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Geospatial techniques for detection of vulnerable areas to contamination at Damietta coast, Nile Delta, Egypt

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Abstract *All kinds of pollutants that are carried out by the River Nile ultimately end up into the Mediterranean Sea leading to pollution of coastal water resources by sewage, garbage, pesticides, agricultural and industrial wastes. The present study aims to locate the most vulnerable areas to contamination along the coast of Damietta, Nile Delta of Egypt using geospatial models based on laboratory investigations of coastal water and sediments pollutants. Twelve coastal surface water and bottom sediment samples, at equal intervals, were collected in-situ and investigated in lab for contaminants of BOD, COD, Cd, Ni, Cr and Pb in water while in sediment samples; only heavy metals were measured. Standard method was followed in water and sediment analyses. ArcGIS V10.1 Software was employed to build a simple geospatial model to locate areas that recorded high levels of water contaminants (i.e. higher than the average value recorded). Another model was built to determine locations recording high levels of sediment contaminants. The study area was divided into four equal sectors from west to east (A, B, C and D) so as to detect the most vulnerable sector to contamination. Results showed that east of the coast (Sectors A and B), where industrial activities and Damietta Port are located, recorded highest levels of water contaminants; BOD 7.8 ppm, COD 161 ppm, Cd 0.08 ppm, Ni 0.17 ppm, Pb 0.72 ppm and Cr 0.91 ppm. Likewise, same sectors recorded highest levels of toxic metals in bottom sediment; Cd 0.04 ppm, Ni 0.16 ppm, Pb 1.2 ppm and Cr 7.78 ppm. The study revealed that the main contributors to contamination of Damietta coast include industrial, shipping and domestic activities. The study recommended the necessity to set rules and instructions to control human activities in order to sustain and manage the coastal resources.*

Keywords; Geospatial, contamination, Damietta coast, Egypt Nile Delta

I. INTRODUCTION

Coastal areas are very important for human beings, as they witness culture and economic exchanges between different nations. Most of the big cities, having famous harbors around the world are situated at coastal areas. About one-third of the human populations are living in and around the seashore areas. Due to abundant natural resources, urbanization and population rapidly increase on coastal areas.

Various developmental projects are installed in the shoreline areas, placing great pressure on it, leading to coastal resources pollution (Kumaravel, 2013). Furthermore, all kind of pollutants that are carried by rivers ultimately ends up into these coastal water resources. Indeed, this leads to variable pollution by sewage, garbage, agriculture waste and pesticides (El-Zeiny, 2010). Pollution of coastal waters can greatly reduce the production of fish, as well as coastal nursery and wetland habitats (Hadeel *et al*., 2011 and Kumaravel *et al*., 2013). Pollutants are generated where man lives and works, therefore find their ways into marine areas that are closest to activities. The pollutant may become dispersed by turbulence and ocean currents or concentrated in the food chain components or in bottom sediment by various physico-chemical processes including adsorption, precipitation and accumulation (El-Matary, 2006).

The coastal zone of the Nile Delta is a promising area for energy resources and industrial activities which contains important wetland ecosystems. Unfortunately, this water resource is facing unprecedented pollution from human activities. El-Deek *et al.* (1994) reported that the increasing in the quantities of industrial wastes, agricultural drainage water, urban sewage and petroleum hydrocarbon pollutants discharged into Mediterranean Sea have drastic effects on its environment. Geospatial techniques have proven to be of great importance in effective management of water resources and hence could also be applied to coastal monitoring and management. Further, the application of Geographical Information System (GIS), in modeling and mapping contaminated areas, helps in decision making process (Ramachandran, 1993 and El-Zeiny, 2015).

The present study aims to locate the most vulnerable areas to contamination along the coast of Damietta, Nile Delta of Egypt using simple geospatial models established on basis of laboratory investigations of coastal water and sediments pollutants.

II. Materials and Methods

A. Study Area

The study area is located along the Mediterranean Sea coast of Damietta Governorate, Northern Nile Delta of Egypt. It lies between longitudes 31o 30' to 32o 6' E and latitudes 31o 20' to 31o 34' N. It is extended for about 10 km offshore the coastline of Damietta, covering a total area of 739.68 km2 (Fig. 1). It is bordered from the North by Mediterranean Sea, from the West and Western South by Daqahlia Governorate, from the East and Eastern South by Manzala Lagoon. The coastline of the study area is extended for about 65.72 km from Gamasa city (Daqahlia Governorate) at the east to Port Said city at the west.

The natural and man-made changes in the coastal zone of the Nile Delta have induced variable processes. The most expressive process refers to shoreline erosion, associated with sedimentation inside the coastal lagoon inlets, estuaries and harbors. Erosion has negatively affected the agriculture and urban areas along the delta promontories at Rosetta, Burullus and Damietta. The coastal zone of Damietta, as a part of the Nile Delta, is a promising area for energy resources and industrial activities. It also contains important wetland ecosystems. Unfortunately, this water resource is facing unprecedented environmental degradation (Abou El-Magd and El-Zeiny, 2014).

Damietta Governorate consists of four districts (i.e. Kafr Saad, Damietta, Faraskour and Azarqa). In the present study, only the two coastal districts (i.e. Damietta and Kafr Saad) are investigated. There are different activities practiced in and around the shoreline; fishing at Manzala Lagoon, recreation activities in coastal cities (i.e. Ras El-Bar and New Damietta cities), industrial activities concentrated in the industrial zone of New Damietta city, navigation in Damietta Harbor, commercial activities in different cities particularly Damietta and New Damietta while agricultural activities are dominant in different parts of the area, especially in the central and eastern parts (El-Zeiny, 2015).

The climatic condition of the area is typical Mediterranean environment with moderate temperature most of the year. The predominant wind direction in the area of study is almost northwest direction most of the year, which creates a general eastward-flowing longshore current (El-Asmar and Hereher, 2010). Statistically, it was found that 81% of these waves originate from the northwest direction, 14% from the northeast and just 5% from southwest (Frihy *et al.*, 2003). Winter season almost records the maximum wave height of 4.2 m which predominantly from the west-north-west wave direction; whereas spring season records the minimum wave height of 1.16 m which originates from the northwest direction. A tidal difference is semi-diurnal and ranges between 25 and 30 cm along the delta coast (El-Gammal *et al.*, 2015).

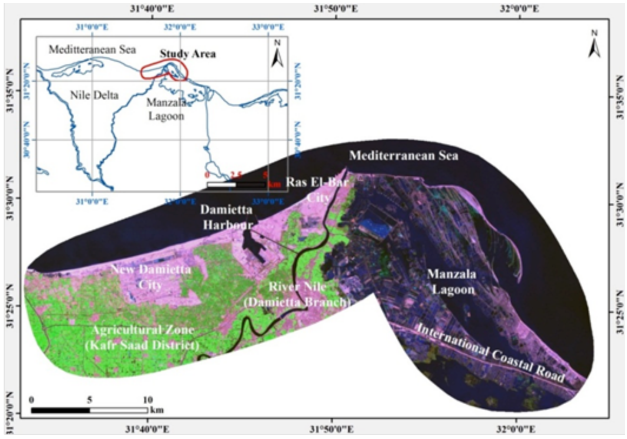

Fig.1. *Location map for the study area and Landsat OLI image 2014*

B. Sampling Method

A total number of 12 water and 12 sediment samples, along the area shoreline, was collected from East to West. A regular random sampling method was used for the sampling process. From each surveyed location, two samples (i.e. water and sediment) were collected in order to assess water and sediment contamination. Description and geographic locations of the collected samples are illustrated in Table 1 and Fig.2.

TABLE I. DESCRIPTION OF WATER AND SEDIMENT SAMPLES SITES

No.	X	Y	Description
1	31.59	31.45	Western borders of Damietta (Nearby Gamasa Petroleum Company)
2	31.64	31.46	Borders of Army Forces (New Damietta City)
3	31.7	31.47	End of New Damietta Beach (Beside Industrial Drain)
4	31.75	31.48	Damietta Harbour (Platforms 13-19)
5	31.77	31.45	Damietta Harbour (Platforms 9-12)
6	31.8	31.5	Ras El-Bar City
7	31.84	31.53	Al Lessan Region (Ras El Bar City)
8	31.9	31.53	Near Deiba Region (Ezbet El Borg)
9	31.96	31.49	Manzala Lagoon Water Inlets (Bogaz)
10	31.98	31.45	Manzala Lagoon Water Inlets (Bogaz)
11	32.02	31.4	Manzala Lagoon Water Inlets (Bogaz)
12	32.06	31.37	Eastern border of Damietta (Beside Port Said)

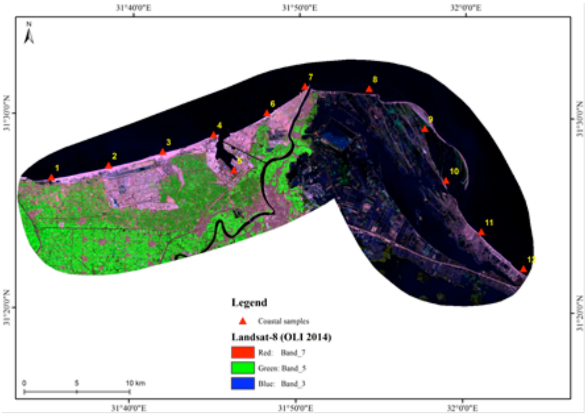

Fig.2. *Water and sediment samples locations*

C. *Laboratory analyses of collected samples*

Biological Oxygen Demand (BOD) was determined by subtracting the DO after five days of collecting the sample (DO_5) from the DO initial at the time of collecting the sample (DO_i) according to APHA (1992): Method 5210 B. Chemical Oxygen Demand (COD) was determined by Manual Method: Dichromate Reflux according to APHA (1992): Method 5220 C. Collected water and sediment samples were analyzed for four toxic heavy metals content (Cd, Pb, Ni and Cr) after extraction according APHA (1992); using Flame Atomic Absorption Spectroscopy (FAAS).

D. *Methodology*

Spatial and non-spatial data sets were integrated for mapping water and sediment characteristics in Damietta coastal zone of Egypt (Fig. 3). Non-spatial data were represented by the lab performed analyses. They were, then, attributed where an ID was assigned for each analysis. Spatial data sets were represented by geographic position of each collected water and sediment sample. Geospatial analyses were performed to define the proper inputs required for the mapping process (i.e. Method, model type and data distributions). Spatial distribution maps (i.e. result of interpolation), for each parameter, was obtained and eventually exported as a raster data layer. The mapped characteristics of coastal water and sediment samples were then modelled so as to determine contaminated areas. To locate the most contaminated Sea water, a GIS model was established in order to select areas recorded highest concentrations of BOD, COD, Cd, Pb, Cr and Ni (Values> Mean). These parameters were selected to indicate water contamination where BOD is related to domestic sewage wastewater, while COD and toxic heavy metals (Cd, Pb, Cr and Ni) refer to industrial pollution (Fig. 4). To determine the most contaminated sediments in the Mediterranean Sea, another GIS model was employed based on selecting the locations recorded high levels of toxic heavy metals; Cr, Ni, Pb and Cd (Values> Mean) which mainly originated from the industrial activities. Both models have been integrated and overlaid in order to determine the most contaminated area along Damietta Shoreline (Fig. 5).

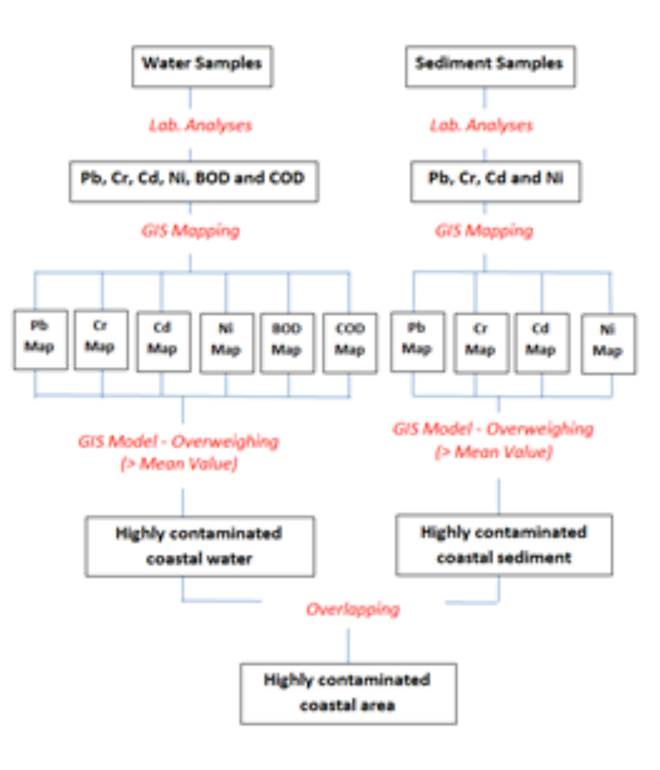

Fig.3. *Methodology adopted in the research*

Fig.4. *Model diagram for detecting contaminated water*

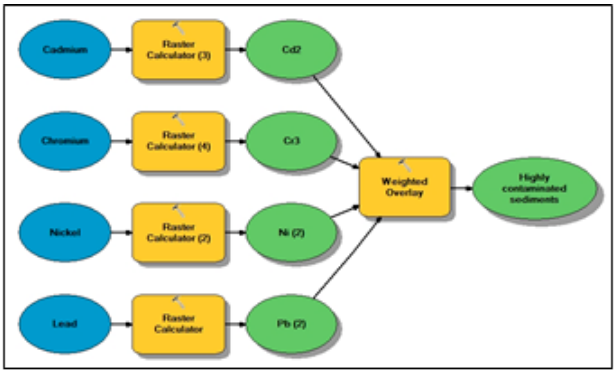

Fig.5. *Model diagram for detecting contaminated Sea sediment*

III. Results and Discussions

A. *Characteristics of coastal water and sediment*

BOD is the direct indication of the extent of pollution in the water body (Jayabhaye, 2009). Mediterranean Sea samples recorded BOD concentrations ranging from 2.7 to 8.5 ppm, which is not matching with finding of El-Zeiny (2010) at Mediterranean Sea (3.7 to 4.23 ppm). Low values of BOD at Mediterranean Sea locations might be attributed to the low levels of pollution and the increase of DO levels as a result of the great wind action in the open sea which increase the solubility of water oxygen (Broecker and Peng, 1982 and Stefansson *et al.,* 1987).

Chemical Oxygen Demand (COD) an important parameter to scout the industrial pollution (El-Alfy, 2011). Concentrations of COD in Mediterranean Sea samples fluctuated from 54 to 203 ppm which are higher that reported by Ying *et al*.(2006) at Sea water (0.74 – 1.1 ppm) and also higher than recorded by El-Zeiny (2010) at Mediterranean Sea (45-72.25 ppm). Maximum COD level (203 ppm) was recorded at location (12), closest to Port Said industrial zone and might greatly be affected by the industrial wastes discharged into the Sea. Second high value (175 ppm) was recorded at location (6) at Ras El-Bar city which could be contaminated from activities of transportation in ferryboats. Furthermore, location 4 (Damietta Harbour) also showed high concentration of COD (161 ppm) which might be due to shipping activities that could contaminate this location, raising amounts of non-biodegradable organic matter discharged into the Sea (Fig. 6).

Levels of Cd in Mediterranean Sea water samples ranged from 0.03 to 0.08 ppm which are lower than given by UNEP (1986) at Mediterranean Sea (0.003 to 0.030 ppm) but higher than given by El-Sonbati, 2012 (0.01 to 0.02 ppm) and El-Serehy *et al.,* 2012 (0.002 ppm). Cadmium is found in marine waters mostly in the dissolved form, distributed in the marine environment at low concentrations and mussels accumulate Cd effectively and may act as a poison to humans (Stankovic et al., 2011). Different activities along the area coast have produced different kinds of wastewaters loaded by Cd from industrial, agricultural and sewage wastewater discharged into the Sea which contributed to Cd elevations in coastal samples (Fig. 7). Only two different levels of cadmium were detected in Mediterranean Sea sediments; 0.02 ppm at locations 1, 2, 3, 4, 5 and 8 as well as 0.04 ppm at locations 18, 6, 7, 9 and 10.

Ni concentrations ranged from 0 to 0.17 at Mediterranean Sea samples. Distribution of Ni concentrations showed that location 1 recorded the highest value which could be due to contaminated effluents, discharged into this location, from the close Petroleum Company. Location 5 (Harbour, platforms 9-12) reported a non-detectable Ni concentration while location 4 (Harbour, platform 13-19) recorded 0.14 ppm Ni due to the excessive activities at this site. Concentrations of Ni element were detected in Mediterranean Sea sediments ranging from 0.06 ppm at location 11 to 0.18 ppm at location 7. High concentration of Ni at Al-Lessan Region, Ras El-Bar City might be attributed to the excessive human activities at this region (e.g. Shipping and discharge of sewage wastewater into this area) (Fig. 8).

Concentrations of lead in Mediterranean water samples fluctuated from 0.22 to 0.72 ppm which is higher than reported by El-Sonbati et al., 2012 (0.08 to 0.1 ppm) and El-Serehy *et al.,* 2012 (0.02 ppm) at Damietta Sea water (Fig. 9). Pb in Sea sediments ranged from 0.38 at location 3 to 1.18 ppm at location 4. High levels of lead, elevated from industrial and recreational activities, were clearly shown at locations 4, 5 and 6 (1.18, 1.10 and 0.84 ppm, respectively). Lead values recorded by El-Serehy *et al.,* 2012 (18.4 to 24.8 ppm) at Mediterranean Sea sediments are approximately twenty times higher than the present results. Lead is a naturally occurring metallic element; however certain human activities can increase environmental concentrations to levels that are potentially toxic to various organisms. Major anthropogenic sources of Pb include base metal mining, ore processing, and smelting; battery manufacturing; uncontrolled disposal of Pb-containing products, such as spent batteries and computer parts; Pb-based paints; and the continued use of Pb in ammunition and fishing tackle. Nevertheless, aquatic animals bio accumulate Pb from water and diet, and can experience toxic effects in Pb-contaminated environments (Scheuhammer *et al.,* 2008).

Present study revealed that Cr concentrations in Mediterranean Sea water samples fluctuated in a narrow range from 0.74 to 0.91 ppm. Chromium concentration in Mediterranean Sea sediments ranged from 1.18 ppm to 3.79 ppm. Values of chromium were obviously decreasing from west to east, except location 5 (Damietta Harbour) which recorded the minimum value of chromium (Fig. 10).

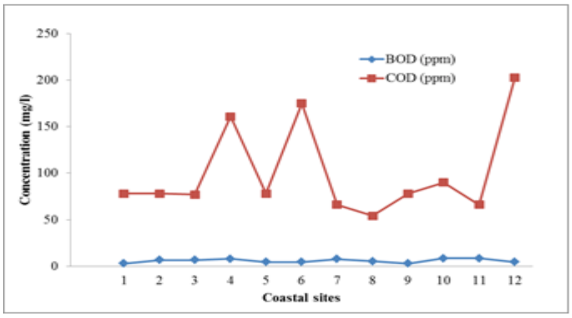

Fig.6. *BOD and COD levels at coastal water samples*

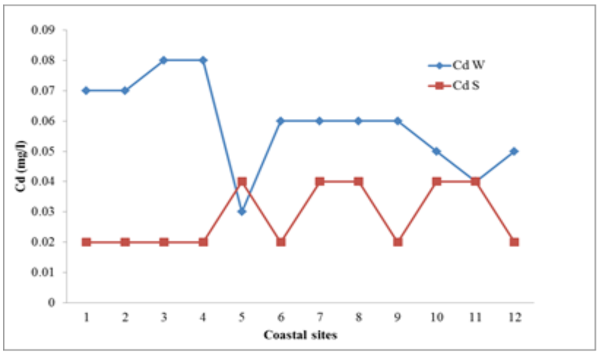

Fig.7. *Cd levels at coastal water (Cd W) and sediment (Cd S) samples*

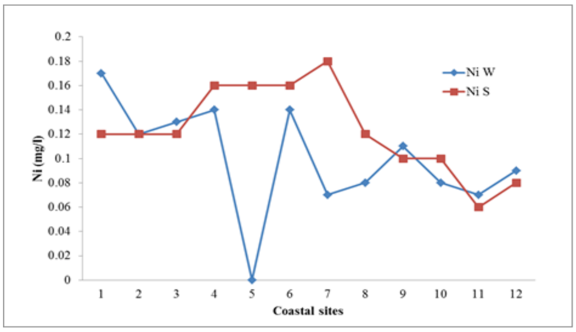

Fig.8. *Ni levels at coastal water (Ni W) and sediment (Ni S) samples*

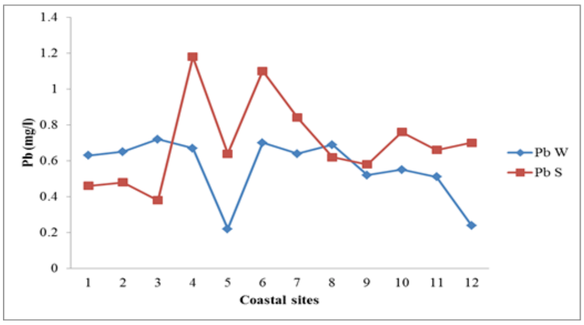

Fig.9. *Pb levels at coastal water (Pb W) and sediment (Pb S) samples*

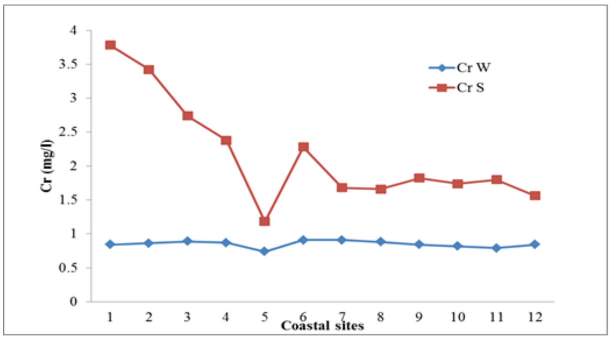

Fig.10. *Cr levels at coastal water (Cr W) and sediment (Cr S) samples*

B. *Models establishment for contamination detection*

Results showed that east of the coast (Sectors A and B), where industrial activities are settled, reported highest levels of all investigated water contaminants; BOD 7.8 ppm, COD 161 ppm, Cd 0.08 ppm, Ni 0.17 ppm, Pb 0.72 ppm and Cr 0.91 ppm due to industrial activities (El-Gammal *et al.,* 2015). Model indicated that most contaminated Sea water was located at downstream of industrial drainage of New Damietta city and extended to Damietta Harbor (Fig. 11). This confirms the impact of industrial and shipping activities on contaminating the Mediterranean Sea water at Damietta (El-Sonbati et al., 2012). Likewise, same area recorded highest levels of toxic metals in coastal sediments; Cd 0.04 ppm, Ni 0.16 ppm, Pb 1.2 ppm and Cr 7.78 ppm. Concentrations of all investigated heavy metals in Damietta sediments exceed the WHO (1984) standards in sediments. The cartographic model of sediment indicated that the highly contaminated sediments, along the Mediterranean Sea, are found in separate areas west of the shoreline, extending from east at Ras El-Bar city to west at Gamasa city (Fig. 12). Industrial and human activities, arisen from Ras El-Bar, Harbor, New Damietta industrial zone and Westani Petroleum Company, are the main contributors to sediment contaminations (El-Zeiny, 2015).

The final produced map, resulted from overlaying the two established models, has shown that sectors A and B represent the most contaminated areas along Damietta shoreline (Fig. 13). The uncontrolled industry and lack of applying industrial wastewater pre-treatment strategies magnify the environmental hazards on Mediterranean Sea, Northern Delta. This has a direct negative impact of aquatic flora and fauna at this area. Also, this area is utilized as a recreational zone which will have a direct impact on inhabitants.

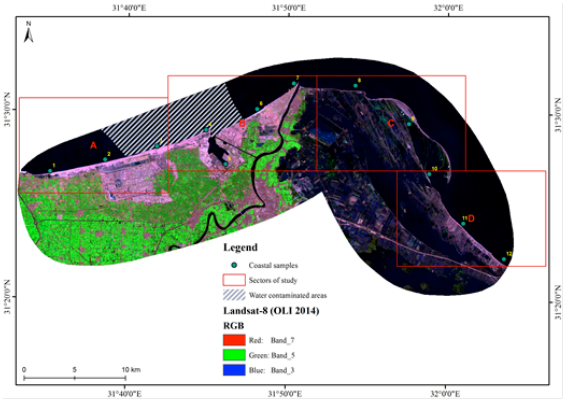

Fig.11. *Highly contaminated Sea water*

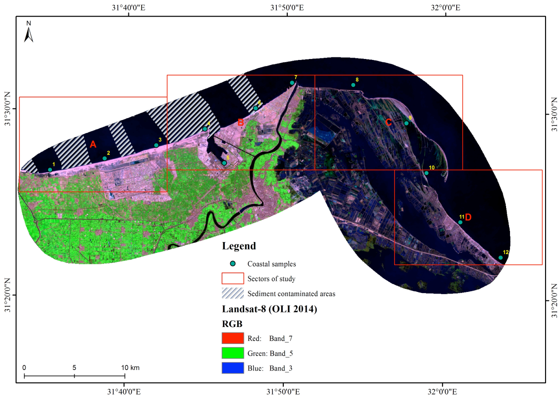

Fig.12. *Highly contaminated Sea sediment*

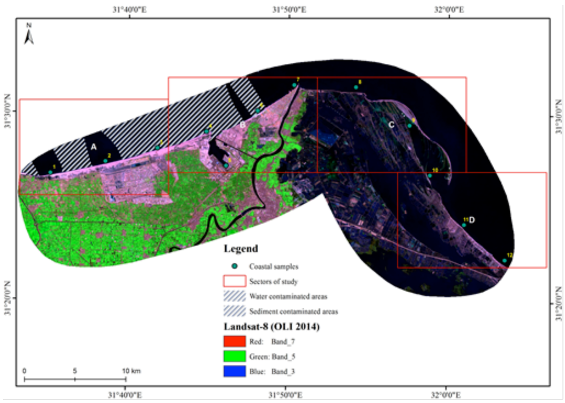

Fig.13. *Highly contaminated area detected at Damietta coast*

IV. Conclusion and Recommendations

It could be concluded that the uncontrolled industrial activities have a great impact on sediment and water quality characteristics at Coastal Zone of Damietta City, Northern Egypt. Furthermore, Geospatial techniques offer a simple and feasible tool for locating most vulnerable areas to contamination. Integration between conventional methods (field work and lab analyses) and advanced techniques (geospatial models) provided more focused analyses on studying coastal environments. Analyses of coastal water and sediment, at same sites, have been integrated and employed in order to give precise detection for high contaminated area.

In order to eliminate and mitigate the interrupting human activities, the study recommended the necessity for;

- Minimizing pollution from industrial sources through technological modernization.
- Controlling activities in Damietta Harbor to reduce contaminants that probably resulted from loading and unloading.
- Controlling discharge of domestic wastewater (Sewage) into waterways at Damietta, particularly the River Nile, which highly and negatively affect the quality of River Nile and ultimately Mediterranean Sea.
- Increasing individuals awareness, education and training in pollution identification and reduction strategies which are critical in achieving successful results.

V. Acknowledgment

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