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Monitoring of Oil Spills along Suez-Ain Sokhna Coastal Zone, Using Remote Sensing Techniques

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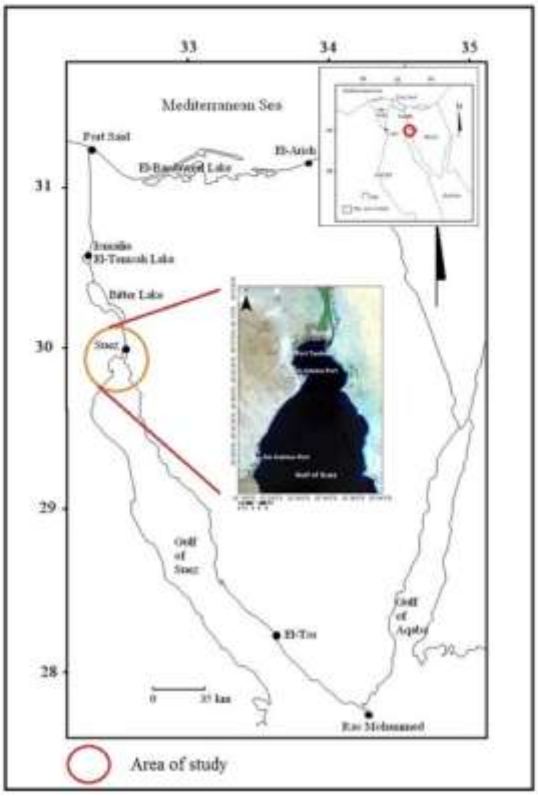
Abstract: *The present study has focused on the determination of inorganic and organic parameters in water and sediments in the North western part of the Gulf of Suez coastal zones. The main objectives of this research are detecting oil spills and specifying the source of this pollution along the Suez-AinSokhna coastal zone. Remote sensing techniques have been utilized to select the most appropriate image processing techniques required to enhance the appearance of water pollution and oil discharges. The result of organic parameters (Total Organic Carbon (TOC) and Oil & Grease) indicated that oil pollution is concentrated in the three main harbors at the area of study; Port Tawfeek, El Attaka and El Ain Sokhna. High hydrocarbon concentration was noticed at Port Tawfeek and El Attaka Sectors. Six sets of remote sensing data are acquired in this study aiming to detect, outline and monitor oil spill along Suez – Ain Sokhna region. These data includes ASTER images for year 2012, Thematic Mapper images for year 1987, Enhanced Landsat Thematic Mapper images for year 2000, 2006 and 2012 and Landsat 8 image for year 2014. The oil spills and slicks were clearly observed in the thermal band (band 6) of the ETM+. Principal Component Analyses was also applied to enhance images and detect locations of the oil slicks. Images enhancement used to detect the location and dispersion of the oil slicks in years 2000, 2006, 2010 and 2012 was applied for the images data in year 2014. The results indicate that coastal zones along Port Tawfeek and Ain Sokhna Port are polluted with oil hydrocarbon. The oil hydrocarbon pollution was noticed obviously in Port Tawfeek, El Attaka and El Ain Sokhna. Results of remote sensing data verify and confirm the chemical analyses and field investigations. The primary sources are oil tankers, ships and navigation trafficking specially at ports (El Attaka and El Adabya). In general, the sources of water pollution on shore are dominant at the northern part of the study area (Port Tawfeek and El Attaka) where the oil tankers are waiting to cross the Suez Canal navigation channel. Moreover this area is the downstream of the Suez City and location of ships services and supplies.*

I. Introduction

The area of study extends about 60km along Gulf of Suez coastal zone from Suez to Ain Sokhna. It locates between latitude 32^{0} 18` – $32^{0}$ 36` E and longitude 29^{0} 36`- $30^{0}$ 00` N (Fig.1). The Gulf of Suez has a relatively flat bottom with a depth ranging between 55 and 73 m. The Gulf of Suez is the main oil province in Egypt. Sixty percent of the total oil production of Egypt is derived from this area. The anthropogenic oil spills from oilrigs and ships have severely affected the inter-tidal zone in the central and southern parts of the Gulf of Suez. Many rocky shores are blanketed with oil pavements and oil is found buried beneath a thin veneer of wind- blown sand in some beach areas.The distribution of potential sources of oil pollution along the study area is diversified. It is extremely prone to oil pollution at Suez city due to navigation, industrial, production and other human activities nevertheless at Ain Sokhna it is sparsely polluted as the area is dominated by touristic and fishing activities.



The present work is focused on the determination of metals and organic matter in coastal water, sediments and its accumulation in collected samples from thewestern side of the northern part of the Gulf of Suez. The main objectives of this study are detecting oil spills and describe the source of this pollution along the Suez-Ain Sokhna coastal zone. In addition, remote sensing techniques will be utilized to selectthe most appropriate image processing techniques required to enhance the appearance of water pollution and oils discharge.

II. Methods & Techniques

The methods and techniques applied during this work have followed an approach that combining both field investigation and remote sensing analyses. The field investigation has included both sampling of materials (soil& water) for further analyses and making an inventory for potential sources of contamination. Field work has been done along two main profiles (Figs. 2 & 3); one extending along coastline (Onshore profile) and the other extending within the Gulf of Suez water (Offshore profile).

The first profile (Onshore) was run along the Gulf of Suez western shore line and covering 11 sites and 12 sampling points. It has included collecting 11 water samples and 11 soil samples. The water samples were sampled according to the standard methods (USGS, 2006). The soil samples were also collected as mixed sample from the shore line for further grain size and organic matter content analyses. Moreover, an inventory for potential sources of contamination and oil spills on shore.

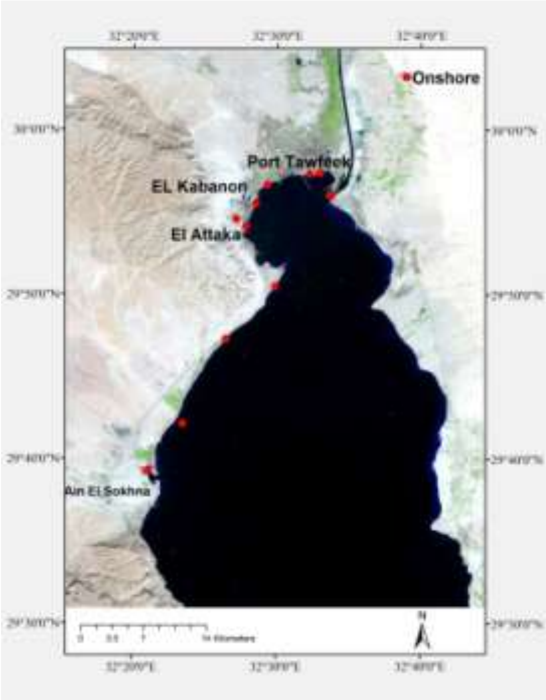


Fig. (2): Location map showing the distribution of onshore profile samples.

The second profile (Offshore) for water and seabed sampling was run offshore using boat. This profile was done jointly with colleagues from Marine Science Institute at Suez. It was run at about 100-3000 meters distance from the shore line. It has included collecting 11 water samples and 11 soil samples. It also has included documentation of potential sources of contamination.

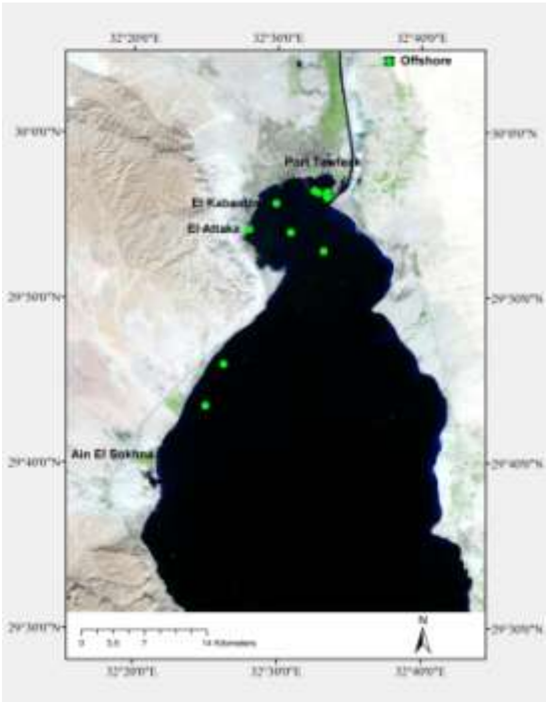


Fig. (3): Location map showing the distribution of offshore profile samples.

2.1.WATER AND SOIL ANALYSES:

2.1.1. Water analysis

- The physical parameters such as dissolved oxygen (DO), pH, temperature and electrical conductivity (EC) were measured on site using Multi 350i WTW. The device has wide range for measuring DO, pH, temperature and EC (salinity) under various temperatures.

- Major ions (cations& anions) and some heavy metals (Fe, pb, Zn, Mn) were analysied.
- The organic species including group and sum parameters (UVA254 and TOC) as well as Oil and grease and dispersed/disssolved petroleum hydrocarbon (DDPH'S) were determined.

2.2. Sea bed and shore soil analyses

2.2.1. Grain size analysis

Each of these soils was size fractionated using standard dry sieve. A grain-size analysis was performed according to (Gee and Bauder, 1986) using a set of sieves that has different diameters of openings (2.0, 1.25, 0.50, 0.25, and 0.06mm).

2.2.2. Organic matter content and organic carbon

The glowing loss method is used for the determination of the organic matter. The dried soil was weighed in a porcelain crucible which was placed in a muffle furnace at 550 c◦. After 2.5 hours the glowed probes were put in a desiccator for half an hour to cool down before they were weighed again. The glowing loss is the weight difference before and after the glowing. It is calculated on basis of the following equation(Ben-Dor and Banin, 1989; Davies, 1974):

Glowing loss [%] $= \frac{m1-m2}{m2-m0} \times 100$

m0 : mass of empty container in g.

m1 : mass of container with soil in g before glowing.

m2 : mass of container with soil in g after glowing.

2.2.3. Dissolved/Dispersed Petroleum Hydrocarbons (DDPH'S)

Spectrofluorometric determination of dissolved hydrocarbons (Parsons et al. 1985). One litre of seawater was poured into 2L capacity glass separatory funnel, extracted twice with 40 and again 40mL of methylene chloride. The extract was stored in dark at low temperature (~5 0C). Before analysis, the stored samples were evaporated to dryness in a rotary evaporator at 30 0C under reduced pressure. The concentrate was dissolved in 10 mL of n-hexane and measured fluorometrically at 415 nm after excitation at 360 nm.

The hydrocarbon concentrations are calculated as follows;

$\mu gL^{-1} = FD\ (Rs - RB)\ \mu/V$

Where, FD = C/R

C: is the concentrarion of the standard crude oil; R : is the fluorometer reading of the standard crude oil, Rs: is the fluorometer reading of the sample, RB: is the fluorometer reading of the blank, µ: is the volume of n- hexane in mL and V: is the volume of the original sample in mL.

2.3. REMOTE SENSING TECHNIQUES:

Digital image processing involves the manipulation and interpretation of digital images with the aid of a computer (Lillesand and Kiefer, 1994). Remote sensing and image processing are powerful tools for many research and applications areas (Jeffrey and John, 1990). Systematic, routine monitoring of marine pollutants and the dynamic systems that transport them require inputs of radar, infrared (to sense sea surface temperature) and visible (to retrieve chlorophyll concentration from space ocean color observation) data in ways that take advantage of their respective strengths. At the present, no existing remote sensing platform, in space or airborne, can meet all of requirements. Verifying the locations of the oil slicks during the field investigation helps in selection of the most appropriate image processing methods and techniques utilized to enhance the areas covered with the oil slicks. The analysis followed several steps to attain the most discriminating features on the images.

Six sets of remote sensing data are acquired in this study aiming to detect, outline and monitor oil spill along Suez – Ain Sokhna region. These data includes ASTER images for year 2010, Thematic Mapper images for year 1987, Enhanced Landsat Thematic Mapper images for year 2000, 2006 and 2012 and Landsat 8 image for year 2014. The main objective of this study is to detect locations of the oil pollution using remote sensing image processing techniques. The possible forms of digital image manipulation are literally infinite. However, in this research these procedures can be categorized into the following types of computer-assisted operations: **image rectification, band combination, band ratioing, Principal Component Analyses and image classification.**

III. Results & Discussion

3.1. Water QUALITY:

Table 1: Statistical analysis of physical and inorganic parameters for onshore water samples.

Variables	Valid N	Mean	Minimum	Maximum	Std.Dev.
PH	12	8.24	7.7	8.77	0.29
Dissolved Oxygen mg/l	12	5.31	3.53	10.91	2.93
T (c°)	12	21.9	20.5	22.9	0.91
EC (mS/Cm)	12	61.85	60.4	63.3	0.77
TDS (mg/l)	12	43380	42280	44306	552.27
Calcium (mg/l)	3	413	390	450	32.15
Magnesium (mg/l)	3	1253	1200	1320	61.10
Sodium (mg/l)	3	14083	14000	14250	144.34
Potassium (mg/l)	3	443	440	450	5.77
Carbonate (mg/l)	3	20	18	21	1.73
Bicarbonate (mg/l)	3	95.6	91.5	103.7	7.04
Sulphate (mg/l)	3	3967	3500	4500	503.32
Chloride (mg/l)	3	23653	22881.2	24166.7	680.22
Iron (mg/l)	3		<0.004	0.021	
Manganese (mg/l)	3		<0.001	<0.001	
Lead (mg/l)	3		<0.001	<0.001	
Zinc (mg/l)	3		0.004	0.018	

Table 2: Statistical analysis of organic parameters for onshore water samples

Parameter	Valid N	Mean	Minimum	Maximum	Std. Dev.
Organic Carbon %	12	0.0074	0.0013	0.0158	0.0041
TOC mg/l	12	7.41	1.26	15.80	4.06
Oil and Grease mg/l	12	81.67	3.00	586.00	163.58

Result analyses of organic parameters including Total Organic Carbon (TOC) and Oil & Grease indicated that oil pollution is concentrated in samples 3, 8 and 12 presenting the three main harbors (Ports) at the area of study; Port Tawfeek, El Attaka and El Ain Sokhna, respectively.

Table 3: Statistical analysis of physical and organic parameters for offshore water samples.

Variable	Valid N	Mean	Median	Minimum	Maximum	Lowe quartile	Upper quartile	Std. Dev.
Organic Carbon %	11	0.011	0.011	0.004	0.016	0.007	0.015	0.0040
TOC mg/l	11	10.55	10.93	4.09	16.06	6.73	14.86	4.036
UVA254cm^{-1}	11	0.077	0.076	0.022	0.167	0.027	0.111	0.0478
DDPHsµg/l	11	8.42	6.92	4.10	14.05	6.00	10.75	3.290
Oil & Grease mg/l	11	0.062	0.059	0.039	0.114	0.043	0.077	0.0237
pH	11	8.23	8.22	8.11	8.35	8.16	8.31	0.084
Temp. ^{0}C	11	24.01	23.70	23.20	25.20	23.40	24.90	0.719

Table 4: Correlations of organic and physical parameters foroffshore water samples(Marked correlations are significant at p < .05000 N=11)

Variables	Organic Carbon %	TOC mg/l	UV254 cm^{-1}	DDPHs µg/l	Oil & Grease mg/l	pH	Temp C^{0}
Organic Carbon %	1.00						
TOC	1.00	1.00					
UV254	0.77	0.77	1.00				
DDPHs	-0.35	-0.35	-0.11	1.00			
Oil & Grease	0.19	0.19	-0.04	-0.61	1.00		
pH	0.19	0.19	-0.10	0.01	0.51	1.00	
Temp	-0.45	-0.45	-0.17	0.36	-0.66	-0.57	1.00

3.2.SOIL CHARACREISTICS:-

3.2.1. Grain size analysis:

The cumulative curves show that the analyzed samples are mainly fine sand texture mixed with broken shells in Port Tawfeek, El Kabanon, El Attaka and Ain Sokhna.

3.2.2. Organic parameters

Organic matter was measured for 11 onshore sediment samples by using glowing loss method, as indicator for the presence of organic carbon. The result showed that the highest values were observed in pot tawfeek, El kabanon, El Attaka port and El Ain El Sokhna port.

3.2.3. Dissolved/Dispersed Petroleum Hydrocarbons (DDPHs)

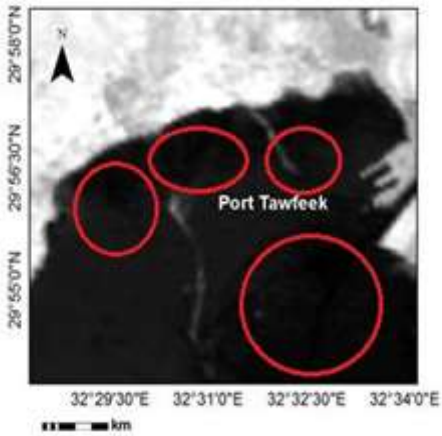
The DDPHs Values ranges from 4.125 to 125.63µg/l. The highest oil hydrocarbon pollution was observed in Port Tawfeek Sector in front of harbor. The second polluted sector is El Attaka, but it has less oil hydrocarbon pollution than Port Tawfeek. The least oil pollution in sea bed sediments was noticed in El Ain Sokhna and El Attaka.

Table 5: Results of The DDPHs concentration analyses for thesea bed soilsamples.

Name of Sector	Sample NO.	Location Sites	Water	Sediment	Sediment factor (Sediment/water)*1000
			µg/l	µg/g	
Port Tawfeek	1	Port Tawfeek	4.1	40.625	9908
	2	Port Tawfeek	5.8	**125.38**	**21616**
	3	Navigation route	8.325	20.5	2462
	4	Zaytiat port	6.925	125.63	18140
	5	Zaytiat port	6.67	113.63	17022
El Kabanon	6	Kabanon	14.05	12.375	880
El Attaka	7	Ataka port	13.925	**92.5**	**9699**
	8	Ataka port	6.65	64.5	9699
	9	Adabya port	10.75	47.125	4383
El Ain Sokhna	10	Tourism village	6	4.25	708
	11	El Sokhna	9.425	4.125	437

3.3. REMOTE SENSING RESULTS

A



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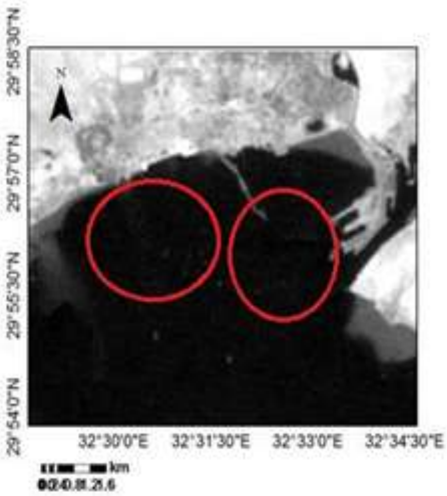

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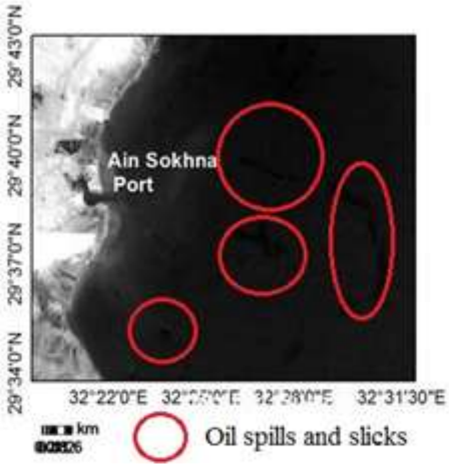
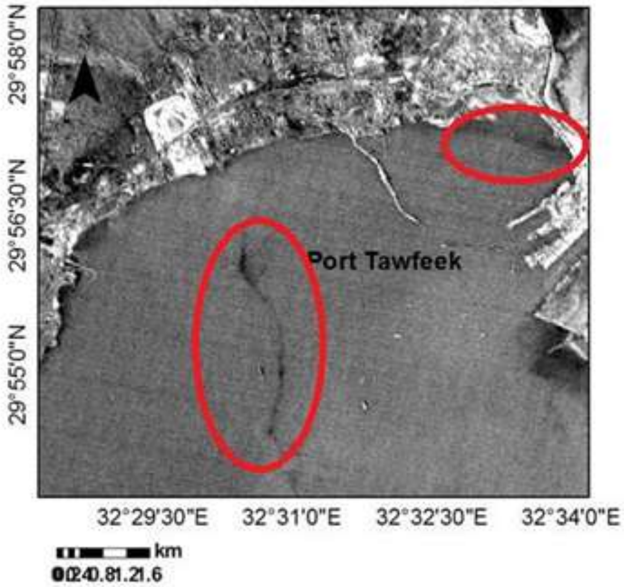


Fig. (4): Thermal band (band 6) in the Landsat images showing oil spills and slicks: A) Port Tawfeek for year 1987 (TM5), B) Port Tawfeek for year 2000 (ETM+) and C) Ain Sokhna for year 2006 (ETM+).

A



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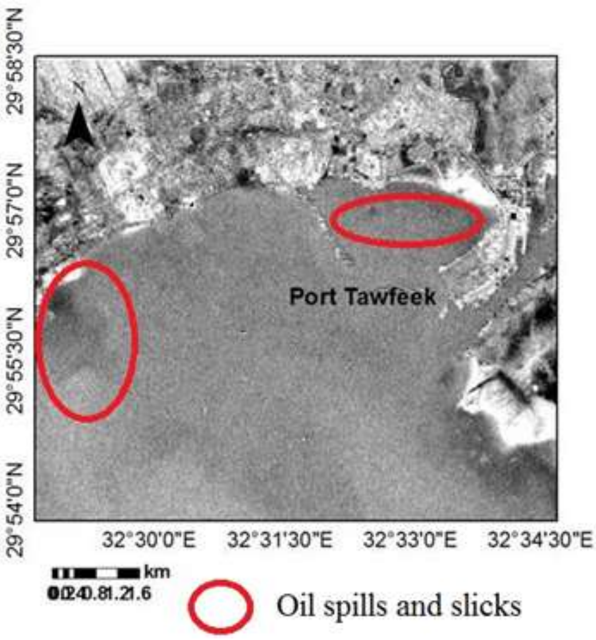

Fig. (5): Principal component of thermal band (band 6), (PC6) in the Landsat images showing oil spills and slicks: A) Port Tawfeek for year 1987 (TM5) and B) Port Tawfeek for year 2000 (ETM+).

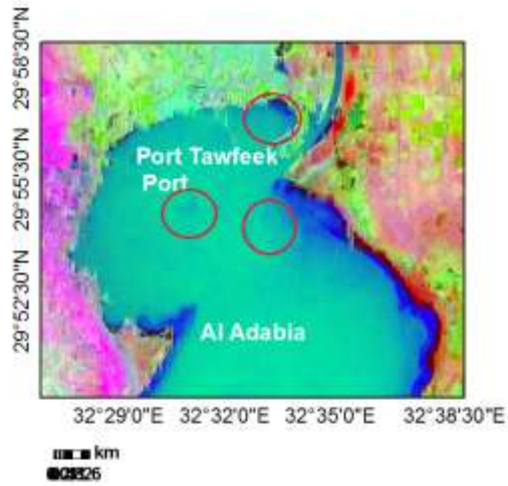

Fig. (6): Band combination PC1, PC2 and PC3 , Red, Green and Blue of ETM+ images showing oil spills dispersion in Port Tawfeek-Al Adabia for year 2000.

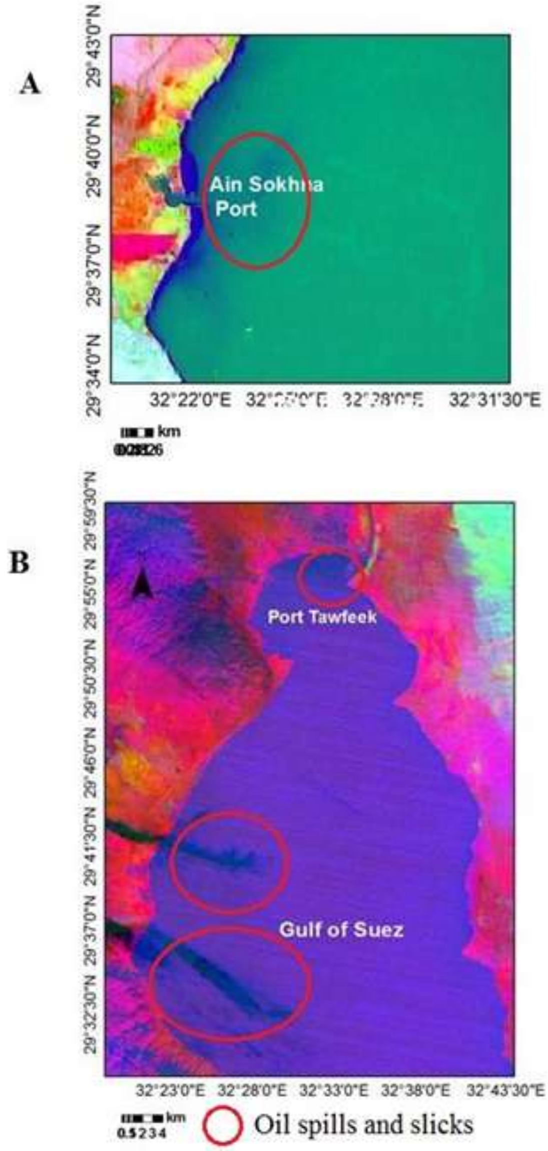

Fig. (7): Band combination of PC1, PC2 and PC3 , Red, Green and Blue showing oil spills dispersion in Ain Sokhna Port; A) in 2006 (ETM+) and B) in 2012 (ASTER).

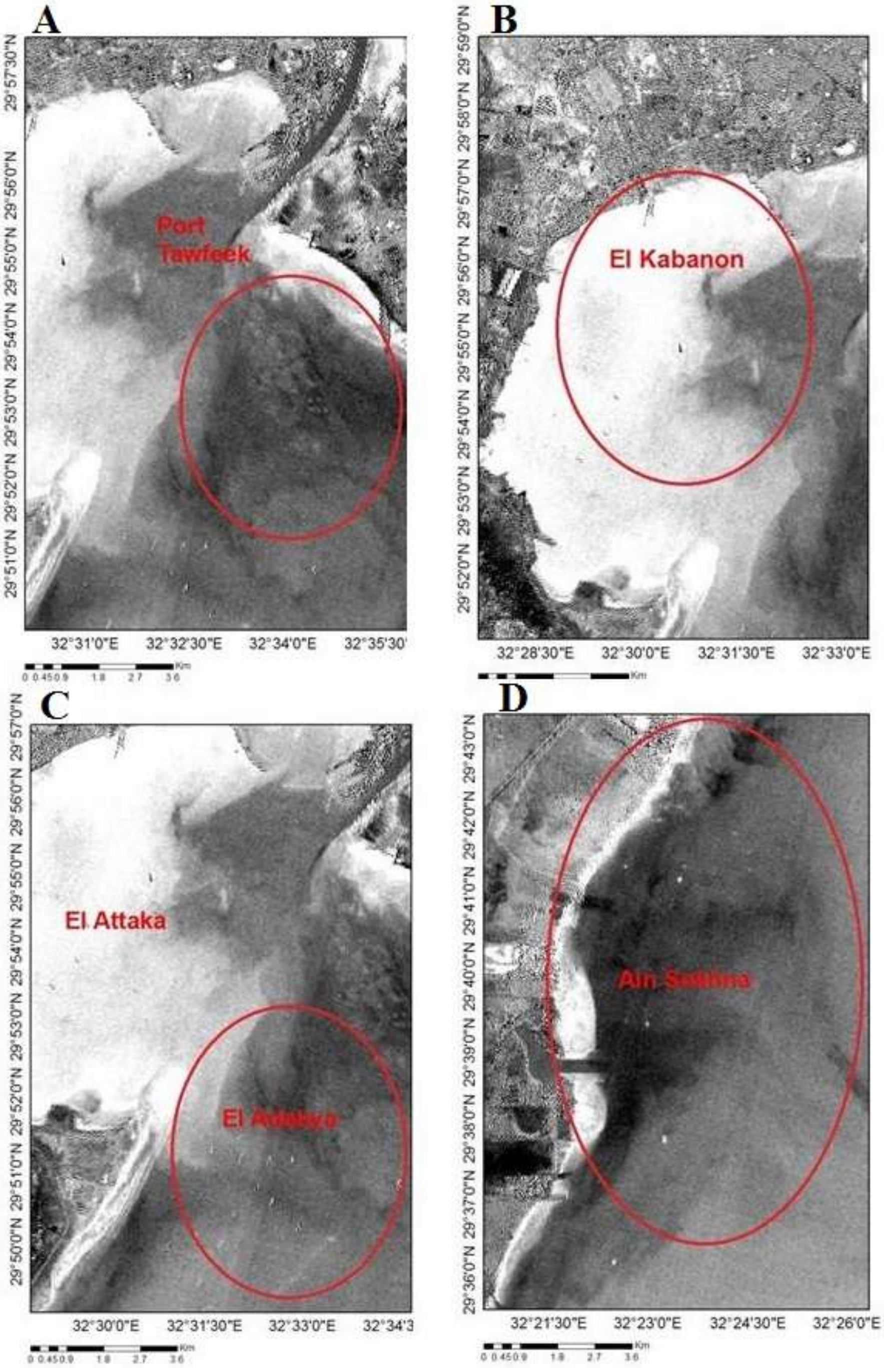

Fig. (8): Principal component of band 10 (PC10, thermal band) in Landsat 8 images 2014showing oil hydrocarbon water pollution in :A) Port Tawfeek, C) El Adabya and D) Ain Sokhna, no hydrocarbon water was detected in B) El Kabanon.

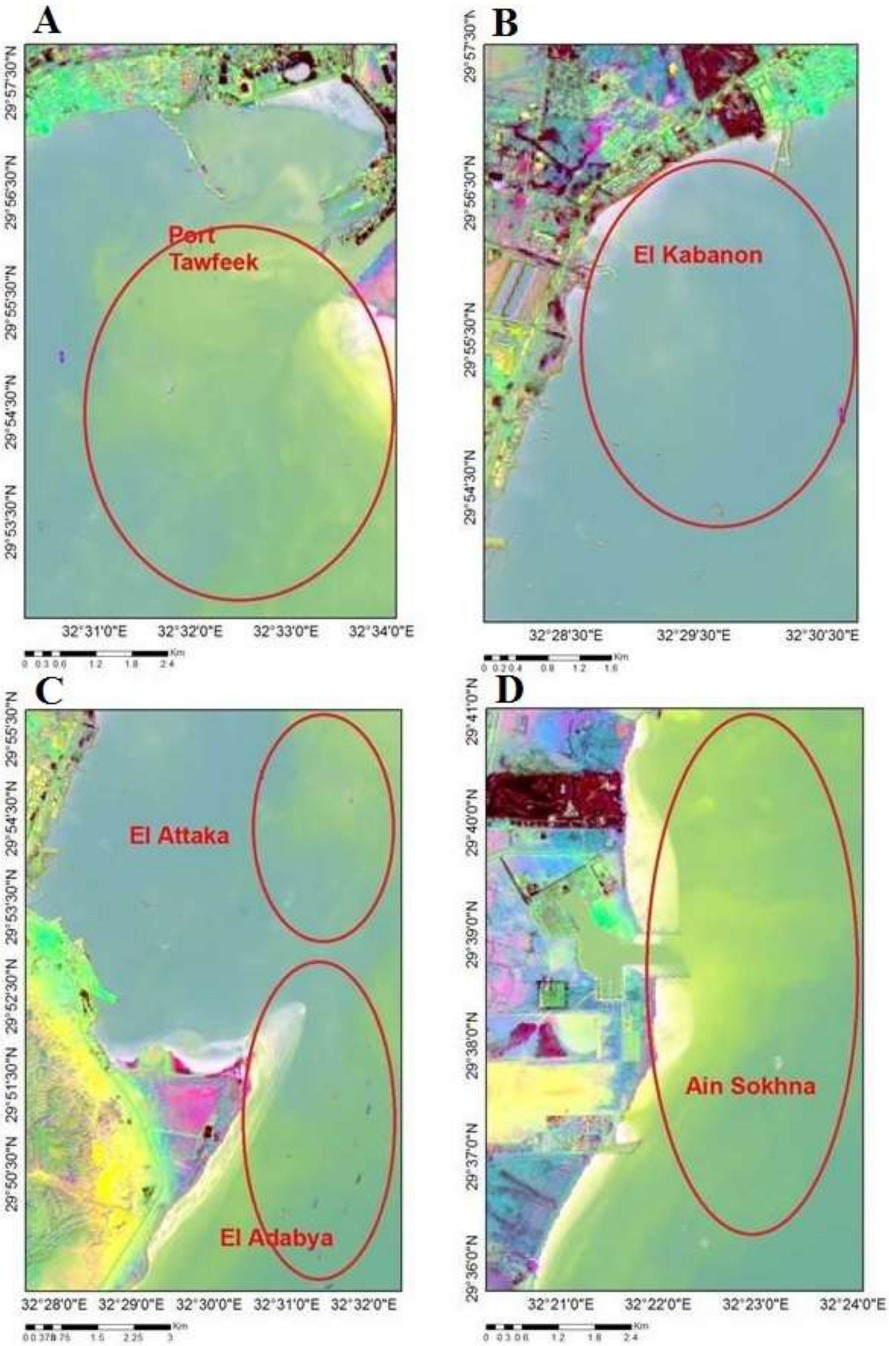

Fig. (9): Band combination of PC3, PC4 and PC5 , Red, Green and Blue in Landsat 8 images 2014 showing oil hydrocarbon water pollution in :A) Port Tawfeek, C) El Adabya and D) Ain Sokhna, no hydrocarbon water was detected in B) El Kabanon.

IV. Conclusion

Physical and chemical analyses of onshore water samples indicated that, there is no significant variation in these parameters along the study sites; Port Tawfeek, El Kabanon, El Attaka and El Ain Sokhna, except the concentration of the dissolved oxygen (DO) in El Attaka sector; dominated by algae and aquatic plants. The result of organic parameters including Total Organic Carbon (TOC) and Oil & Grease indicated that oil pollution is concentrated in the three main harbors (Ports) at the area of study; Port Tawfeek, El Attaka and El Ain Sokhna, respectively.

Oil water pollution was observed in offshore water samples which collected from the study sites having ship building industries. Oily ballast water and tank washing by vessels are the main source of the hydrocarbon pollution specified in water samples. However, this pollution was not observed in El Kabanon, where there is no oil hydrocarbon spills. The Dissolved Dispersed Petroleum Hydrocarbon (DDPH) has the lowest values in the samples characterized by high hydrocarbon concentration (Oil & Grease).A significant negative linear correlation (r=-0.61) was observed between the DDPH (µg/l) and Oil & Grease (mg/l). This relation reflects the dispersion effect of waves along the offshore profile. In contrary, high significant positive linear correlation (r= 0.77) between the TOC (mg/l) and UVA254 (cm-1), the result indicated that the dominant dissolved type of total organic carbon along the offshore profile is from aromatic origin (Hydrocarbon source). Consequently, we can use the low cost UVA245 analysis instead of TOC analysis to detect the hydrocarbon water pollution. In addition, linear correlation coefficient indicated significant negative relationship (r=-0.66) between the measured temperature and the Oil &Grease. This can be explained as the effect of temperature on the dispersion and removal processes of oil hydrocarbon.

The study sites are subjected to oil hydrocarbon water pollution produced from ship building industries and the discharge of oily ballast and tank washing by vessels. The oil hydrocarbon pollution was noticed obviously in Port Tawfeek, El Attaka and El Ain Sokhna. Results of remote sensing data verify and confirm the chemical analyses and field investigations.

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