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Environmental implications of surface sediments from coastal lagoons in the Red Sea coast

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Abstract

Several investigations including nature and geochemistry of surface sediments were carried out on forty-two sediment samples collected from Abu-Shaar, Abu-Galwa, Umm al-Huwaytāt and Marsa Shūni lagoons located along with the Egyptian Red Sea coast. The sediments of Abu-Galawa and Abu-Shaar lagoons had highest carbonate content due to dominance of biogenic sediments from the surrounding coral reefs and very little of terrigenious influx. The mud content recorded high values in Umm al-Huwaytāt and Marsa Shūni lagoons as compared with other two lagoons due to high contribution of terrigenous influx, especially near Umm al-Huwaytāt lagoon.The sediments of Marsa Shūni lagoon had highest total organic matter content as compared to other three lagoons resulting from high contribution of terrestrial input by Wadi El-Shūni. Phosphorus content in sdiments samples from Umm al-Huwaytāt lagoon recorded highest values. The investigation of distribution of heavy metals (Fe, Zn, Cu, Pb and Cd) in surficial sediments of the coastal lagoons indicated that the degree of metal pollution was caused by anthropogenic activities or by natural impact by wadies. The present study provides information about nature and geochemistry of sediments and the extent of pollution that represents primary data base for managers to assess anthropogenic impacts, and better for detecting remedial meseaurs in future.

Key words

Coastal lagoons, Egypt, Geochemistry, Red sea, Texture

Introduction

Coastal lagoons and their adjacent near shore zones are important for several living organisms. They also act as buffers to wave energy. Coastal lagoon ecosystem includes variety of habitats that comprise sabkha, salt marshes, mangrove forests, swamps, intertidal pools and seawater systems. All these possess rich biological diversity, as well as, complex food chain (Green-Ruiz and Paez-Osuna, 2001); De Pippo*et al.,* 2004; Smith, 2001). The Egyptian Red Sea coastal lagoons are being stressed due to over exploitation and have become vulnerable to human related activities (Mansour *et al* ., 2000).

The main environmental problems and threats to the Red Sea ecosystem include tourism activities, land filling, dredging, oil seepage, water pollution, solid waste disposal, navigation activities, phosphate shipment pollution and fishing activities (Madkour., 2011). Because of human activities, pollution extends along the shore, and is discharged to the nearshore waters. Bottom sediments (Madkour, 2004) may directly or indirectly capture some of these pollutants. In case of successive concentrations of these pollutants in bottom sediments, the later

will act as a reservoir for pollutants.

Several studies on marine surface-sediments have been carried out on the Egyptian Red Sea Coastal zone. Out of which some important contributions have been made Mansour *et al.,* (2000) ; Madkour (2005); Mohammed *et al.* (2005); Mansour *et al.,* (2005); Madkour *et al.;* (2006), Madkour and Ali (2008); Mohamed *et al.,* (2011); El-Taher and Madkour (2011); Madkour (2011); Madkour *et al.*, (2012); El-Taher and Madkour (2013); Madkour *et al.,* (2013); Mansour *et al.,* (2013); Madkour *et al.,* (2014) and El-Taher and Madkour (2014).

The present study was initiated to investigate the distribution, composition and dispersal patterns of surface marine sediments in coastal lagoons along the Egyptian Red Sea Coast. Results of analyses for grain size characteristics, carbonate content, total organic matter, phosphorus content and heavy metals concentration have been used as finger prints to locate sites of sediment accumulation, and to identify sediment sources in the area. This database will help the managers in identifying anthropogenic impact and for better assessment of the remedial measures. Accurate documentation of existing levels of pollution is needed to detect small changes for future activities.

Materials and Methods

Forty-two sediment samples were collected from four selected localities Abu-Shaar, Abu-Galwa, Umm al-Huwaytāt and Marsa Shūni lagoons along the Egyptian Red Sea coast. The location of these coastal lagoons and their position are shown in Fig.1. The sampling was carried out by a grab sampler and Scuba diving (Fig. 2). Scuba diving was used in coral rich area where grab sampler failed to collect samples. The collected samples were placed in labeled plastic bags for laboratory analysis. Grain size analysis provides basic information for the geochemical investigations of marine sediments. Sieving analysis was performed by the technique of Folk and Ward (1957). All the geochemical analyses were carried out on bulk samples and average data were considered for interpretation. Total carbonate content was determined by treating the samples with 1N HCl. Insoluble residue remaining after acid wash was determined and carbonate percentage was calculated. Organic matter was determined by sequential weight loss at 550 ºC (Dean, 1974). Total phosphorus was determined according to (APHA 2012). Fe,

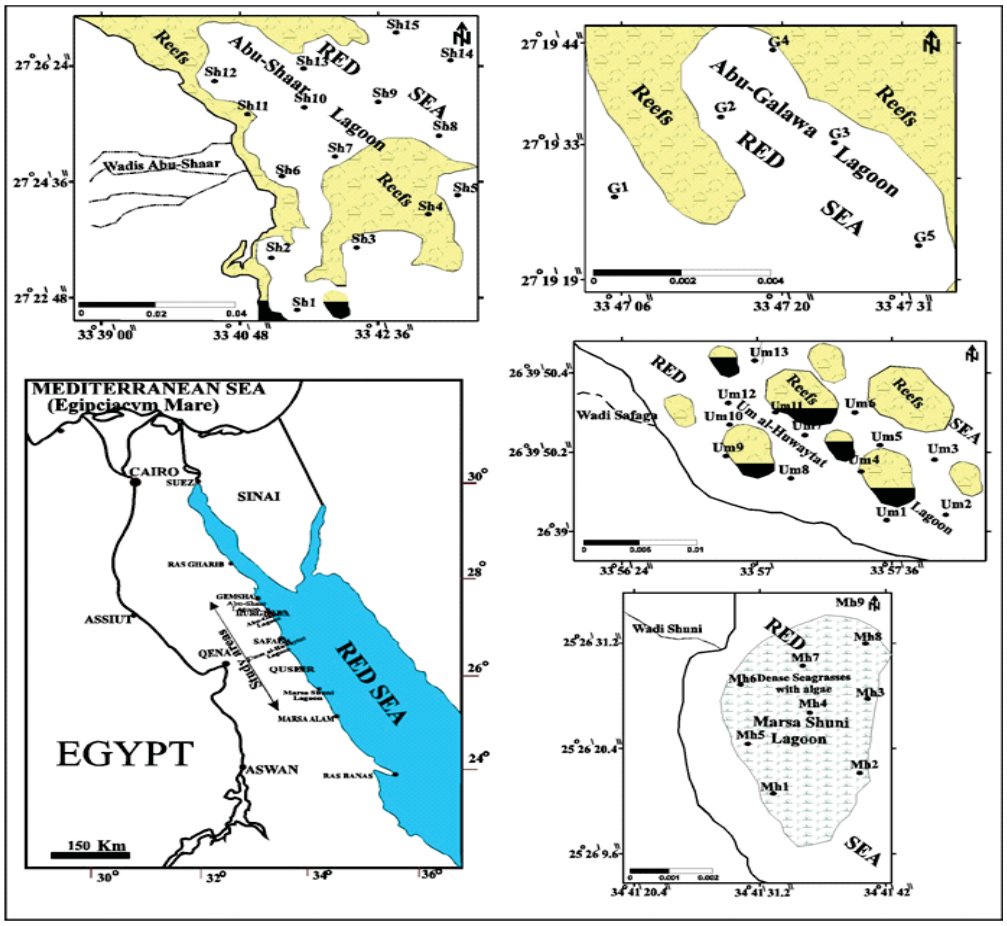

Fig. 1 : Location maps of the studied coastal lagoons along the Egyptian Red Sea coast

Zn, Cu, Pb and Cd concentration was determined by the method of Oregioni and Aston (1984). About 0.5 g of prepared bottom sample was completely digested in a Teflon crucible by using a mixture of concentrated nitric, perchloric and hydrofluoric acids, 3 : 2 : 1 ratio respectively. Acids were slowly added to the dried sample and left overnight before heating. Samples were heated for 2 hrs on hot plate at approximately 200 °C, then cooled and filtered to get rid of the nondigested parts. The solution was made to 25 ml, and the concentration of elements determined by Atomic Absorption Spectrophotometry (GBC-932 Ver. 1.1) determined. Analyses were carried out in the laboratories of the National Institute of Oceanography and Fisheries, Red Sea Branch (Madkour, 2011).

The obtained data of granulometric and geochemical analyses were statistically analyzed in order to exclude the characteristic parameters. Statistical treatment included average, correlation coefficient and cluster analysis. Cluster analysis was performed using SPSS Package (Statistical Package for Social Sciences).

Results and Discussion

Grain size analysis gives an idea about particle size and characteristics of sediments. The surface marine sediments of the investigated lagoons were found to consist of a wide variety of texture classes, from coarse sand to sandy mud. Sediments of coastal lagoons were composed of 78% sand (Fig. 3). Coarse and medium sands are the most abundant fractions inAbu-Shaar and Abu-Galwa sediments, whereas fine and very fine sand fractions were dominant in Umm al-Huwaytāt and Marsa Shūni sediments (Fig. 3). In Abu-Shaar lagoon sand fraction ranged between 71.7% and 98.3%, averaging 86.4% while Abu-Galawa lagoon included of sand fraction between 67.3% and 94.6%, averaging 84.3% (Table 1; Fig. 3). Gravel was common in Umm al-Huwaytāt lagoon and reached up to 22.3% in sediments with average of 7.5%. On the other hand, highest value of mud content was recorded in Umm al-Huwaytāt and Marsa Shūni lagoons (Fig. 3).

The results of mean size indicated that sediments ranged from coarse sand to coarse silt. Sediments of Umm al-Huwaytāt lagoon varied from medium sand to coarse silt while sediments of Abu-Galawa and Marsa Shūni lagoons were coarse to very fine grained sand. Dominance of mud fraction was responsible for the poor sorting in the remaining samples of all lagoons. The results of skewness and kurtosis values at the bottom sediments in the coastal lagoons indicated that the sediments were nearly symmetrical skewed in all the studied lagoons except those of Marsa Shūni lagoon where sediments were coarse skewed. Kurtosis varied from leptokurtic in Abu-Shaar, Umm al-Huwaytāt and Marsa Shūni lagoons to very leptokurtic in Abu-Galawa lagoon. This variation in characteristics of sediments was produced on one side by types of flux of clastic sediments and on the other side by diversity of biogenic grains (Madkour *et al*., 2014).

Fig. 2 : The bottom facies of coastal lagoons: terrestrial materials (a) and some patches of coral reefs (b) in Abu-Shaar lagoon; collection of some samples and biogenic sand with seagrasses in Abu-Galawa lagoon (c & d); phosphate shipment operations in abu-Tartour Harbour near Umm al-Huwaytāt lagoon (e) and high turbidity lead to high distribution of soft corals (f); high density of seagrasses and algae resulting from high contribution of terrigenous influx by Wadi Shūni in Marsa El- Shūni lagoon (g & h)

Statistical analyses performed with SPSS program using Ward's method, on all grain size data obtained by sieving and pipette methods is shown in (Fig. 4). Cluster analysis revealed the presence of six main clusters according to the abundance of size fraction. Cluster 1 represented 14.3% of the total samples and was characterized by high sand fraction (84.8%), high gravel (12.12%) and low mud (3.04%). Cluster 2 included 16.71% of the total samples and was characterized by high sand fraction (95.98%) with low amount and mud contents. Most samples of cluster 1 and 2 fell in Abu-Shaar lagoon (Fig. 4). Cluster 3 showed high number of samples and represented 33.3% of the total samples. It was distinguished by abundance of sand (81.8%) and high relative mud content (15.2%) (Fig. 4). It included a mixture of samples of the studied coastal lagoons. Sediment samples of cluster 4 belonged to Umm al-Huwaytāt lagoon. Sediment

Table 1 : Physical and geochemical properties of sediment samples from the studied coastal lagoons

Variables	Abu-Shaar (n= 15)		Abu-Galawa (n= 5)		Umm al-Huwaytât (n= 13)		Marsa Shûni (n= 9)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Gravel	0.3 - 12.9	5.52	0.3 - 5.5	2.51	0.5 - 22.3	7.50	2.63 - 10.6	6.15
Sand	71.7-98.3	86.35	67.3 - 94.6	84.30	42.5 - 82.4	63.30	62.2 - 93.5	78.72
Mud	0.9 - 20	8.14	0.25 - 31.8	13.19	5 - 56.4	29.30	0.54 - 31.46	15.13
Mz	1.2 - 3.6	2.17	0.80 - 4.12	2.54	1.12 - 4.6	2.93	0.86 - 3.26	2..25
Sorting	1 - 2.42	1.62	1.2 - 1.4	1.28	1.44 - 2.81	2.24	1.23 - 2.77	2.01
SKI	-0.5 - 0.24	-0.09	-0.12 - 0.31	0.04	-0.17 - 0.41	0.09	-0.55 - -0.01	-0.16
KG	0.6 - 3.8	1.30	1.04 - 3.72	1.93	0.67 - 2.46	1.32	0.76 - 3.63	1.40
Carbonate%	58.8 - 95.6	81.12	69.1 - 98.2	91.76	53.4 - 96.2	74.56	70 - 88	78.08
TOM%	2.2 - 3.5	2.89	2.8- 3.2	3.01	1.91 - 4.19	2.86	2.5 - 5.60	4.00
P*	233 - 5828	3698.90	3328 - 5790	4795.20	994 - 9676	5420.80	3112 - 5066	4199.78
Fe*	235.6 - 1189.3	563.65	98.3 - 899.9	432.35	1063.2 - 2856	1876.53	978.3 - 1978	1485.89
Zn*	1.85 - 18.51	9.35	0.97 - 5.65	3.26	3.65 - 32.55	14.32	3.96 - 25.94	11.98
Cu*	0.65 - 4.39	1.30	0.08 - 1.93	0.38	1.53 - 12.53	5.08	0.98 - 3.53	1.38
Pb*	0.62 - 6.56	4.32	0.21 - 3.86	2.67	3.65 - 23.56	11.65	1.69 - 15.36	7.97
Cd*	0.36 - 0.95	0.65	0.09 - 0.56	0.37	0.83 - 1.93	1.06	0.46 - 1.34	0.56

*=values ppm TOM=total organic matter n= number of samples

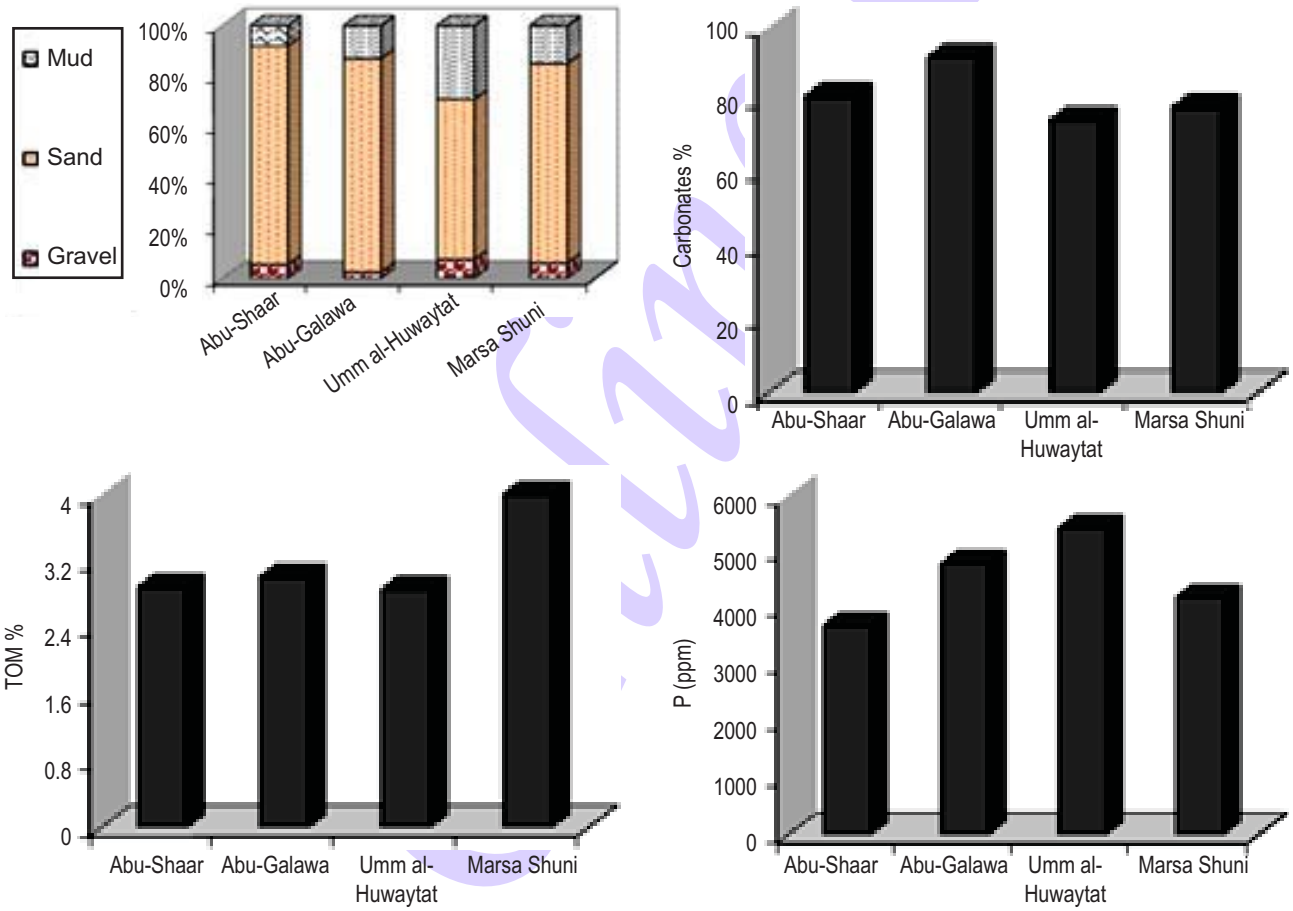

Fig. 3 : Average distribution of texture, carbonate, total organic matter and phosphorus content in sediments of studied coastal lagoons

samples in Umm al-Huwaytāt lagoon showed highest value of mud content as compared with other coastal lagoons. This was possibly due to shipment of phosphate ore in Abu-Tartour Harbour and packing of cement in Safaga Harbour near this

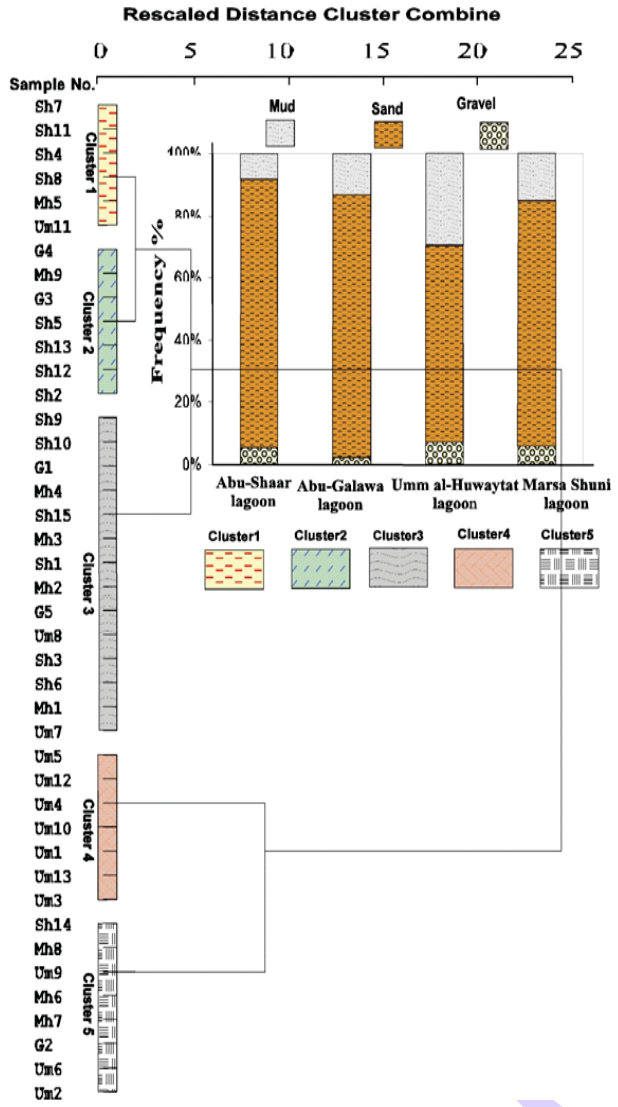

Fig. 4 : Dendrogram from cluster analysis (Ward's method) and histogram exhibiting cluster of grain size texture

lagoon. Cluster 5 represented mixture of samples of the study areas and was distinguished by high mud fraction (26.6%). High value of mud content in coastal lagoon might be attributed to influence of terrigenous flux by wadies. Fine grains were transported offshore by sea waves (Mansour *et al.*, 2005).

Surface marine sediments from Abu-Shaar, Abu-Galwa, Umm al-Huwaytāt and Marsa Shūni lagoons were analyzed to detect the concentration and distribution of Fe, Zn, Cu, Pb and Cd in order to understand the effect of human activity on the quality of surface marine sediments, (Table 1; Fig. 4). Iron is an essential element in the marine ecosystem and consequently it is one of the most abundant elements in marine sediments of the Red Sea . It also performs an essential role in biogenic activities. Iron was recorded as high concentration in sediment samples of Umm al-Huwaytāt and Marsa Shūni lagoons as compared with Abu-Shaar and Abu-Galawa lagoons (Fig. 4). High concentration of iron in all the studied sediment samples of Umm al-Huwaytāt and Marsa Shūni lagoons might be attributed to high contribution of terrigenous fragments, including mafic minerals (Mansour *et al.*, 2013).

Carbonate content in surface marine sediments of coastal lagoons varied between 74.6% at Umm al-Huwaytāt lagoon and 91.8% at Abu-Galawa lagoon (Table 1; Fig. 3). Carbonates content in Umm al-Huwaytāt and Marsa Shūni lagoons was low to medium as compared to carbonate content of other two lagoons, indicating the over supply of terrigenous materials by wadies. Abu-Shaar and Abu-Galawa lagoon samples showed highest carbonate content. These two areas were rich in coral reefs (Fig. 3).

Organic matter is mainly derived from autolysis of dead cells or actively excreted by diverse organisms as, benthic algae, copepods, sea urchins, as well as planktic species (Kenneth, 1988). The average range of total organic matter content varied from 2.86% at Umm al-Huwaytāt lagoon to 4% at Marsa Shūni lagoon (Table 1; Fig. 3). Increase in organic matter content of bottom sediments was primarily due to high rate of sedimentation leading to high input of sediment from wadies and anthropogenic activities. High productivity in some lagoons due to seagrasses and benthic algae faces are main reason for high organic matter content in coastal lagoons, especially in Marsa Shūni and Abu-Galawa lagoons (Fig. 3). Abnormal increase in this nutrient content cause deflection in the environmental stability. Total phosphorus content in sediments. Sampled from coastal lagoons varied from 3698.9 ppm at Abu-Shaar lagoon to 5420.8 ppm at Umm al-Huwaytāt lagoon (Fig. 3).

High phosphorus content in Umm al-Huwaytāt lagoon was found near phosphate loading berth in Abu-Tartour Harbour, which decreased with increasing distance from the berth. Increase phosphorus increased content in most sediment samples of coastal lagoons indicate that phosphorus might be derived from terrestrial source to sea through wadies draining the excavated upper Cretaceous phosphate rock and by landfilling process. Abu-Hilal (1985) stated that in the Gulf of Aqaba phosphorus showed a general distribution pattern similar to that of calcium content where phosphorus was found to co-deposited with calcium carbonates (Klotz, 1988).

The average concentration of zinc in marine sediments in the coastal lagoons ranged between 3.01 ppm at Abu-Galawa lagoon and 14.3 ppm at Umm al-Huwaytāt lagoon. High zinc concentration compared might be due to the influence of terrigenous fragments rich in zinc. This may be attributed to phosphate shipment operations in Abu-Tartour Harbour near Umm al-Huwaytāt lagoon. McMurtry *et al.* (1995) found that phosphate rocks contain large amounts of zinc and cadmium as impurities. Moreover, human activities contribute to the influx of

anthropogenic zinc.

Copper is an essential nutrient found in very low concentration in proteins identified in biological systems. Copper recorded highest average value of 5.08 ppm in Umm al-Huwaytāt lagoon. High concentration of copper in Umm al-Huwaytāt lagoon is attributed to high and continuous incoming suspended and particulate sediments from human activities in addition to weak reworking effects in lagoon (Dar, 2004 ; Kumar and Achyuthan., 2007).

Pb and Cd was recorded in low cocentrations in the coastal lagoons, except in Umm al-Huwaytāt lagoon where it was recorded highest (11.7 ppm and 1.06 ppm). Generally, Cd concentration in marine sediments reflect anthropogenic inputs of Cd contained materials. Marsa Shūni lagoon also recorded high Pb content (7.97 ppm). Highest Pb contents in Umm al-Huwaytāt and Marsa Shūni lagoons are attributed to the local reducing conditions and metal retention in these sediments (Madkour and Ali, 2009)

Disttribution of organic matter in sediments is dependent on organic material supply and hydrodynamic energy of the basin. The main source of phosphorus content in coastal lagoons is derived from terrestrial materials. Generally, the behavior of heavy metals in coastal lagoons is complex, and human impact on some coastal lagoons is clearly reflected by their concentrations.

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