO_4$) and hydrofluoric acids (HF) with the ratio 3: 2: 1 respectively according to (Chester *et al.,* 1994 and Rajaganapathy *et al.,* 2011). Acids were slowly added to the dried sample and left overnight before heating. Samples were heated at temperature of approximately 200°C, then left to cool and filtered to get rid of the non digested parts. The solution was justified to a volume of 25ml, then the concentration of elements were determined by AAS (Atomic Absorption Spectrophotometery) technique, using GBC–932 ver. 1.1 with detection limits 0.01 ppm of the National Institute of Oceanography and Fisheries, Red Sea Branch. Results were expressed in ppm.

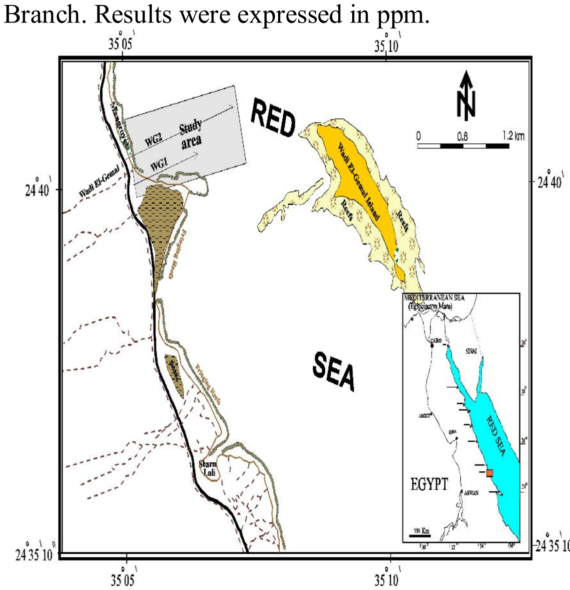

Fig. 1. Location map of study samples of Wadi El-Gemal area along the Egyptian Red Sea coast.

3. Results and Discussion:

3.1. Nature of Sediments and grain size:

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%). Mud constitutes 0.1 to 63% and gravel is very rare (0.0 to 8%) (Table 2; Fig. 3). 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.

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. Madkour (2005) stated that the sediments of Wadi El-Gemal are characterized by a fine texture.

Table (1).The measured hydrographic parameters of water mass in Wadi El-Gemal area after (Madkour 2005).

Depth (m)	pH	Salinity o/oo	Temp. °C	DO Mg\L	Eh	TDS g\L	SPC ms\cm
Surface	8.1	39.9	29	4.6	336	37.9	59.9
5	8.2	39.9	24	4.9	346	37.8	59.7
Surface	8.1	39.9	24	4.7	345	37.9	59.7
10	8.2	40.0	24	5.3	352	37.9	59.8
Surface	8.2	39.9	24	5.9	357	37.8	59.4
20	8.2	40.0	23	6.4	363	37.8	59.7

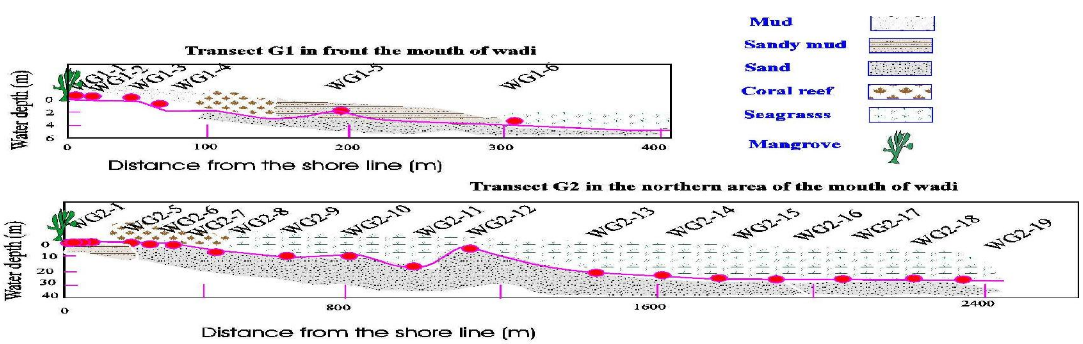

Fig. 3. Transects show sample depth (solid line with solid circles) and bottom facies at Wadi El-Gemal area.

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%	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*	Depth	D.Sh
No.	Gravel	Sand	Mud	Mz	6I	SkI	KG												(m)	(m)
WG1-1	7	40	53	4.2	3.5	0.0	1.1	11.9	3.0	5.4	3306	968	217	71	96	124	4	0.14	0	0
WG1-2	0	86	14	3.1	1.1	0.2	2.0	5.7	1.1	1.9	3166	808	160	28	16	77	3	0.03	0.2	20
WG1-3	4	80	16	3.0	1.5	0.0	2.6	11.5	2.4	4.4	3146	797	283	454	47	69	2	0.06	1	50
WG1-4	3	96	0	1.8	1.3	-0.1	1.0	40.3	2.5	4.5	3217	926	248	72	40	156	3	0.02	beach	150
WG1-5	0	99	0	2.6	0.8	-0.2	0.8	19.9	1.4	2.6	2915	561	69	25	43	60	1	0.03	2	250
WG1-6	0	94	6	3.0	0.7	0.1	1.4	10.7	0.9	1.7	3168	800	133	30	40	73	2	0.14	7	350
WG2-1	0	74	26	3.3	1.2	-0.2	1.6	8.7	0.9	1.7	2932	553	45	15	13	32	1	0.11	0	beach
WG2-2	0	36	64	4.2	1.3	-0.3	1.7	9.3	2.2	3.9	3030	567	64	26	14	45	1	0.08	1	150
WG2-3	0	99	1	2.4	0.4	0.2	1.3	12.4	2.4	4.3	3045	755	70	29	14	51	2	0.11	0.5	310
WG2-4	1	98	1	2.3	0.7	0.0	1.6	55.4	2.4	4.4	2674	317	28	8	13	23	1	0.12	1.5	330
WG2-5	6	92	2	1.3	1.5	-0.1	0.8	59.0	2.1	3.8	2539	301	21	7	34	13	0	0.07	2.5	530
WG2-6	0	83	17	2.6	1.9	-0.2	1.1	14.2	0.9	1.7	3043	720	59	16	13	39	2	0.11	2.5	770
WG2-7	0	99	1	2.3	0.5	0.1	1.6	46.7	1.4	2.5	2969	611	51	8	14	33	1	0.09	1.5	1100
WG2-8	8	92	0	0.8	0.9	-0.4	1.2	69.5	2.3	4.1	2266	163	18	5	69	11	0	0.06	3	1130
WG2-9	0	90	10	2.6	1.4	-0.4	1.1	31.3	2.1	3.9	2920	491	51	9	49	40	1	0.02	9	1240
WG2-10	0	94	6	2.2	1.4	-0.3	0.8	33.6	1.5	2.7	2952	518	50	11	56	49	0	0.04	6	1280
WG2-11	1	87	13	3.3	0.8	-0.1	2.3	21.8	2.0	3.6	2922	425	51	10	34	50	3	0.08	10	1320
WG2-12	0	77	23	2.9	1.7	-0.2	1.2	36.4	2.8	5.1	2890	384	56	10	73	42	2	0.09	7	1370
WG2-13	0	77	23	3.5	1.2	0.0	2.6	65.0	2.8	5.0	2654	273	30	7	75	19	1	0.02	13	1410
WG2-14	0	64	36	3.9	1.0	0.2	2.2	26.2	1.8	3.3	2979	459	58	15	47	56	2	0.16	15	1480
WG2-15	0	56	43	4.2	1.7	0.2	1.8	35.1	3.6	6.5	2942	459	61	16	61	48	3	0.02	17	1610
WG2-16	0	83	16	2.9	1.3	-0.1	1.2	51.0	3.3	5.9	2790	395	44	11	57	45	2	0.09	22	1810
WG2-17	0	96	4	2.4	0.9	0.0	1.1	38.6	1.7	3.1	2829	398	40	8	54	51	2	0.09	25	2050
WG2-18	0	95	5	2.5	0.9	0.0	1.1	42.7	3.3	5.9	2728	330	30	7	16	32	2	0.14	30	2230
wG2-19	0	89	11	2.7	1.1	0.0	1.2	31.5	2.1	3.7	2871	435	42	7	58	43	2	0.03	35	2310
Min.	0	36	0	0.8	0.4	-0.4	0.8	5.7	0.9	1.7	2266	163	18	5	13	11	0	0.02	0	0
Max.	8	99	64	4.2	3.5	0.2	2.6	69.5	3.6	6.5	3306	968	283	454	96	156	4	0.16	35	2310
Avg.	1	83	16	2.8	1.2	-0.1	1.4	31.5	2.1	3.8	2916	537	79	36	42	51	2	0.08	9	969

Mz = mean size 6I = sorting SKI = 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, totoal organic matter and heavy metal of marine sediments at wadi El-Gemal area.

	Gravel	Sand	Mud	Mz	Carb.%	TOM%	Fe*	Mn*	Zn*	Cu*	Pb*	Ni*	Co*	Cd*	Depth(m)	D.Sh(m)
Gravel	1															
Sand	-0.1	1														
Mud	0.0	**-1.0**	1													
Mz	-0.4	**-0.8**	**0.8**	1												
Carb.%	0.3	0.3	-0.4	**-0.5**	1											
TOM%	0.2	-0.3	0.3	0.2	0.4	1										
Fe*	-0.2	-0.3	0.3	**0.5**	**-0.8**	-0.2	1									
Mn*	0.1	-0.2	0.2	0.3	**-0.7**	-0.3	**0.9**	1								
Zn*	0.3	-0.2	0.1	0.2	**-0.5**	0.0	**0.7**	**0.8**	1							
Cu*	0.3	-0.1	0.1	0.1	-0.3	0.1	0.3	0.4	**0.7**	1						
Pb*	0.4	-0.3	0.2	0.1	0.3	**0.5**	-0.1	-0.1	0.1	0.1	1					
Ni*	0.2	-0.2	0.2	0.2	-0.4	0.0	**0.8**	**0.8**	**0.8**	0.3	0.2	1				
Co*	0.0	-0.3	0.3	**0.5**	-0.4	0.3	**0.7**	**0.6**	**0.6**	0.2	0.2	**0.7**	1			
Cd*	0.0	-0.2	0.2	0.2	-0.2	-0.1	0.1	0.1	-0.1	-0.1	-0.2	0.0	0.1	1		
Depth(m)	-0.3	0.1	0.0	0.1	0.3	0.4	-0.3	**-0.5**	-0.4	-0.2	0.2	-0.2	0.2	0.0	1	
D.Sh(m)	-0.3	0.2	-0.1	-0.1	**0.5**	0.3	-0.4	**-0.6**	**-0.6**	-0.4	0.3	-0.4	0.0	-0.1	**0.9**	1

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} Al Ghardqa	Beltagy {1984} North Red Sea	Nawar & Shata {1989} Mersa El-At	El - Mamony {1995}				Nawar et al., {1997} Hurghada area	Mansour {1999} Sharm Abu Makhadeg	Mansour et al., {2000b} Red Sea coast	Dar {2002} Hurghada area	Mansour *et al.*, {2011}				
					Wadi El Hamra	Wadi El Esh	Wadi Abu Shaar	Wadi Khashir					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

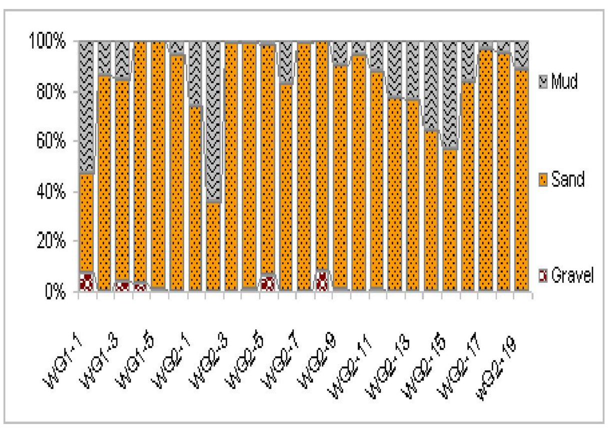

Fig. 3. Distribution of gravel, sand and mud fractions of marine sediments of Wadi El-Gemal area

3.2. Geochemistry:

3.2.1. Carbonate content:

The carbonate content in surface sediments of Wadi El-Gemal area ranges between 5 % and 69 % with an average of 31% (Table 2; Fig. 4. 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=-0.5 and –0.4respectively; Table 3). A weak positive correlation is obtained between carbonate and sand fraction (r=0.3) and gravel (r=0.3) 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= 0.5) (Table 3). This indicate that carbonate content generally increase seaward.

3.2.2. Organic matter:

The total organic matter of sediment samples is relatively high varying from 1.7% to 6.5% with an average of 3.8% (Table 2; Fig. 4). 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.

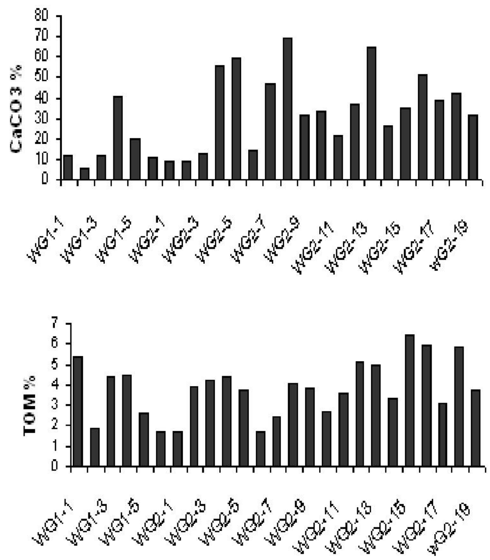

Fig.4 Distribution of carbonate content,total organic mater of marine sediments of Wadi El-Gemal area

3.3. Heavy metals distribution*:*

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 ppm to 968 ppm with an average of 536 ppm. 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 ppm to 383 ppm, averaging 79 ppm. 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 ppm to 453 ppm with an average of 36 ppm. 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 12.8ppm to 96 ppm, averaging 42 ppm. 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 ppm to 156 ppm with an average of 51 ppm. Nickel content show general expected trends, (Table 2) illustrating a decrease in seaward direction. Mansour *et al.,* (2011) reported that Ni concentration in the marine sediment not display trends indicative of large anthropogenic contribution to these sediments. Therefore, the main source is due to the contribution of terrigenous fractions.

Cobalt is found in relatively lower concentrations and ranging between 0.2ppm and 4 ppm, averaging 2 ppm. 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 0.2 ppm, averaging 0.1 ppm. 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 (Mansour *et al.,* 2011). 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 (Mansour *et al.,* 2011) and in Abu-Makhadaeg area (Mansour, 1999) compared to that in the present work (Table 4).

Generally, Madkour (2005) stated that heavy metals concentrations in the marine sediments of Wadi El-Geamal area, the values of heavy metals concentrations in the present work are similar to recorded in 2005 by Madkour. 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.

3. 2.1. Heavy metals Clusters:

Statistical computations (cluster analysis) were performed with the program SPSS using a hierarchical cluster analysis (Ward's method). Based on 8 heavy metal (Fe, Mn, Zn, Cu, Pb, Ni, Co and Cd) concentrations, coral reef species from the studied localities are divided into five main clusters (Fig 6; Table 5).

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	49	7	13	18	0	0.1
Min.	3043	720	59	16	13	39	2	0.0
Max.	3168	808	160	30	40	77	3	0.1
X	3105	771	106	26	20	60	2	0.1
Cluster 2 (3 samples)								
S	80	89	33	221	31	44	1	0.1
Min.	3146	797	217	71	40	69	2	0.0
Max.	3306	968	283	454	96	156	4	0.1
X	3223	897	249	199	61	117	3	0.1
Cluster 3 (5 samples)								
S	52	21	7	2	14	4	0	0.0
Min.	2790	384	40	7	34	42	2	0.0
Max.	2922	435	56	12	73	51	3	0.1
X	2860	407	47	9	55	46	2	0.1
Cluster 4 (8 samples)								
S	38	55	8	7	20	10	1	0.1
Min.	2915	459	45	8	13	32	0	0.0
Max.	3030	611	69	26	61	60	3	0.2
X	2955	527	56	16	37	46	1	0.1
Cluster 5 (5 samples)								
S	185	67	5	1	29	8	1	0.1
Min.	2266	163	18	5	13	11	0	0.0
Max.	2728	330	30	8	75	32	2	0.1
X	2572	277	25	7	41	20	1	0.1

* = values ppm S= standard deviation X= average

Cluster 1 contain 4 samples, is characterized by high concentrations of Fe (X= 3105ppm, S= 71 ppm); Mn (X= 771 ppm, S= 41 ppm), Zn (X= 106 ppm, S= 49 ppm) and Ni (X= 60 ppm, S= 18 ppm). 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 ppm, S= 14 ppm). 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.

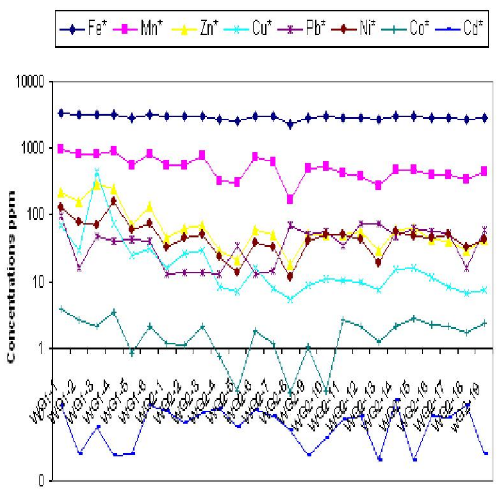

Fig. 5. Distribution of heavy metals of marine sediments at Wadi El-Gemal area

4. Conclusions:

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.

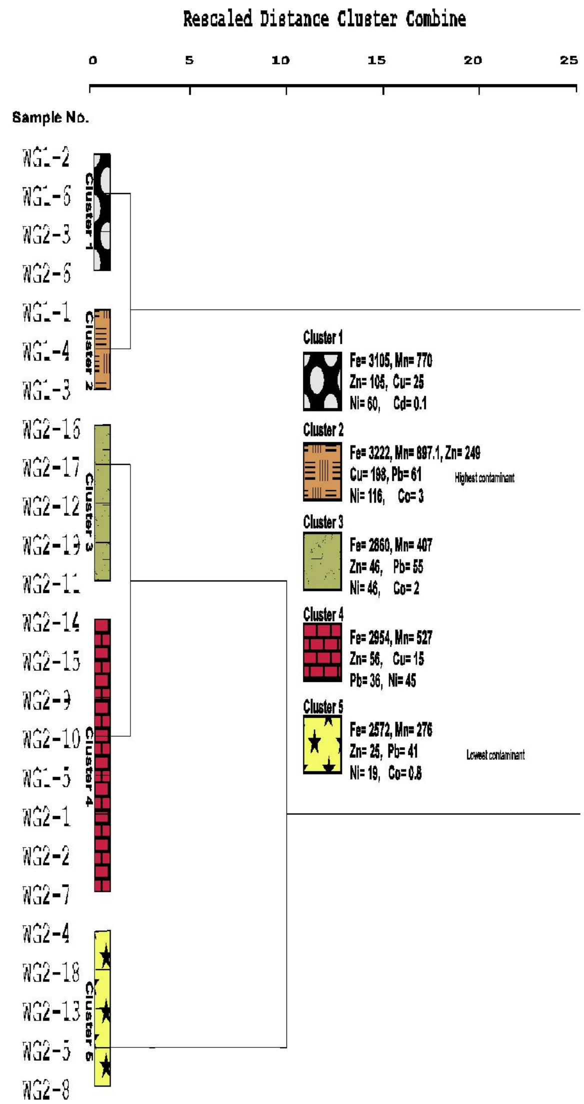

Fig. 6. Dendrogram from cluster analysis (ward's method) of heavy metals of sediment samples throughout Wadi El-Gemal area.

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 concentration of these metals in marine sediments can be used to monitor the natural inputs 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. 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. 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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Corresponding Author:
Prof. Dr. Mohamed Anwar K Abdelhalim
Department of Physics and Astronomy
College of Science
King Saud University
P.O. 2455, Riyadh 11451
E-mail: abdelhalimmak@yahoo.com
mabdulhleem@ksu.edu.sa

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