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EVALUATION OF POLLUTION RATE BY PETROLEUM OIL AND ITS EFFECT ON MANGROVE COMMUNITIES ALONG THE RED SEA COAST, EGYPT.

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ABSTRACT

The present investigation was conducted to evaluate the pollution rates by petroleum oil and its effect on one of the most important and economic plant species; *Avicennia marina* (Forssk) Vierh .growing at three sites along the Red Sea Coast of Egypt; SI (south Safaga) S II (Wadi Abo Hamra) and SIII (Sharm El-Bahari). The total petroleum hydrocarbons were investigated in sediments, water and plants. Particle size distribution was determined for three microhabitats in each sites; habitate facing the sea shore (A), the middle of estuary (B) and the deltaic ridge of the estuary(C). Results of the present work indicated that the fine fractions of soil were the most dominant in each microhabitats of all sites. The total and individual hydrocarbons dominated in the fine sediments more than in the coarse ones. Also, results revealed that SI (south Safaga) was the most contaminated allover the studied sites. The plant heights recorded the least value at south Safaga site.

Keywords: oil pollution, mangrove communities, Red Sea Coast, Egypt.

INTRODUCTION

Mangroves and salt marshes are very important in coastal regions as a land scaping for such areas and as an important nursery habitat for many species of birds and fishes. Also, they exert controlling influence against coastal erosion. However, mangroves are susceptible to human disturbance, particularly, oil pollution as they are located in low wave energy sheltered bays and are periodically inundated by tides. The floating oils washed to mangroves are difficult to remove and remain stranded on aerial roots, stems and leaves after the tide ebbs, forming a coating blockage, leading to oxygen deficiency and suffocation (Duke *et al*, 1997 & Duke *et al*, 1998 and Mille *et al*, 1998). Because of the unique rooting systems (Pneumatophors), mangroves help protecting against erosion of the shore and even encourage seaward build up of sediments (CDA, 1996).

Many mangroves localities along the Red Sea coast of Egypt are exposed to water currents, waves and man-made pollution allowing fine and coarse sediments from floods, landfillings, mining and load/unload harbours to be settled in mangrove areas. Through tidal waves, the pneumatophors act as traps for all types of pollutants. Continuing exposure and intimate contact between mangrove subtract and sea water charged pollutants lead to hidden of the pneumatophors due to physical damage or suffocation. The accumulation of suspended materials with other pollutants in the mangrove stands may have retarded the mangrove plants to produce new pneumatophors or to replace the lost ones. In the study area, the crynohalophyte *Avicennia marina* constitutes pure communities of mangrove ecosystems as restricted small spots.

There has been very little work on mangrove ecosystems at the Red Sea Coast of Egypt. Fragmented information has been mentioned in some works on geographical distribution, ecology, flora, geomorphology and transplantation. However, data on the oil polluted-mangrove ecosystems in Egypt were not reported have as yet been published.

The present investigation may be the first one conducted to evaluate the effect of petroleum pollution on the naturally growing populations of *Avicennia_marina* at certain sites along the Red Sea Coast extending from Safaga to El-Qusier city.

MATERIALS AND METHODS

The studied sites:

Through GPS techniques, three localities distributed from South Safaga to South El-Qusier city along the Red Sea Coast of Egypt, were chosen to carry out the present investigation, Fig.(1). The first locality (SI), 16 Km South Safaga city, is located at Lat.26° 36` 52“ N and long.34 00 38 E, the second one (SII) Wadi Abo Hamra, is located at Lat.26° 23` 41“ N and Long 34° 07` 04“ E (40 Km North of El-Qusier city) and the third locality (SIII) Sharm El-Bahari (33 Km South El-Qusier) located at Lat. 25° 52` 02“ N and long. 34° 24` 48“ N. Soil, water and plants were investigated as follows.

Soil sampling and analysis:

In each site of mangrove swamp (SI, SII&SIII), three micro-sites (A) quietly facing the shore, (B) the middle of estuary and, (C) the deltaic ridge of the estuary were set up and soil samples were collected at a depth 0-40 Cm, air-dried, sieved through a 2 mm mesh size and analyzed for:

- Particle size distribution was determined according to Wild *et al.* (1979). Soil particles were categorized into four fractions; coarse sand (Φ_1).medium sand (Φ_2), fine sand (Φ_3) and (silts + clay, Φ_4).

-Total hydrocarbons: The extraction and analysis of poly-cyclic aromatic hydrocarbons were carried out in fine sand and mud fractions (Φ_3 & Φ_4) based on Wang *et al* (1994). Soil samples were extracted with 1:1 n-hexane and dichloromethane mixture once, and dichloromethane twice. The extract was collected, filtered, concenterated, cleaned and fractionated by a self-packed silica gel column. The fraction was then analyzed by GC-FID (Gas Chromatography-Flame Ionization Detector, Hewlett-Packard HP 5890). The results were expressed as mg/Kg.

Water sampling and analysis:

Three water samples were collected from each site (SI, SII&SIII), purified and analyzed for total hydrocarbons as mentioned before.

Plant sampling and analysis:

In each microsite representative plant samples were collected as follows:

- Sample (a) from the basal portion of the plant, sample (b) from the middle part and sample (c) from peaks. The plant material was air dried and ground into fine powder and analyzed for the following:
- Total hydrocarbons were measured according to Wang *et al.* (1994).

- *Primary metabolites:*
- Total carbohydrate contents were measured as described by Chaplin and Kennedy (1994). The results were expressed as percentage.
- Total chlorophyll contents as mg/g fresh weight were determined according to Vernon and Seely (1966).
- Total lipids were estimated as a percentage according to Guenther (1972) by using soxhelet apparatus.

Also, plant heights were measured in each site and the average heights were recorded

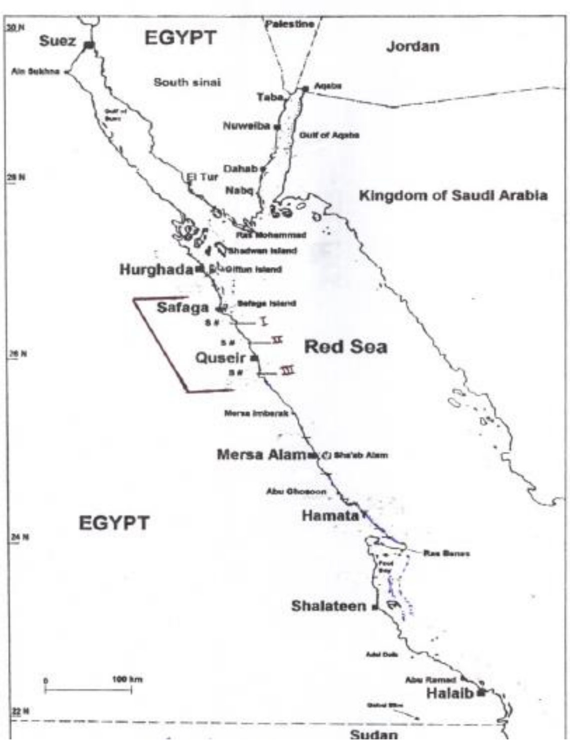

Fig. (1) Map showing the studied locations of some mangrove sites along the Red Sea Coast, Egypt.

RESULTS AND DISCUSSION

Soil analysis:

As shown in table (1), the particle size distribution of the soil supporting the mangrove swamps at the study area showed that the total average percentage of coarse fractions were 29.9,44.23 and 24.16 %,while the total average percentage of the relatively fine fractions were 70.03,55.77&70.17 % at SI (south Safaga),SII (Wadi Abo Hamra) and SIII (Sharm El Bahari),respectively. The distribution of the different fractions is different from one site to another. The relatively fine fraction (Φ_3 & Φ_4) are the real sensor to study the impacts on the mangrove swamps where they are mostly the movable forms of impacts in the marine ecosystem and have the ability to be transported for a long distance through the aqueous medium to the depositional areas. The mangrove environment in the sheltered slack water conditions allows the deposition of fine particles normally enriched with metals, high inorganic matter and minerals (Ramanathan *et al*, 1999).

In Egypt, many of the mangrove localities in the northern Red Sea coastal zone are exposed to currents; waves and man, made pollution allowing coarse, fine and suspended sediments from floods, land filling, mining and load /unload harbours to be settled in the mangroves areas.

The relatively fine sediments (Φ_3 & Φ_4) have nearly sub equal representation at all sites, where the average percentages are 45.73 & 24.3, 35.59 & 20.2 and 45.63 & 24.53 at SI, SII and SIII, respectively. It has been found that the dominant fraction among then was Φ_3 followed by Φ_4. The sub equal distribution of Φ_3 & Φ_4 may be attributed to the presence of terrestrial feeding source of sedimentation and to the accumulated materials from the coastal areas as well as to the suspended material loads in the water column.

Table (1):Particle size distribution of soil supporting the mangrove swamps of the study sites along the Red Sea coast of Egypt.

Items / Site & depth		Coarse fraction: Coarse sand Φ_1	Coarse fraction: Medium sand Φ_2	Total Φ_1+ Φ_2	Fine fraction: Fine sand Φ_3	Fine fraction: Silt & clay Φ_4	Total Φ_3+ Φ_4
SI (0 - 40 cm) safaga	A	8.4	23.0	31.4	47.4	21	68.4
	B	8.9	21.2	30.1	47.8	22.1	69.9
	C	7.2	21.0	28.2	42.0	29.8	71.8
	Average	8.17	21.73	29.9	45.73	24.3	70.03
SII (0 - 40 cm) w-Abu-Hamra	A	9.1	32.5	41.1	41.3	17.1	58.4
	B	7.5	38.5	46.0	35.3	18.7	54.0
	C	6.7	38.4	45.1	30.1	24.8	54.9
	Average	7.87	36.49	44.23	35.59	20.2	55.77
SIII (0 - 40) Sharm El-Bahari	A	8.7	32.3	41.0	46.8	21.2	68.0
	B	9.1	20.0	29.1	48.6	22.3	70.9
	C	7.3	21.1	28.4	41.5	30.1	71.6
	Average	8.37	24.5	24.16	45.63	24.53	70.17

A= the micro-site facing the sea shore **B= the middle of estuary**
C= the deltaic ridge of the estuary

Hydrocarbons distribution:

Total hydrocarbons (TH) were investigated in soil, water and plant material of *Avicennia marina*, Table (2), at the study sites, south Safaga, Wadi Abo Hamra and Sharm El-Bahari. As shown in table (2) there is a variation within and between the sites in total hydrocarbons of soil, water and plant samples. Concerning soil samples, it is found that total hydrocarbons were 3 folds in silt + clay fractions (Φ_4) more than in (Φ_3) at all sites, for example at SI they reached 24.45 & 8.16, 16.17 & 5.39 and 12.21 & 4.09 mg/Kg in the micro-sites A (Φ_4 & Φ_3), B (Φ_4 & Φ_3) and C (Φ_4 & Φ_3), respectively. In this regard, the present study was in agreement of Sherrer and Millie, (1990), Suprayogi and Murray, (1999), Pezeshki *et al*. (2000) and Zhang *et al*. (2007) where they concluded that the petroleum hydrocarbons tend to adsorb onto organic matter and fine clayey particles in muddy sediments, leading to less penetration into deeper root zone than sandy sediments. However, there were differences between the study sites in horizontal distribution of total hydrocarbons. Data presented in table (2) indicated that SI (south Safaga) is the most polluted one, SII (Wadi Abo Hamra) is partially polluted, while, SIII (Sharm El-Bahari) is non-polluted or has negligible values of total hydrocarbons in its microsites (A, B & C). The intensive pollution rates at Safaga area may be due to the presence of Safaga harbour which receives pollutants from loaded and/or unloaded ships. At the same time, the coastal area around Safaga Bay shows a high development in tourist industry making new sources for pollution impacts. Although SI is highly polluted among all sites, but the values of total hydrocarbons are still below the permissible level suggested by Levings and Garrity (1997) who stated that the sub-lethal effects of hydrocarbons including leaf losses, reduction in shoot and leaf biomass of red and black mangroves were recorded when the concentrations of oil residue in mangrove sediments were between 100 and 1000 µg g^{-1}dry weight. The mortality and/or damage due to oil contamination depend on the type, quantity and weathered state of the oil, the mangrove species and the prevailing climatic and tidal conditions (Burns And Codi, 1998 and Tam *et al.,* 2005) and the degree of penetration and degradation of oil (Vandermeulen *et al*., 1988 and Zhang *et al*., 2007).

Regarding total hydrocarbons in water samples, table (2), it has been found that South Safaga (SI) has the highest values of total hydrocarbons followed by SII (Wadi Abo Hamra) and SIII, (Sharm El Bahari). The pollution rates of water samples by total hydrocarbons reached the values of 11.45, 2.37 and 0.14 mg/Kg at SI, SII and SIII respectively. The present study suggests that the high pollution rates of water and sediments by hydrocarbons at south Safaga area than at other sites may be due to chronic contamination resulting from lubrication processes of ships and other equipments of Safaga harbour. In this respect, Proffit *et al*. (1995) and Tam *et al*. (2005) reported that different lubricating oils have negative effects on survival growth of mangrove seedlings.

The most interesting point here is the vertical distribution of total hydrocarbons in *Avicennia marina* plants. The hydrocarbons were presented in the basal portion and sometimes in the middle ones at site I only (South Safaga), while they were completely disappeared in the upper most portions of the plants at all sites. The explanation of this phenomenon may be due to; firstly the growth of mangrove swamps along the Red Sea coast of Egypt being an open pattern leading to fast weathering and degradation of oil residues, secondly, the oil residues may be too small to penetrate the surface fine fraction and to reach the absorption root zones and; thirdly, the crynohalophytic species *Avicennia marina* may have a self-rhizoremediation characteristic.

The previous studies indicate that vegetated soils are capable of effective degradation, removal and mineralization of total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pesticides, chlorinated solvents and surfactants than non vegetated soil. The phytoremediation processes are most effective when contaminants are present at low to medium levels, as high contaminant levels can inhibit plant and microbial growth and activity (US EPA, 2000). Mc Cutcheon and Schooner (2003) defined phytoremediation as the utilization of vascular plants, algae and fungi to control, breakdown or remove wastes or to encourage degradation of contaminants in the rhizosphere or root region of the plant. Plant processes that promote the removal of contaminants from soil and water are either direct or indirect. The direct processes include plant uptake into roots or shoots and transformation, storage or transportation of the contaminants, while the indirect processes involve the degradation of contaminants by microbial, soil and root interactions within the rhizosphere (Hutchinson *et al*., 2003). The present study suggests that the presence of hydrocarbons particularly basal portion may be due to the effects of sea water spray bearing contaminants.

Apart from toxic effects, if oil pollution and /or anthropogenic activities along the Red Sea coast of Egypt were taken in consideration, the growth aspects (plant height, flowering,…..etc) were affected. The mangroves growth at the study areas may also be affected by other environmental factors (high salinity, pH, temperature and topographic features within and between the different sites). The average plant height reached 2.54, 3.55 and 3.2 m at SI, SII and SIII, respectively. The least plant height recorded in south Safaga (SI) may be due to the fact that this area suffers from very high rate of land filling with high rate of pollutants. In this regard, Mandura *et al.* (1987& Mandura *et al*. 1988) stated that the Red Sea mangroves did not grow as luxuriously as most other tropical mangroves, and this may be atrributed to some factors such as : high salinity, poor soil texture low precipitation and low nutrients content. On the other hand, CDA (1996) reported that the rooting systems of mangrove plants (pneumatophores) act as traps for all types of pollutants. The continued exposure and intimate contact between mangrove substrate and sea water charged pollutants lead to the disappearance of the pneumatophores due to suffocation or physical damage. Also, the continuous accumulation of suspended materials with pollutants in the substrates of mangrove stands may have retarded the plant ability to produce new pneumatophores or to replace the lost ones.

Primary metabolites:

The analyzed primary metabolites included total carbohydrates, total nitrogen, total lipids and total chlorophyll, table (3). The results of the present work indicated that there are horizontal and vertical variations in all parameters of the primary metabolites within and between the studied sites (SI, SII&SIII). Concerning total carbohydrates, results revealed that there is a tendency of decrease in total carbohydrate contents on moving from SI and SIII exceptions. On the other hand, total carbohydrates content increase horizontally from sea shore to deltaic ridge.

On contrasting carbohydrate contents, total nitrogen tends to decrease horizontally and vertically within and between the different sites. In respect to total chlorophyll, there is a slight increase that on pronounced between SI (South Safaga) and SIII (Sharm El Bahari) where the total chlorophyll clearly increased in the vertical direction.

T2-3

Regarding total lipids, they are approximately the same either horizontally or vertically allover the studied sites. They recorded the least values among the detected primary metabolites, table (3). In this respect, Ata *et al* (2005) concluded that the primary metabolites total carbohydrates, total ash, total nitrogen and total lipids increased from sea shore to the deltaic ridge. The increase of the primary metabolites was associated with high rates of soil sedimentation and the increase of mineral ions. They also mentioned that the primary metabolites increased from North to South direction of the Red Sea coast.

Data presented in table (4) shows the distribution of petroleum hydrocarbon fractions allover the studied sites along the Red Sea coast of Egypt. The results revealed that SI (South Safaga) is the most polluted one by petroleum hydrocarbons in sediments and water followed by SII &SIII. Some of the hydrocarbon fractions are carcinogenic such as flourancene, pyrene, benzo(a)anthracene, chrycene and benzo(b)flourancene. However, pollution rates by hydrocarbons are still below the permissible levels in all elements of mangrove ecosystems allover the studied sites. The long-term exposure to sun light and high temperature leads to fast degradation of oil either in soil or water surface.

The present investigation is the first attempt dealt with the evolution of pollution rates by petroleum oil and its effect on mangrove communities in Egypt. The study concluded that petroleum hydrocarbons showed different patterns of distribution among the studied sites.

South Safaga (SI) was the most polluted site followed by SII and SIII, respectively. This may be due to that SI lies in vicinity of Safaga harbour where shipping terminals and lubrication processes take place.

There are horizontal variations in pollution levels in sediments and water. The most interesting point is the vertical variation in hydrocarbons distribution in the plant materials. The petroleum hydrocarbons were concentrated in the colloidal fine fractions (silt & clay) more than in coarse ones.

Although the pollution rates by petroleum hydrocarbons still below the world permissible levels in all elements of mangrove ecosystem (soil, water, plants) allover the studied sites, but with time lapse and the increasing of oil field exploration the pollution intensity may increased to serious levels bearing destructive injuries to the very important and economic mangroves. The results indicated that the oil residues were too small to penetrate and reach the absorption zones of root systems. The A suggestion could be raised here is that the mangrove plants are self-rhizoremediated. In Egypt, the Red Sea mangroves do not grow as luxuriously as most other tropical mangroves, i.e., they have an open-growth pattern leading to fast weathering and degradation of oil residues, if present, due to prolonged exposure to solar radiation allover the day. However, the above reasons deserve the priority for conservation of such economic ecosystems.

Apart from toxic effect of petroleum hydrocarbons on marine halophytes, results of field surveys are difficult to interpret because natural communities exhibit great spatial and temporal variability, rendering controls difficult to arrange.

T4

Controlled experiments on multispecies systems are preferable to field surveys, because the environmental variables and the distribution and amounts of the toxicant can be closely controlled and treatment can be replicated.

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تقييم معدلات التلوث بزيت البترول وأثر ذلك على مجتمعات المنجروف بساحل البحر الأحمر لمصر

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استهدفت الدراسة الحالية تقييم معدلات التلوث بزيت البترول وتأثيره على أحد أهم الأنواع النباتية الاقتصادية فى مصر وهو نبات الشورى *Avicennia marina* النامى طبيعيا بثلاث مواقع مختلفة على ساحل البحر الأحمر لجمهورية مصر العربية – الموقع الأول جنوب سفاجا ، الثانى وادى أبو حمرة والثالث شرم البحرى. تم تقدير الهيدروكربونات البترولية فى كل من التربة والمياه والنبات. كما تم تقدير قوام التربة المرافقة للنبات فى المواقع الثلاثة.

أوضحت الدراسة أن القوام الدقيق (الناعم) للتربة كان سائدا فى المواقع الثلاثة. تركزت الهيدروكربونات البترولية فى قوام التربة الناعم. كما أوضحت النتائج أن اكثر المواقع تلوثا بزيت البترول هو جنوب سفاجا. وقد كانت معدلات التلوث فى كل المواقع أقل من المسموح به دوليا. كما أوضحت النتائج أن أعلى تراكم لمحتوى الكربوهيدرات أمكن الحصول عليها فى قمة نبات الشورى فى المنطقة القريبة من البحر لموقع جنوب سفاجا مقارنة بالمواقع الأخرى . كما أمكن الحصول على أعلى نسبة من النتروجين الكلى فى قاعدة بنات الشورى فى المنطقة القريبة والبعيدة من البحر بموقع جنوب سفاجا، . كما أوضحت النتائج أن أعلى قيمة للكلوروفيل الكلى أمكن الحصول عليها فى قمة نبات الشورى فى المنطقة القريبة من البحر فى موقع الشرم البحرى, أمكن الحصول على أعلى قيمة من الليبيدات موقع الشرم البحرى الكلية من قاعدة النبات فى المنطقة البعيدة عن البحر فى موقع الشرم البحرى.

Table (2):Average plant height and total hydrocarbons in soil, water ad plat samples of mangrove sites at the Red Sea coast of Egypt.

Sites / Item's			SI Safaga						SII w-Abo-Hamra						SIII Sharm El-Bahrai					
			Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4
Total hydrocarbons	Soil mg\Kg		8.16	24.45	5.39	16.17	4.09	12.21	1.56	4.66	1.20	3.49	0.83	2.45	0.19	0.432	0.042	0.123	0.011	0.051
	Water mg\L		11.45						2.37						0.14					
	Plant mg\Kg	a	2.41		1.4		1.086		0.415		0.03		-		-		-		-	
		b	0.83		0.61		-		-		-		-		-		-		-	
		c	-		-		-		-		-		-		-		-		-	
Average plant height (m)			2.54						13.55						3.2					

a : basal portion of the plant **b: middle portion of the plant** **c: peaks portion of the plant**

Table (3): Hydrocarbons distribution in the different soil, of the mangrove sites, Red Sea coast of Egypt.

Sites / Hydrocarbon items	SI Safaga						SII w-Abo-Hamra						SIII Sharm El-Bahrai					
	A		B		C		A		B		C		A		B		C	
	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4	Φ_3	Φ_4
Naphthalene	0.19	0.57	0.13	0.38	0.11	0.29	0.04	0.11	0.03	0.08	0.02	0.06	0.01	0.015	0.001	0.004	ND	0.001
Aceaphthylene	0.49	1.46	0.32	0.97	0.24	0.73	0.1	0.28	0.07	0.21	0.05	0.14	0.01	0.028	0.003	0.008	ND	0.003
Acenaphthene	1.92	5.75	1.28	3.83	0.97	2.91	0.36	1.09	0.28	0.83	0.18	0.55	0.04	0.092	0.010	0.03	0.005	0.012
Fluorene	1.76	5.27	1.17	3.51	0.88	2.64	0.34	1.03	0.27	0.75	0.17	0.52	0.03	0.08	0.007	0.02	0.004	0.01
Phenanthrene	0.73	2.19	0.49	1.46	0.37	1.11	0.14	0.42	0.11	0.32	0.07	0.21	0.02	0.04	0.003	0.01	0.001	0.002
Anthrancene	0.38	1.14	0.25	0.76	0.19	0.57	0.07	0.22	0.05	0.16	0.04	0.11	0.01	0.018	0.002	0.005	ND	0.004
Flouranthee	0.55	1.64	0.36	1.09	0.27	0.82	0.10	0.31	0.08	0.23	0.07	0.20	0.01	0.03	0.003	0.009	ND	0.002
pyrene	0.24	0.72	0.16	0.48	0.12	0.36	0.05	0.14	0.03	0.10	0.02	0.07	0.01	0.018	0.002	0.005	ND	0.002
Benzo [a]anthrathene	0.25	0.76	0.17	0.51	0.13	0.38	0.05	0.15	0.04	0.12	0.03	0.08	0.01	0.02	0.002	0.006	ND	0.002
chrysene	0.19	0.57	0.13	0.38	0.11	0.29	0.04	0.11	0.03	0.08	0.02	0.06	0.01	0.015	0.001	0.004	ND	0.002
Benzo[b]fluranthene	0.53	1.59	0.35	1.06	0.27	0.80	0.10	0.30	0.08	0.23	0.07	0.20	0.01	0.03	0.003	0.009	0.001	0.004
Benzo[k]fluranthene	0.38	1.15	0.26	0.77	0.19	0.58	0.07	0.22	0.06	0.17	0.4	0.11	0.01	0.018	0.002	0.005	ND	0.002
Benzo[a]pyrene	0.55	1.64	0.32	0.97	0.24	0.73	0.10	0.28	0.07	0.21	0.05	0.14	0.01	0.028	0.003	0.008	ND	0.003

Table (4): Total carbohydrates, total nitrogen, total chlorophyll and total lipids of Avicennia Marina (Forssk) Vierh in different sites at the Red sea coast of Egypt

Sites / Items	SI									SII									SIII								
	A			B			C			A			B			C			A			B			C		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
Total carbohydrate	3.2	3.2	3.4	3.6	3.9	4.0	4.4	4.4	4.5	2.8	2.8	3	3.9	3.8	4.1	4.2	4.1	4.2	2.9	3.1	3.5	3.2	3.4	3.5	3.7	3.7	3.9
Total nitrogen	4.3	4.2	4.3	3.4	3.3	3.3	1.9	2.0	1.9	3.1	3	3.2	1.3	1.2	1.4	0.8	1	0.9	2.6	2.5	2.7	1.14	1.13	1.12	0.43	0.5	0.4
Total chlorophyll	8.2	7.9	8.5	8.1	8.0	8.5	8.3	8.2	8.4	8.4	7.9	9.1	8.3	8.7	8.6	8.4	8.4	8.6	8.3	8.5	9.2	8.4	9.1	9.3	8.5	9.2	9.4
Total lipids	2.6	2.4	2.6	2.4	2.5	2.3	2.0	2.1	2.1	2.2	2.2	2.3	1.8	2.0	2.1	1.8	1.9	2.0	2.8	2.1	2.3	2.5	2.6	2.4	2.6	2.4	2.7