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Assessment of Heavy Metals as a Potential Threat Influenced Coastal Ecosystem along the Northern Red Sea Coast of Egypt

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Abstract

Red Sea is considered as enclosed water bodies, where natural and human-induced stresses created intense impacts on marine ecosystem. Coastal surface sediments are widely utilized as indicator for pollution level. Recent sediments were collected from selected five sites along the Egyptian northern coast of the Red Sea, located between El Quseir and Marsa Alam areas. Concentration and distribution of eight heavy metals (Cu, Zn, Pb, Cd, Fe, Mn, Ni and Co), combined with some geochemical parameter and grain size analysis have been evaluated, to assess quality of benthic environment, the source and threats gradient on coastal marine environment. Three level of threats gradient have been distinguished, mainly originated from anthropogenic sources and ranged from relatively high in El Quseir Harbor, moderate in El Hamrawein and low in Marsa Abu Dabbab, Wadi El Quseir El-Kadium and Sharm El-Bahari. Un-severe heavy metal pollution gradient are represented in the investigated sites.

Keywords: Coastal environment • Anthropogenic source and impact • Geochemical aspects • sediment • Pollution • Heavy metals

Introduction

The marine environment of the Red Sea has been considered for a long time as being relatively unpolluted relative to other enclosed water bodies [1]. However, there is a growing risk of marine pollution and environmental degradation from urban expansion, tourism activities and industrial development, leading to excessive sedimentation, which consequently damage marine ecosystem and benthic communities [2]. In recent times, some forms of pollutants, such as phosphate mining, oil field, waste, sewage and other anthropogenic activities are associated with mobilization of metals into the marine environment and therefore coral reefs have been severely damaged. Recent increases in the mortality of reef-building corals worldwide have raised alarming questions about their future survival [3]. Accordingly, Coral reefs have been given more attention all over the world and therefore several investigations on the human impacts and metal contamination in the aquatic environment as well as recent sediments and physical characteristics of seawater were carried out on the Egyptian Red Sea coast.

In general, there are two types of environmental pressures on coral reefs or any ecosystem – natural forces and human impacts. Natural forces have shaped the distribution of coral reefs over the ages. A broad range of temperature and sea-level changes occur over hundreds and thousands of years, moreover diseases, storms and predation are more intense but have shorter-term impacts [4]. Adding human pressures to natural variability may degrade local reef ecosystems faster. Given time, corals and reef communities mostly recover from acute or short-term natural stresses after the condition healed. However, these stresses may make key organisms more vulnerable to long-term, low-level and perhaps undetectable stresses created by human populations (sedimentation, tourism activities, landfilling, dredging, oil pollution, water pollution, solid waste disposal, navigation activities, phosphate shipment pollution and fishing activities, nutrification etc.).

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Heavy metals are among the worst contaminants that may affect the aquatic environment and they are originated from both natural and anthropogenic sources. Heavy metals are known by their prevalence, bioavailability and severity of their toxicity [5]. The rapid growth in industrialization and urbanization may lead to environmental pollution with organic and inorganic pollutants. Heavy metal contamination in aquatic ecosystem may cause serious threat and severe health risk to humans [6]. Sediments act like sink and sources of heavy metals in aquatic systems as they are impacted by the physical and chemical of seawater [7]. Heavy metals can transport by water or wind to coastal areas, where they can be deposited to sediments reflected water pollution level [8].

There are many stressors and threats to the coral reef ecosystem in the Red Sea. They range from large scale impacts of climate change to specific areas affected by local developments [9,10]. The main environmental problems and threats to the Egyptian section of the Red Sea includes oil pollution, water pollution, solid waste disposal, navigation activities, phosphate shipment pollution and enormous number of activities such as fishing, mining, phosphate fertilizers manufacture, agricultural applications, coal combustion, cement production, street construction as discussed by many authors e.g. [11-13]. As a result of these human activities along the shore, discharged pollutants to the nearshore waters captured and concentrated within bottom sediments, created reservoir of accumulated pollutants, through time sediments release those metals to the overlying water column. Metals become potentially toxic when they dissolve in water. Corals absorb metals such as lead, mercury, tin, zinc, cadmium, copper, cobalt, iron, manganese, nickel, aluminum, vanadium and silver. However, high concentrations of these metals can kill corals and other marine organisms and the lower concentrations can inhibit coral growth and reproduction and may contribute to coral bleaching. Therefore, it is important to improve the quantitative and qualitative data on heavy metals in any marine environment. The objective of this study is to assess pollution levels, corresponding to different anthropogenic sources along the northern Red Sea coast, reveal from heavy metals concentration and distribution coupled with geochemical and grain size data set.

Study areas

At the Egyptian coastal side of the northern Red Sea, five locations were selected along the area around El Quseir and Marsa Alam, arranged from North to South (El Hamrawein area, Wadi El Quseir El-Kadium, El Quseir Harbor, Sharm El-Bahari and Marsa Abu Dabbab) to represent different conditions and various human activities which might cause stress to benthic ecosystem, as illustrated in (Table 1 and Figure 1). In total, nineteen samples were collected from the selected sites.

Site 1-El Hamrawein area: It is considered as one of the old phosphate harbors on the Egyptian Red Sea coast, located at about 20 km north of Quseir city. The study area lies between latitudes 26°15'06"N and 26°15'11"N and longitudes 34°12'09"E and 34°12'06"E (Figure 1). This harbor lies at the mouth of Wadi El-Hamrawein. Terrigenous sediments have been transported to the marine environment through this wadi. The shoreline is occupied by fine to coarse beach sands. The tidal flat is very narrow and slopes gently seaward. Most sediment samples have brown color due to phosphate shipment operations (Figure 2). Corals appear at 1 km from the beach and characterized by low diversity as all marine fauna and flora in this site. This may be due to spread of phosphate dust, especially during the shipping process [14,15].

Site 2-Wadi El Quseir El-Kadium: Wadi El Quseir El-Kadium is the site

Table 1. The coordination of the study areas and samples locations.

Location	Sample	Coordination	
		Latitudes	Longitudes
El Hamrawein	H	26°15'11"N	34°12'8"E
	H1	26°15'10"N	34°12'6"E
	H2	26°15'8"N	34°12'9"E
	H3	26°15'6"N	34°12'9"E
Wadi El Quseir El-Kadium	K	26°10'4"N	34°14'34"E
	K1	26°9'58"N	34°14'36"E
	K2	26°9'52"N	34°14'38"E
	K3	26°9'41"N	34°14'42"E
El Quseir Harbor	Q	26°6'15"N	34°17'13"E
	Q1	26°6'10"N	34°17'14"E
	Q2	26°6'9"N	34°17'6"E
	Q3	26°6'6"N	34°17'2"E
Sharm El-Bahari	S	25°52'40"N	34°25'4"E
	S1	25°52'20"N	34°25'12"E
	S2	25°52'12"N	34°25'5"E
	S3	25°52'6"N	34°25'55"E
Marsa Abu dabbab	D	25°20'18"N	34°44'17"E
	D1	25°20'14"N	34°44'20"E
	D2	25°20'12"N	34°44'25"E

Figure 1. Location of the studied areas.

Figure 2. General view of site areas. a) El Hamrawein Harbor and phosphate shipment most of sediment samples have brown color due to phosphate shipment operations, b) Wadi El Quseir El-Kadium, c) El Quseir Harbor, constructions directly on the beach, waste dumps, fishing boats near the beach area, d) Sharm El-Bahari area, limited diving tourism activities, e) and f) Marsa Abu Dabbab, different human activities at the beach area of including fishing boats and different tourism activities.

of an ancient port located about 80 km south of Hurghada and 8 km north of the modern port of El Quseir City. This old port lies at the head of a bay or marsa, behind which is a silted lagoon or sabkha. The small inlet cuts the Late Pleistocene coral reef that runs parallel to the shore [16]. Surrounding the site to the west and south are the foothills of the Eastern Desert that comprise Plio-Pleistocene gravels. At El Quseir El-Kadium Bay, fringing reefs are distributed along the coast, interrupted by bays that are usually located at the mouth of wadis [17] (dry river valleys). The beach is 8 m wide, 50 cm high and sloping 12° toward the Sea. The sandy substrate extends to 9 m where some scattered stones found. The presence of living coral colonies were in the form of separated small- branched colonies of *Acropora* sp. and *Stylophora* sp. at a depth of 45 cm [10]. The water depth increases as we go seaward to be 90 cm, where coral flourished, making a number of communities where coral reef fishes were so abundant associated with dominant brown algal species. The diversity of the fish and coral fauna is high and are generally in a good ecological condition. The bay is utilized for scuba diving by a single dive center. The diving tourism does not impose an immediate threat to the coral reefs' health. However, due to sedimentation, the water inside the bay is frequently turbid.

Site 3-El Quseir Harbor: El Quseir Harbor is located in El Quseir City on the western coast of the Red Sea, situated about 140 km south of Hurghada and about 160 km east of the Nile Valley and it is considered from old harbors on the Egyptian Red Sea coast. It is lying at latitudes 26°06′06″ N to 26°06′15″N and longitudes 34°17′ 02″E to 34°17′13″E). The salinity of the water in Quseir Harbor is relatively high, while the climate is typical for the coast of the Northern Red Sea, it is warm and arid. The average water temperatures in the spring season were around 23.5°C. This harbor lies in a small bay at the mouth of Wadi Ambaji. Terrigenous sediments have been transported to the area by this Wadi, especially in the southern part of El Quseir harbor. The beach sediments are coarse sands. The tidal flat is very narrow and extends smoothly with a gentle seaward slope [17]. The sediments covering the bottom of this area are of fine sand to sandy mud and may have brown color due to phosphate shipment operations. The marine environment at this area effected by the spread of algal blooms, dense seagrasses, coral bleaching and declining of productivity in addition to the poor biological activity of marine organisms especially coral reefs [14,18]. In the nearest past, the harbor was used in phosphate shipment that dramatically reduced the benthic communities in and around the harbor. Moreover, the nearshore area of the harbor suffers from the direct impact of the city due to subsurface wastewater seepage [10].

Site 4-Sharm El-Bahari: Sharm El-Bahari is located at 103 km north Marsa Alam and 13 km south El Quseir City between latitudes 25°52′6″N to 25°52′40″N and longitudes 34°24′4″E to 34°24′55″E. It represents protected mangrove swamp. Trees growing on the northern side are more protected and attain large crowns. The southern section is occupied by dwarf trees, which not exceed 2 m height. The mangrove swamp is healthy and the density increases at the entrance of Sharm and at the northern side. The Sharm is surrounded with raised beach from both north and south wards [15]. Construction of coastal road and tourist development (Figure 2) in the area is expected to have impacts on groundwater seepage [12,15,17].

Site 5-Marsa Abu Dabbab : Marsa Abu Dabbab is lying 97 km southeast of El Quseir and it is considered a bay surrounded by raised beach from both the north and south wards. This bay is situated at 30 km north Marsa Alam between latitudes 25°20'12"N and 25°20'18"N and longitudes 34°44'17"E and 34°44'25"E. It lies off wadi Abu Dabab which extends to about 17.5 km inside the eastern desert. The marine area is relatively shallow and the depth increases sea ward, where the nearshore zone is flanked with coral reefs from the southern and northern sides, while the middle part is famous with big seagrass bed [15]. This area is exposed to diving and snorkeling activity and used as a small port for tourism and fishing boats.

Material and Methods

Sediment has been sampled from five sites along the Egyptian Red Sea coast: El Hamrawein area, Wadi El Quseir El-Kadium, El Quseir Harbor, Sharm El-Bahari, Marsa Abu Dabbab. Nineteen sample of sediments, represented different environmental zones such as beach, intertidal zone and offshore zone until 7.5 m water depth, were collected from these selected localities by hand, grab sampler and scuba diving (was used in areas rich in corals where grab sampler failed to collect samples). Oceanographic parameters that control the coastal features of the Red Sea, were determined in a water sample overlying each sampling site, such as salinity (S), temperature (Temp), hydrogen ion concentration (pH), total dissolved salts (TDS) and specific conductivity (SPC) (Spec) were measured at different depths of the studied localities as shown in (Table 2).

Concentrations of eight heavy metals (Cu, Zn, Pb, Cd, Fe, Mn, Ni and Co) were determined according to (Chester et al., 1994) by AAS (Atomic Absorption Spectrophotometery) technique, results were expressed in ($\mu g\ g^{-1}$). Grain size analysis provides basic information for the geochemical marine sediments have been carried out according to Folk RL, et al. [19,20]. Total carbonate content (TC) and total organic matter (TOM) have been measured for all sediment samples according to [21-23].

Results and Discussion

Oceanographic parameters

Oceanographic conditions prevailing along the shore have an exchangeable influence on the coastal features. The oceanographic parameters affect the shore environment and simultaneously have an impact on the shore activities. Most oceanographic parameters were measured at the study areas shown in (Table 2 and Figure 3). All parameters were measured during collecting samples by Hydrolab Instrument in the winter season.

Total dissolved solids (TDS) are naturally present in water or are the result of mining or some industrial treatment of water. TDS contain minerals and organic molecules that provide benefits such as nutrients or contaminants e. g. toxic metals and organic pollutants. Water with total dissolved solids concentrations greater than 1000 mgL^{-1} is considered to be “brackish”. Changes in TDS concentrations in natural waters often result from industrial effluent, changes to the water balance by (limiting inflow, or increased water use or increased precipitation), or by salt-water intrusion [24,25]. The water salinity and TDS variations are harmonious in the studied areas, where the average value of salinity and TDS are 41 psu, 31.02 ppt in El Hamrawein, 41.22 psu, 38.77 ppt in Wadi El Quseir El-Kadium, 42 psu, 39.3 ppt in El Quseir Harbor, 41.5 psu, 31.15 ppt in Sharm El-Bahari and 40.6 psu, 31.4 ppt in Marsa Abu Dabbab, respectively.

The maximum concentrations of salinity and TDS were recorded in El Quseir Harbor area while the minimum values were in El Hamrawein and Marsa Abu Dabbab areas. The high values of water salinity and TDS may affect by the shallowness water and the presence of the mangrove forest, while the semi closed shallow area and the presence of desalination plant outlet led to raising them. The salinity and TDS recorded low values in both El Hamrawein and Marsa Abu Dabbab compared to the other three studied areas resulting from stronger mixing water with the sea water, in addition to associate the natural reasons as the shallowness, the local current system and arid climate [15]. The ion hydrogen (pH) fluctuated in narrow limit in the area under study with average between 7.6 and 8.5 (Table 2), the differences of pH values may affect by seagrasses spreading.

Sediment distribution

In general, the distribution of sediments and the variation of their grain characteristics are controlled to a great extent by the nature of the coastal sediments, bottom facies and hydrodynamic status along the coast as mentioned by Abdelfatah MM, et al. [26]. The areas under study receive sediments from two different sources: the terrigenous rock fragments and skeletal carbonates from the sea (siliclastic and carbonate sediments, respectively). Generally, the particle size of the sediments changes from coarse sand near the beach to fine sand with increasing distance from the beach towards the deeper water. The sand, mud and gravel contents of the study areas are given in (Figure 4).

The sediments of the investigated beach and intertidal bottoms facies have a little variation in the sediment type. Generally, sand is recorded as the highest value of sediment type along the five localities, composed of over

Table 2. The average of hydrographic parameters of water mass in the studied areas.

Location	Avg. Hydrographic Parameters of Water Mass						
	Depth (m)	PH	Sal %	TDS (ppt)	Temp (C°)	Spec. grav. (ot)	Conductivity (ms/cm)
El Hamrawein	2 to 4	7.6	41	31.02	21	29.9	62.4
Wadi El Quseir El-Kadium	5	8.5	41	38.77	21.8	30.3	63.2
El Quseir Harbor	5	8	42	39.3	22.4	29.8	62.8
Sharm El-Bahari	6	8.1	42	31.15	22.2	29.8	62.6
Marsa Abu dabbab	7.5	8.13	41	31.4	21.6	30.4	62.1

Note: All parameters were measured during collecting samples by hydrolab Instrument in the winter season.

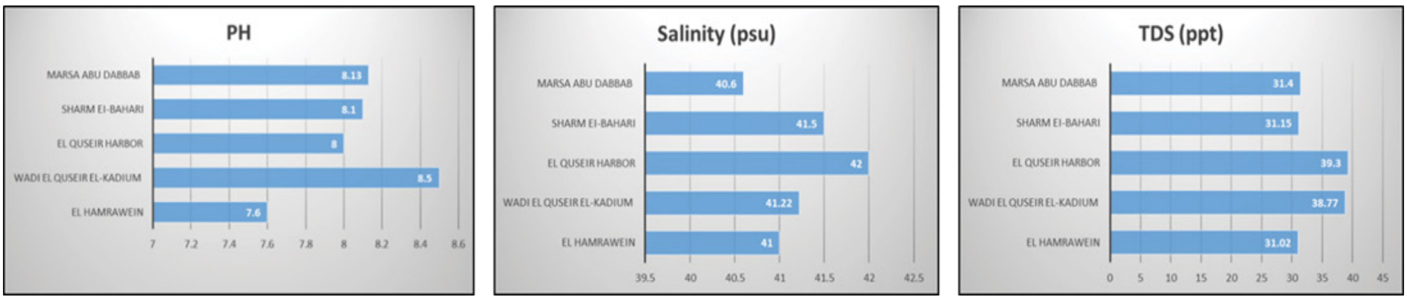


Figure 3. Distribution of pH, total dissolved salts (TDS) and salinity in surface water at the study areas.

86.1%. The average abundance of sand size fraction in the study areas ranged between 95% at El Quseir Harbor area and 86.1% at Sharm El-Bahari. Lowest values in mud fraction recorded in Wadi El Quseir El-Kadium, where Mud is relatively lower in in the intertidal sediments than beach samples. Gravel has the highest ratio in El Hamrawein location due to the abundance of terrestrial sediments at wadi El Hamrawein downstream, while the lowest ratio recorded in El Quseir Harbor.

Geochemical analysis

Carbonates: The main sources of carbonates content in the studied localities seem to result from more than one source, that is, mixed from residual from weathering of limestone rock on the sea floor, together with terrestrial from erosion of boundary limestone rock in addition to biogenic from accumulation of skeletal parts of marine animals and plants which is the most important source of calcareous sediments. The environmental parameters controlling carbonate deposition are temperature, light, sedimentation, salinity, pressure and water depth [27]. Reference to Maxwell (1968) sediments classified based on carbonate content to high carbonate (>80%), impure carbonate (80 – 60%), transitional (60 – 40%), terrigenous (40 – 20%) and high terrigenous (<20%). Following this classification most sediment samples of El Hamrawein, El Quseir Harbor, Sharm El-Bahari and Marsa Abu Dabbab areas belonging to transitional carbonates (with averages 54.03, 51.2, 40.08 and 55%, respectively), while samples of rich biogenic materials at Wadi El Quseir El-Kadium area are impure carbonate (average 76.1%) (Figure 5).

Total organic matter: The organic matter is mainly derived from the autolysis of dead cells or actively excreted by diverse organisms as benthic algae, copepods, sea urchins, as well as planktonic species. Organic matter is composed of light-weight materials and there is a close connection between the presence of fine sediments and the contents of organic matter. Accumulation of organic matter in the sediments usually affects by the size of the depositional basin, the width of the tidal flat, the bottom relief, the amount of sediments in the tidal flat, the current strength in the area of accumulation and other morphological features [28]. In addition, the decrease in organic matter after sedimentation is mainly due to decomposition and transformation. Organic matter affects the aquatic ecosystem by interacting with inorganic matter to form complex compounds, which include in its structure several other elements. It also serves as a source of food for several animal groups such as (Sea cucumber) [15].

The average distribution content of total organic matter (TOM) varies from 3.8% at El Quseir Harbor to 6.9% at Wadi El Quseir El-Kadium (Figure 6). The variation of organic matter content of the sediments in the studied localities, especially in beach samples, is mostly due to the local effects of the anthropogenic contamination. Other factors for the high rate of organic matter are the input of sediments from Wadies, land filling and dredging and obviously spots to direct discharge of domestic waste and sewage of urban areas. In addition, high productivity and the abundance of sea grass and algae bottom facies in some areas are the important reasons for high organic matter content in the most studied areas as mentioned by Mohamed, et al. [15]. The TOM content in the surface sediments of the studied localities appears to be primarily controlled by variations in lithogenic, biogenic and mixtures of sediments. Therefore, the organic matter plays a vital role in the marine environments, tending to be accumulated and fixed in the highly reducing environment [14].

Heavy metals concentration and distribution: Sources of heavy metals are classified into natural and anthropogenic sources. Heavy metals can transport by water or wind to coastal areas, where they can be deposited to sediments. In the marine environments, metals present as dissolved ions and complexes colloids suspended solids and solids in sediments [29]. This variability may induce changes in heavy metals distribution between dissolved and particulate phases and thus changes of their toxicity and consequently controlled distribution of benthic organisms [30]. Marine sediments are widely known as a significant and important archive of geochemical information. In the present work, the concentration and distribution of eight metals (Cu, Zn, Pb, Cd, Fe, Mn, Ni and Co), were analyzed from the marine sediments of El Hamrawein, Wadi El Quseir El-Kadium, El Quseir Harbor, Sharm El-Bahari and Marsa Abu Dabbab and presented in Figure 7.

Analysis of marine sediments of the studied localities reveal the degree of anthropogenic effect and relevant potential sources of pollution [31]. The measured concentration of heavy metals (Cu, Zn, Pb, Cd, Fe, Mn, Ni and Co), in sediment samples from five sites, show a wide range of variation. El Quseir Harbor followed by El Hamrawein site are recorded the highest concentration of heavy metals.

The Cu content varies from 9.22 $\mu g\ g^{-1}$ at Sharm El-Bahari to 36.77 $\mu g\ g^{-1}$ in El Quseir Harbor. Marine sediments in El Quseir Harbor and El Hamrawein recorded the highest values of Cu concentrations compared with the other studied localities. Cupper is usually included in the soft parts of several marine organisms. It is not stabilized in the lattice structure of calcite but rather

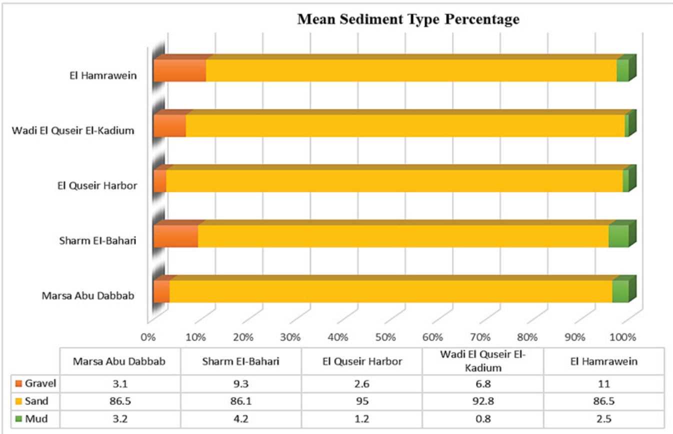


Figure 4. The distribution of gravel, sand and mud fractions of the marine sediment samples at the study areas.

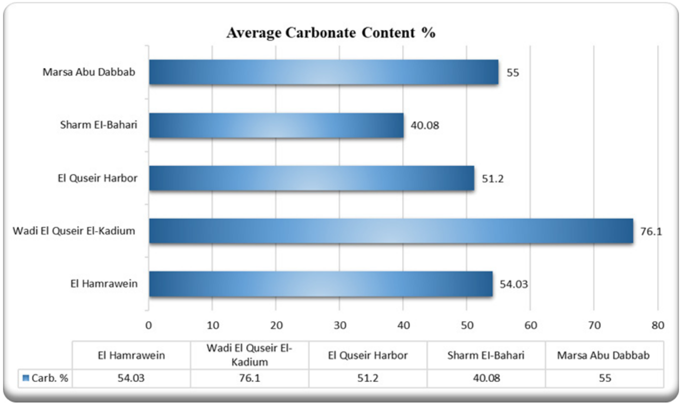


Figure 5. Distribution of average carbonate content of marine sediments at the studies localities.

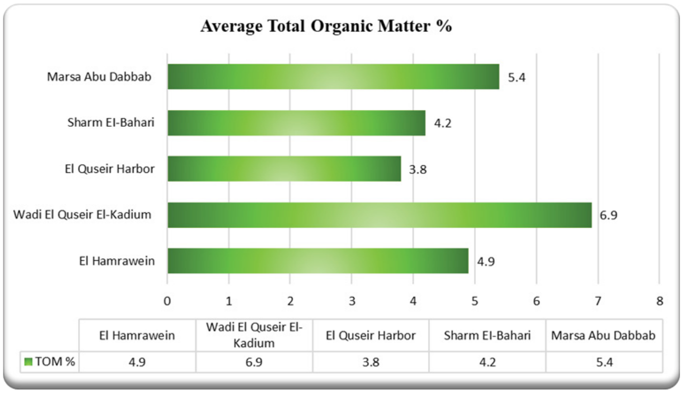
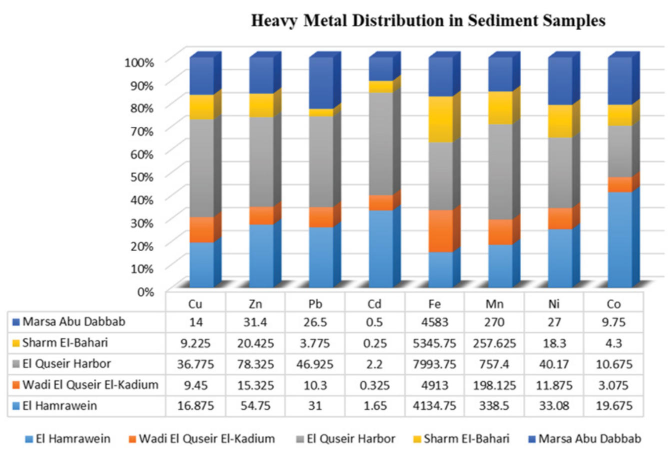


Figure 6. Distribution of average total organic matter of marine sediments at studied localities.

escapes and moves through the sediments and possibly returns to the water column upon the death of organisms. The highest value of Zn content in marine sediments recorded in El Quseir Harbor and El Hamrawein. The increase in Zn content is due to the influence of terrigenous fragments rich in this element and principally derived from volcanic and metamorphic rocks. In the marine environment, zinc concentration is slightly influenced by human impacts, but it will continue to rise resulted in ecological damage, where zinc has very long residence time in the environment [32]. The Pb level in El Quseir Harbor is high (46.9 µg g^{-1}) compared with their concentrations in most sediment samples in the studied areas except in El Hamrawein and Marsa Abu Dabbab which are 31 µg g^{-1} and 26.5 µg g^{-1} respectively. The occurrence of cadmium in marine environment is rare, therefore, the impact of Cd on the environment is considerably small. The lowest concentration is in Sharm El-Bahari area, which considered as most protective sites along the investigated areas, while the highest one is recorded in El Quseir Harbor followed by El Hamrawein indicating that the main source of Cd is an anthropogenic origin. El Quseir Harbor recorded the highest values of Fe and Mn compared with the other studied sites, most likely originated from natural and anthropogenic sources. Mn is a member of the Fe-Co group and it is an essential metal in the terrestrial sediments, where it is mainly associated with iron [11]. It is transported into the marine environment by landfills, marine paints, remains of construction and the corrosion of steel constructions and pipelines. The high mean values of Mn in the sediment samples may result from the shipment of mineral products from phosphate mines in the Eastern Desert. In addition, there are many solid wastes and disposal of garbage from the boats in addition to, sunken boats at the area. Nickel content in sediments, varies from 11.87 µg g^{-1} at Wadi El Quseir El-Kadium area to 40.17 µg g^{-1} at El Quseir Harbor. The main source of nickel is the terrestrial sediments, either naturally by wadis or by human activities due construction and dredging activities [33]. El Quseir Harbor and El Hamrawein areas recorded the high values of Ni content compared with the other localities. For Cobalt, the main anthropogenic sources of Co are oil fuels, marine pigments and landfilling. In the present study, Co average values range from 19.67 to 3.07 µg g^{-1}. Highest value is recorded in El Hamrawein area followed by El Quseir Harbor, while the lowest one is recorded in Wadi El Quseir El-Kadium area.

Comparison of heavy metal concentration in the investigated samples along studied sites with the Permissible Levels of heavy metals (µg g^{-1}) for marine Sediments Quality Guidelines according to Canadian, Ontario and Florida Guidelines [34-36] (Table 3), it is demonstrated that most of the heavy metals concentrations in El Quseir Harbor are exceed The Threshold Effect Level (TEL) (except Zn and Fe), while El Hamrawein site recorded relatively high Cd and Ni concentration which exceed The Threshold Effect Level (TEL). The other studied sites are located within the ranges of The Threshold Effect Level (TEL).

Cross correlation between five investigated sites is summarized in Figure 8, illustrated that the water salinity and TDS variations are relatively minor in the studied areas, the highest concentrations of salinity and TDS were recorded



	Cu	Zn	Pb	Cd	Fe	Mn	Ni	Co
Marsa Abu Dabbab	14	31.4	26.5	0.5	4583	270	27	9.75
Sharm El-Bahari	9.225	20.425	3.775	0.25	5345.75	257.625	18.3	4.3
El Quseir Harbor	36.775	78.325	46.925	2.2	7993.75	757.4	40.17	10.675
Wadi El Quseir El-Kadium	9.45	15.325	10.3	0.325	4913	198.125	11.875	3.075
El Hamrawein	16.875	54.75	31	1.65	4134.75	338.5	33.08	19.675

Figure 7. Heavy metals distribution of marine sediments at the five studied localities.

Table 3. Permissible levels of heavy metals (µg g^{-1}) for marine sediments quality guidelines according to Canadian, Ontario and Florida guidelines.

Metals	Levels of heavy metals (µg g^{-1})		
	TEL	PEL	SEL
Cd	0.6 - 0.7	4.21	10
Cu	16 - 18.7	108	110
Ni	15.9 – 16	42.8	75
Zn	120 – 124	271	820
Pb	30.2 - 46.7	112	250
Mn	460	-	1110
Fe	20000	-	40000

TEL: The Threshold Effect Level; PEL: The Probable Effect Level; SEL: The Severe Effect Level.

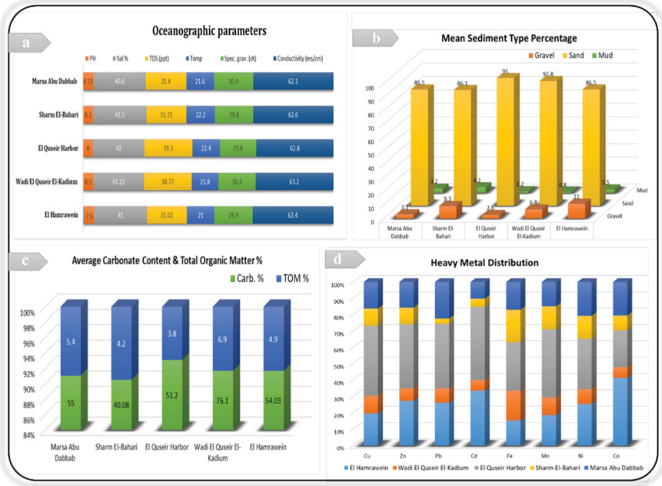


Figure 8. Cross correlation of study areas. a) Oceanographic parameters, b) Sediment types, c) Geochemical properties (carbonate and total organic matter percentages at the different stations) and d) The average concentrations of heavy metals (µg g^{-1}) in sediment samples.

in El Quseir Harbor area due to shallowness water, while the lowest values were in El Hamrawein and Marsa Abu Dabbab areas. The ion hydrogen (pH) fluctuated in narrow limit in the area under study with average between 7.6 and 8.5, the differences of pH values may affect by seagrasses spreading. The area under study receives sediments from two different sources (biogenic and terrigenous) from both the seaside as well as the landside. Grain size analysis shows that the sand recorded the highest ratio of sediments type along the five studied locations, ranged between 95% at El Quseir Harbor area and 86.1% at Sharm El-Bahari. Wadi El Quseir El-Kadium recorded the lowest values in mud fraction. Gravel has the highest ratio in El Hamrawein location due to the abundance of terrestrial sediments at wadi El Hamrawein downstream, while the lowest ratio recorded in El Quseir Harbor.

The analyzed data illustrated that the carbonate content (TC) in the investigated sediments of the studied localities varies between 40.08 and 76.1% and the relatively high average carbonate content derived from phosphate shipment and skeletal parts of marine fauna especially coral reefs. While the oversupply of terrigenous materials in some areas were the main reasons in carbonate percentage declining. The average distribution content of total organic matter (TOM) varies from 3.8% at El Quseir Harbor to 6.9% at Wadi El Quseir El-Kadium. The variation of organic matter content of the sediments in the studied sites, is corresponding to high sedimentation rate from the anthropogenic activities either in the Sea or along the coast, besides, the presence of seagrass cover in the tidal flat zone in some areas. Heavy metal analysis was carried out in the sediment samples of the study areas and the results show that the average concentration of heavy metals (Cu, Zn, Pb, Cd, Fe, Mn, Ni and Co) recoded high mean values in sediment samples from El Quseir Harbor compared with the other studied area due to mining and tourism activities. Patch reefs and fringing reefs characterize the area in front of Wadi El Quseir El-Kadium. Sharm El-Bahari area which recorded the lowest values of heavy metals, except Fe, compared with the other studied area. Numbers of anthropogenic activities were observed in Sharm El-Bahari and Marsa Abu Dabbab area. It is obviously observed that marine fauna and flora are characterized by low diversity in El Hamrawein area, as they seriously affected by the phosphate pollution, particularly, by the washing and upgrading processes of the ore and its shipping, which is reflected by the concentration of heavy metals in the marine sediments at this area.

Conclusion and Recommendations

Recent marine sediments of five different sites around El Quseir and Marsa Alam areas, along the northern Red Sea coast of Egypt have been utilized to demonstrate the anthropogenic stress influenced coastal ecosystem and consequently coral reef health. Generally, anthropogenic sources and relevant controlling factors which impacted the abundance and diversity of marine community, revealed pollution stress along the studied areas. However, the heavy metal pollution gradient, according to world and the global guidelines, recorded in the investigated sites, is relatively not severe. Assessment and cross correlation of grain size distribution, carbonate content, total organic matter and heavy-metal concentrations among the five selected sites, reveal quality levels of marine sediments. Pollution and threats gradient ranged from high in El Quseir Harbor, followed by El Hamrawein, while moderate to low in Marsa Abu Dabbab, Wadi El Quseir El-Kadium and Sharm El-Bahari, respectively.

El Quseir Harbor recorded the most impacted site, the highest salinity and TDS were recorded in El Quseir Harbor area associated with highest sand ratio of sediments, as Terrigenous sediments have been transported to the area from Wadi Ambaji, lowest values in mud fraction and total organic matter (TOM) corresponding to coral bleaching and declining of productivity as a result of poor biological activity of benthic marine organisms impacted by anthropogenic sources. Most of the heavy metals are reach the Probable Effect Level (PEL) in El Quseir Harbor corresponding to human induced activity due to mining and tourism activities. The source of heavy metal pollution over El Quseir Harbor is transported into the marine environment by landfills, marine paints, remains of construction and the corrosion of steel constructions and pipelines and many solid wastes and disposal of garbage from the boats and sunken boats at the area. The significant increase in mean values of Mn in the sediment is mainly referring to the shipment of mineral products from phosphate mines in the Eastern Desert through El Quseir Harbor.

El Hamrawein location is the second impacted site following El Quseir Harbor. It is characterized by high gravel sediment ratio due to the abundance of terrestrial sediments at wadi El Hamrawein downstream associated with by low diversity of marine fauna and flora. It is seriously affected by the phosphate pollution, sourced from washing and upgrading processes of the ore and its shipping, which is reflected by the concentration of heavy metals in the marine sediments at this area. Phosphate pollution is also impacted Marsa Abu Dabbab but with low extent compared with El Quseir Harbor and El Hamrawein. Wadi El Quseir El-Kadium area rich in biogenic materials inhabited good ecological conditions for coral reef and benthic ecosystem. Sharm El-Bahari is represented protected mangrove wetland recorded the lowest values of heavy metals, compared with the other studied areas.

Consider the national interest of natural resources values, in particular coral reefs ecosystem and its preservation, along the Red Sea coast of Egypt, continuous monitoring of heavy metal concentration is a must and highly recommended, in order to flag potential anthropogenic activities, resulted in increase of heavy metal concentration, which impacted coastal ecosystem and might threats marine life.

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