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Distribution of PAHs in Water, Sediments Samples of Suez Canal During 2011

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Abstract

PAHs are important environmental pollutants because of their ubiquitous presence and carcinogenicity. Monitoring and survey of PAHs in the Suez Canal passage is of paramount required information to rejuvenating the preceding data to make a correlation between them and the present status of pollution. Samples of surface water and sediments were collected from Suez Canal which is divided regionally into three sectors (Port said, Ismailia and Suez sectors) during 2011, and by using Gas chromatographic analysis of Σ16 individual PAHs concentrations, giving the following results in whole surface water and sediments samples ranged from (11.71-499.59 ng/l) and (103.41-238.76 ng/g) respectively. The maximum concentration in water samples (499.59 ng/l) was achieved at the end of the canal at location XI during spring and the minimum concentration (11.71 ng/l) was achieved at location IV during spring. While, the minimum concentration in sediments samples 103.41 ng/g at location IX and the maximum concentration 238.76 ng/g at location III, with an average mean concentration 148.91 ± 6.65 ng/g d.w

Regionally, locations XII, II and VI recorded the highest annual mean values of PAHs in water samples. While locations III, V and XII recorded the highest values along Suez Canal in sediments samples.

According to annual mean, Ismailia sector recorded the highest sector with annual mean 179.12 ng/l. Whereas, Port Said sector recorded the lowest with annual mean of 117.43 ng/l in water samples. In which sectors (Port Said and Suez) recorded the highest mean concentrations in sediments samples reach to 181.38 and 139.77 ng/g respectively and (Ismailia Sector) recorded the lowest 125.58 ng/g.

It is noticed that the fluoranthene, benzo (a) anthracene, pyrene, indeno (1, 2, 3-cd) pyrene and benzo (k) fluoranthene were the most dominant PAHs in water samples. While, acenaphthylene and acenaphthene were the lowest fractions of PAHs. In conversely, pyrene is the most dominant fraction in sediment samples.

According to the present measurements and observations, it can be concluded that, the worst affected region in the canal was in the vicinity of Suez and Port Said Cities, due to the dense industrial activities and their waste disposal.

Keywords: Suez Canal; PAHs; Hydrocarbons; Seawater; Sediments

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Introduction

In recent years, contamination of surface water has become a major challenge to environmentalist and environmental issue in the rapid developing countries and oceanic ecosystems. The pollution means: the environmental damage caused by wastes discharged in the ecosystem, the occurrence of wastes in the ecosystem and finally the wastes themselves [1-3].

Suez Canal is an important navigational rout between east and west which is the most important man made waterway in the world and an open gate with slightly unbalanced water levels at the Red Sea and Mediterranean which is considered as a transitional zone that connects between two basically different basins, the Indo-pacific Red Sea basin and the Atlanto-Mediterranean basin which in turn influenced the fauna and flora. It minimizes the time for ships operating between both European and American ports and ports located in southern Asia, eastern Africa, and Oceania [4-8].

The canal located in Egypt between longitudes 32° 20/E and 32° 35/E and between latitudes 29° 55/N and 31° 15/N with an average 193 km which extending between north of Port Said and south of Port Tawfiq. At the northern part, the canal receives polluted brackish water from Lake Manzalah, which is the largest lake connected the Mediterranean Sea and Suez Canal [9]. The middle part is affected by polluted brackish water from Lake Timsah that attracts a large number of the holiday visitors, suffering from increasing pollution levels which are essentially caused by untreated domestic and industrial wastes [2]. Great and Little Bitter Lakes in the southern part (between km 97.5 at Defersoir and km 134.5 at Ginefa) considered as dynamic resources ecosystems [6, 7, 10-13].

The objectives of this work are to evaluate the levels of PAHs in water and sediments along the Suez Canal province using GC technique for the purpose of importance in assessing the sources and the extent of oil pollution in the region.

Materials and Methods

Sampling locations

Suez Canal was divided into 3 sectors, selected to represent a full coverage to the area under investigation. Four locations in each sector **(Figure 1).**

Sector A: (Port Said): I) Port Said, II) Port Fouad, III) El-Raswa and IV) El-Qantara

Sector B: (Ismailia): V) Temsah Lake, VI) EL-Defersoir, VII) Fayed and VIII) Fanara

Sector C: (Suez): IX) Kabrit, X) Shandora, XI) El-Maddya and XII) Port Tawfiq.

Surface water samples were collected seasonally and sediments collected once during of 2011 from 2012 locations adequately covering the different Canal's basin [14].

Water samples

1 L of water was acidified to pH 2 using 10% HCl to preserve against bacterial action during transportation using well-established techniques [15, 16]. The results were expressed in ng/l.

Sediments samples

10-20 g of dried samples and extracting in a Soxhlet-extractor with methylene chloride. The siphon cycle was around 20-30 min, repeating at least 10 times. As the extraction was completed, the methylene chloride was evaporated over the rotary evaporator to a volume of less than 20 ml. The extract was then transferred to a 25 ml volumetric flask. The Soxhlet extraction flask was rinsed with methylene chloride and the rinsing solution was used to make the volume up to 25 ml. The results were expressed in ng/g.

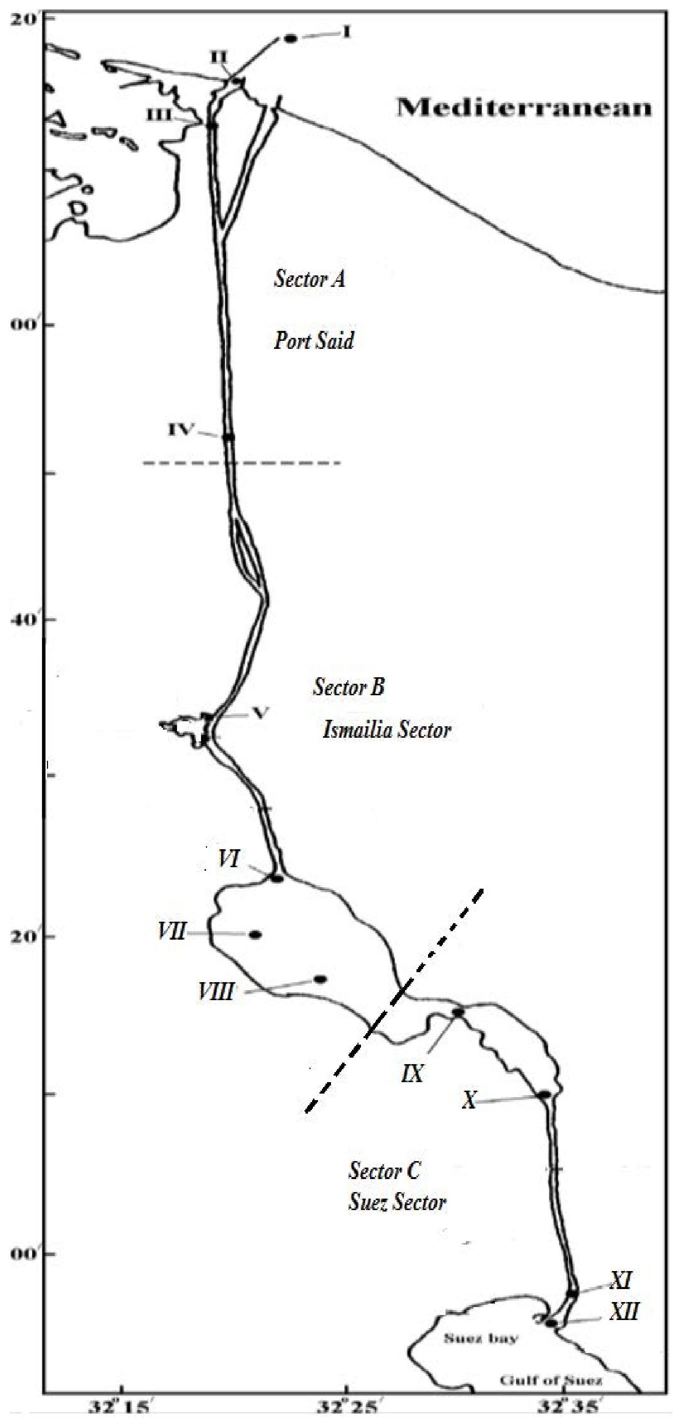

Figure 1 Sampling locations of the investigated area along the Suez Canal during 2011.
1- Port Said sector (I-Port Said, II-Port Fouad, III-El Raswa and IV-El Qantara)
2- Ismailia sector (V-Temsah Lake, VI-El Defersoir, VII-Fayed & VIII-Fanara)
3-Suez sector (IX-Kabriet, X-Shandora, XI-El Maadya and XII-Port Tawfiq)

Results and Discussion

1-Hydrocarbons in water samples

Total levels of Σ16 individual PAHs concentrations in whole surface waters ranged from (11.71-499.59 ng/l). The maximum concentration (499.59 ng/l) was recorded at the end of the canal in location XI during spring. In contrast, the minimum concentration (11.71 ng/l) was achieved at location IV during spring **(Table 1)**.

Regionally, locations XII, II and VI recorded the highest annual mean values of PAHs (235.30, 156.22 and 222.34 ng/l) at Suez, Port Said and Ismailia sectors respectively, this may be due to heavy shipment activities concentrated at Suez and Port Said Harbors and highest traffic density of oil tanker, oil refineries effluents results from petroleum companies and fisheries activities. Also, industrial wastes of electrical Power Station at Abu Sultan, agricultural lands and tourist villages [5, 17-21] **(Figure 2a).**

Seasonally, ΣPAHs in Suez Canal varied between (75.72-346.50), (11.71-499.59), (98.53-262.38) and (80.76-157.28) ng/l during winter, spring, summer and autumn, respectively **(Table 1)**. The highest seasonal average of PAHs (167.61 and 195.57 ng/l) was recorded during winter and spring respectively. While, the lowest concentrations were recorded during summer and fall during autumn. This is may be due to the concentration of PAH patterns differs according to the emission sources which increased in the end of the winter heating period, which is globally characterized by increased use of fossil fuels for heating and subsequent higher releases of PAHs to the environment. Also, may be due to spreading of pollutants due to climate conditions (wind, current and rain) [17, 22-25] **(Figure 2b).**

Table 1 Annual and seasonal variations of PAHs in water samples (ng/l) in the area of investigation during 2011.

Locations		Winter	Spring	Summer	Autumn	Mean ± SD
I	Port Said	75.72	50.06	126.76	92.33	86.22 ± 32.14
II	Port Fouad	105.83	285.87	130.44	102.75	156.22 ± 87.32
III	El-Raswa	109.97	127.45	130.44	157.28	131.29 ± 19.54
IV	El-Qantara	136.94	11.71	152.81	82.52	96.00 ± 63.74
Port Said Sector		107.12	118.77	135.11	108.72	117.43 ± 12.87
V	Lake Timsah	243.17	187.27	262.38	95.01	196.96 ± 75.06
VI	El-Defesoir	346.5	359.99	98.53	84.34	222.34 ± 151.37
VII	Fayed	203.03	194.27	98.85	80.76	144.23 ± 63.38
VIII	Fanara	320.08	62.23	134.04	95.54	152.97 ± 115.20
Ismailia Sector		278.2	200.94	148.45	88.91	179.12 ± 80.35
IX	Kabriet	88.36	71.43	109.65	91.46	90.23 ± 15.66
X	Shandora	107.7	72.92	120.52	113.04	103.55 ± 21.08
XI	El-maadya	99.67	499.59	127.37	119.89	211.63 ± 192.33
XII	Port Tawfiq	174.37	424.04	188.04	154.74	235.30 ± 126.57
Suez Sector		117.53	266.99	136.4	119.78	160.17 ± 71.71
Seasonal Average		167.61	195.57	139.99	105.81	

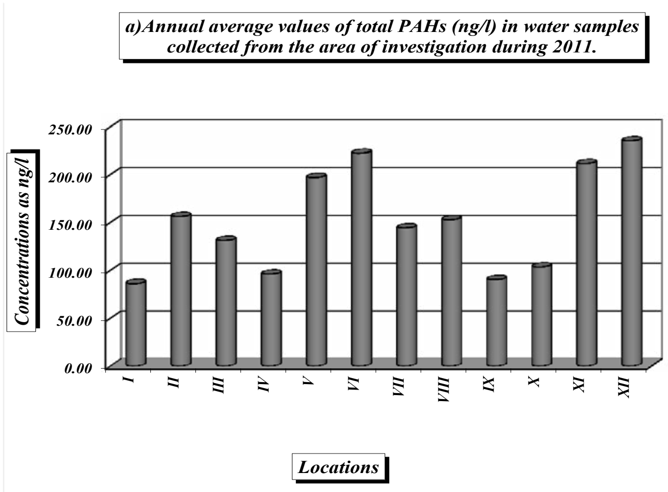

Figure 2a Annual average values of total PAHs (ng/l) in water samples collected from the area of investigation during 2011.

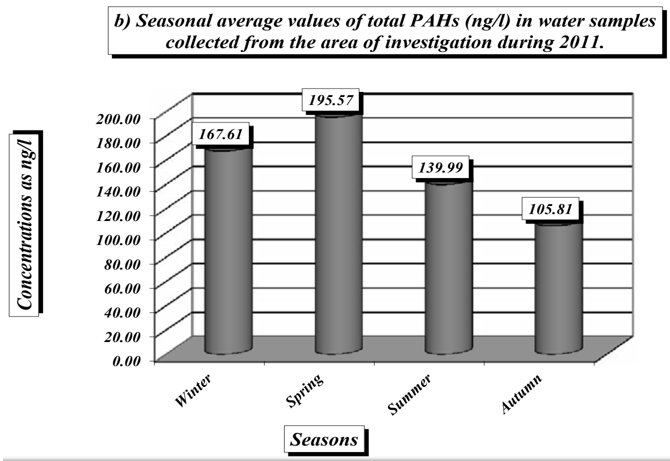

Figure 2b Seasonal average values of total PAHs (ng/l) in water samples collected from the area of investigation during 2011.

According to annual mean, Ismailia sector recorded the highest sector with annual mean 179.12 ng/l. Whereas, Port Said sector recorded the lowest with annual mean of 117.43 ng/l. This may be due to the presence of some potential polluters such as dry docks, ships and tankers passing through the Suez Canal, also due to the presence industrial wastes of electrical Power Station at Abu Sultan, agricultural lands and tourist villages [2, 25-27] **(Figure 2c).**

It is noticed that the fluoranthene, benzo (a) anthracene, pyrene, indeno (1, 2, 3-cd) pyrene and benzo (k) fluoranthene were the most dominant PAHs in most samples. While, acenaphthylene and acenaphthene were the lowest fractions of PAHs **(Table 2)**. These compounds are components of fossil fuels and a portion of them is associated with their combustion and usually emitted from catalyst and non-catalyst automobile and are often results from combustion of both diesel and natural gas [28] **(Figure 2d)**.

By sectors view

Ismailia sector recorded the highest total value followed by Suez sector and finally Port Said sector was the lowest sector. This may be due to Lake Timsah region is a semi-closed region reflecting domestic and/or agricultural activities [17] **(Figure 2e).**

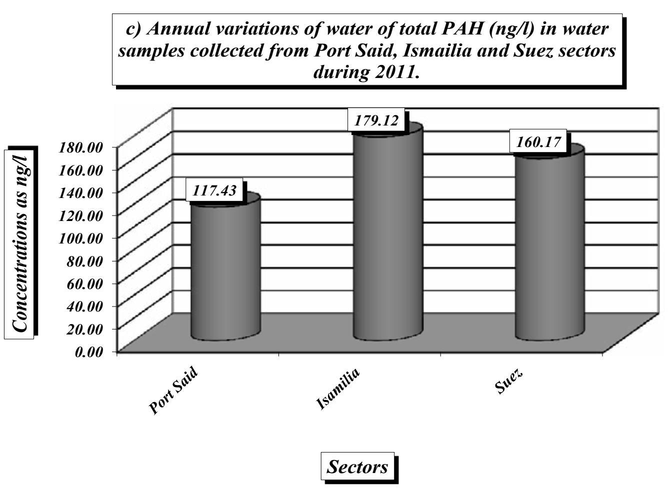

Figure 2c Annual variations of water of total PAH (ng/l) in water samples collected from Port Said, Ismailia and Suez sectors during 2011.

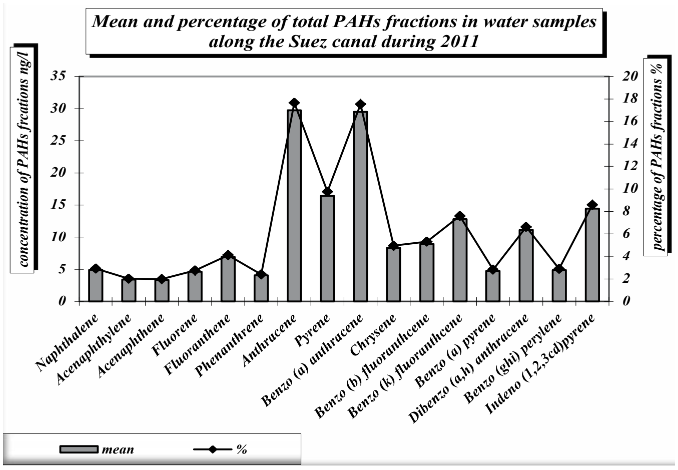

Figure 2d Mean and percentage% of PAHs fractions in water samples along Suez Canal during 2011.

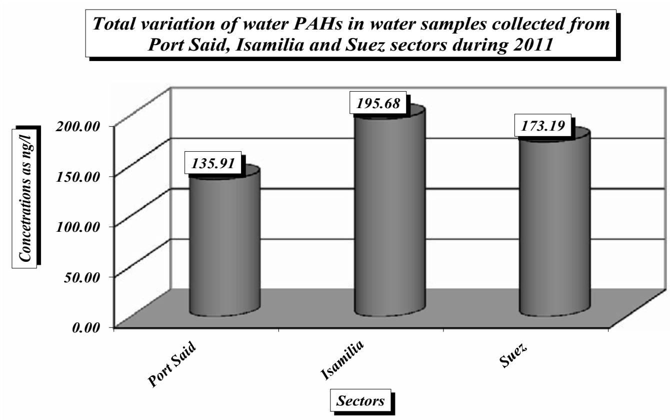

Figure 2e Total variation of water PAHs (ng/l) in water samples collected from Port Said, Ismailia and Suez sectors during 2011.

Table 2 Variations of total, fractions and % of LMW/HMW PAHs (ng/l) in water samples collected from Port Said, Ismailia and Suez sectors during 2011.

	Fractions	Port Said	Ismailia	Suez	Sectors mean ± SD	%
1	Naphthalene	4.38	4.60	5.74	4.91 ± 0.73	2.92
2	Acenaphthylene	4.16	3.35	2.73	3.41 ± 0.72	2.03
3	Acenaphthene	3.75	3.50	2.79	3.35 ± 0.50	1.99
4	Fluorene	4.07	4.98	4.85	4.63 ± 0.49	2.75
5	Anthracene	7.65	5.60	7.54	6.93 ± 1.15	4.12
6	Phenanthrene	4.63	4.10	3.45	4.06 ± 0.59	2.41
	ΣLMW	**28.65**	**26.14**	**27.09**	**27.29 ± 1.33**	
7	Fluoranthene	10.05	56.66	22.50	29.74 ± 24.13	17.67
8	Pyrene	14.57	18.23	16.47	16.42 ± 1.83	9.76
9	Benzo (a) anthracene	22.89	32.97	32.63	29.50 ± 5.72	17.53
10	Chrysene	6.46	9.70	8.82	8.33 ± 1.67	4.95
11	Benzo (b) fluoranthene	9.88	9.32	7.68	8.96 ± 1.14	5.32
12	Benzo (k) fluoranthene	13.56	14.23	10.58	12.79 ± 1.94	7.60
13	Benzo (a) pyrene	3.67	5.51	5.10	4.76 ± 0.97	2.83
14	Dibenzo (a,h) anthracene	8.41	8.40	16.61	11.14 ± 4.74	6.62
15	Benzo (ghi) perylene	4.18	3.84	6.64	4.89 ± 1.53	2.90
16	Indeno (1,2,3-cd) pyrene	13.59	10.70	19.06	14.45 ± 4.25	8.59
	Total mean	**135.91**	**195.68**	**173.19**	***168.26 ± 30.19***	**100.00**
	ΣHMW	**107.26**	**169.55**	**146.10**	**140.97 ± 9.00**	

2-Hydrocarbon in sediments samples

Total levels of Σ16 individual PAHs concentrations in sediments samples ranged from (103.41-238.76 ng/g). The maximum concentration (238.76 ng/g) was recorded at location III. In contrast, the minimum concentration (103.41 ng/g) was achieved at location IX **(Table 3)**.

Regionally, locations III, V and XII recorded the highest values along Suez Canal at Port Said, Ismailia and Suez sectors respectively during 2011.This may be related to heavy shipment activities concentrated at Port Said and Suez Harbors, highest traffic density of oil tanker and highly polluted area by sewage and agricultural drainage, brackish water from Lake Manzalah, Temsah Company, Osman workshop for repairing ships. In addition to ships passing through Canal and the surrounding drain out fall, covered drainage which indirect main point for sanitary waste water as well as industrial effluents [18-20, 25, 27-30] **(Figure 3a).**

Table 3 Variations of PAHs fractions (ng/g) in sediment samples collected from the area of investigation during 2011.

Fractions	Port Said sector				Ismailia sector				Suez sector				Mean	SD	%
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII			
Naphthalene	9.89	10.63	15.75	4.05	4.62	6.37	13.89	12.85	7.02	7.51	12.11	13.41	9.84	3.87	6.61
Acenaphthylene	5.58	4.98	5.45	3.22	2.51	3.13	3.87	1.67	1.65	2.12	2.77	4.34	3.44	1.40	2.31
Acenaphthene	6.65	5.72	4.89	1.66	1.67	1.85	3.13	4.17	2.39	3.13	3.34	3.34	3.50	1.60	2.35
Fluorene	9.79	15.92	7.59	0.84	2.48	2.95	4.17	1.56	1.37	0.92	2.77	5.55	4.66	4.50	3.13
Anthracene	6.50	9.70	7.41	3.87	6.46	3.84	6.46	5.55	3.34	3.78	6.26	14.70	6.49	3.17	4.36
Phenanthrene	11.28	10.35	8.13	3.78	11.33	3.69	9.25	7.11	4.88	5.54	6.37	9.25	7.58	2.76	5.09
Fluoranthene	22.47	15.81	15.71	9.25	22.01	13.69	16.92	9.08	11.37	12.20	13.13	19.79	15.12	4.54	10.15
Pyrene	32.29	34.04	52.00	16.00	39.13	16.46	16.92	16.66	9.05	33.12	37.19	46.54	29.12	13.76	19.55
Benzo (a) anthracene	16.66	15.84	19.05	12.20	15.70	9.25	12.91	7.29	26.46	9.25	7.50	14.30	13.87	5.48	9.31
chrysene	8.20	9.70	16.50	6.50	8.80	5.60	7.00	5.50	4.50	3.40	6.50	8.50	7.56	3.37	5.08
Benzo (b) fluoranthene	7.02	6.46	7.50	5.45	3.87	3.04	4.62	1.47	4.06	2.29	4.52	7.29	4.80	1.99	3.22
Benzo (k) fluoranthene	19.61	17.47	24.16	8.13	11.37	14.79	9.25	13.98	12.29	9.05	9.34	20.81	14.19	5.28	9.53
Benzo (a) pyrene	6.64	7.41	9.70	3.70	4.17	6.46	6.47	7.39	4.06	3.69	4.62	7.51	5.99	1.92	4.02
Dibenzo (a,h) anthracene	18.50	14.70	22.29	8.32	7.39	11.19	4.80	13.46	6.46	9.61	9.05	18.78	12.05	5.53	8.09
Benzo (ghi) perylene	4.74	5.81	13.03	1.67	1.30	6.78	1.85	8.96	3.13	3.99	4.71	8.32	5.36	3.48	3.60
Indeno (1,2,3-cd) pyrene	4.91	5.27	9.60	17.56	5.49	2.97	2.93	0.82	1.38	2.08	4.96	6.41	5.36	4.54	3.60
Total PAHs	**190.71**	**189.82**	**238.76**	**106.21**	**148.31**	**112.05**	**124.44**	**117.52**	**103.41**	**111.69**	**135.14**	**208.83**	**148.91**		**100.00**

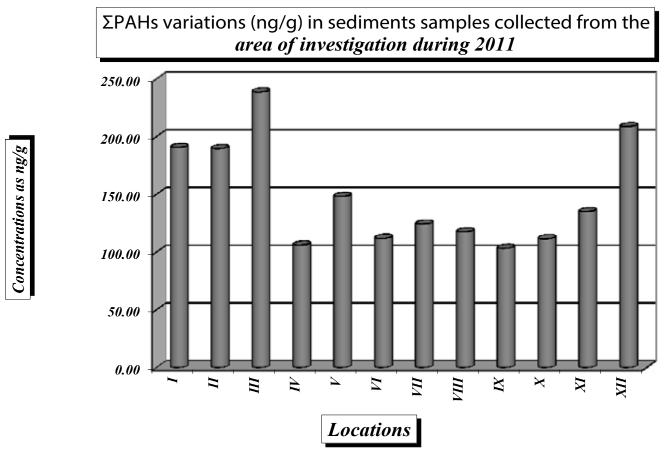

Figure 3a ΣPAHs variations (ng/g) in sediments samples collected from the area of investigation during 2011

By sectors view

It is clear from **Table 3** that Port Said and Suez sectors recorded the highest mean concentrations, while Ismailia sector recorded the lowest 125.58 ng/g. This may be due to heavy shipment activities, highest traffic density of oil tanker and higher consumption during maintenance in shipyard which concentrated at Port Said and Suez Harbor. In addition to different sources of oil pollutants, oil refineries effluents result from petroleum companies, industrial wastes resulting from power station, fertilizer companies and fisheries activities [18, 19] **(Figure 3b).**

It is noticed that according to ΣPAHs fraction pyrene is the most dominant fraction in sediment samples **(Table 3)**. The average mean concentration was 29.12 ng/g and its percentage 19.55% of total PAHs, the second dominant fraction is fluoranthene with average mean concentration 15.12 ng/g and its percentage 10.15% of total PAHs, the third abundant is benzo (k) fluoranthene with average mean concentration 14.19 ng/g and

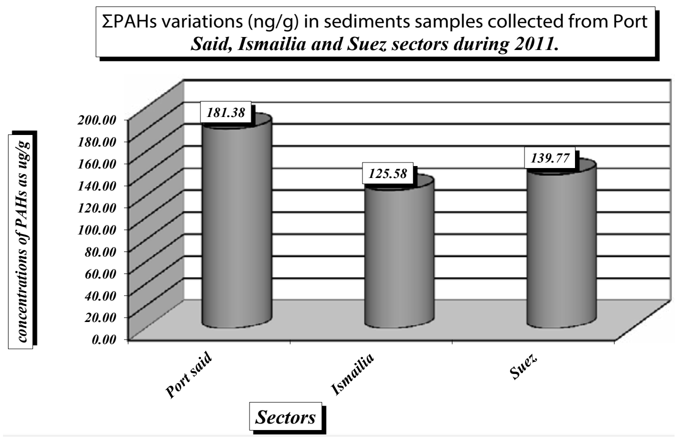

Figure 3b ΣPAHs variations (ng/g) in sediments samples collected from Port Said, Ismailia and Suez sectors during 2011.

its percentage 9.53% of the total PAHs, the fourth fraction was Benzo (a) anthracene with average mean concentration 13.87 ng/g and its percentage 9.31% of the total PAHs and the last most dominant fraction was dibenzo (a, h) anthracene with average mean concentration 12.05 ng/g and its percentage 8.09%. While, Acenaphthylene and Acenaphthene recorded the lowest **(Figure 3c)**.

Finally, variations of percent of LMW/HMW, ratio of fluoranthene/pyrene (FL/PY) and phenanthrene/anthrathene (PH/AN) had been used for different and identify the origin of hydrocarbons, typical markers for pyrolysis or incomplete combustion in Suez Canal water samples.

In which Σ6 LPAHs: Σ10 HPAHs ratio >1 often indicate PAHs with petrogenic origin predominate sources, while low (Σ LPAHs/ Σ HPAHs) ratio <1 suggest PAHs of pyrolytic origin. While, FLA and PY.

FL/PY ratio <1 suggested that the origin of PAHs was attributed to petrogenic inputs (petroleum), and values >1 were related to a pyrolytic origin (combustion sources).

Ratio of phenanthrene relative to anthrathene (PH/AN) (ratio) if >10 indicates that the source is petrogenic where petroleum often contains more phenanthrene than anthracene as phenanthrene is the most thermodynamically stable tricyclic aromatic isomer. Low PH/AN <10 indicates the major PAHs input were from combustion of fossil fuel [31, 32].

In the present, in water samples the ratio showed (Σ LPAHs/ Σ HPAHs) ratio <1 that means pyrolytic origin. The ratio of (FL/PY) at Port Said sector was (<1) at all locations suggested that the origin of PAHs was attributed to petrogenic inputs (petroleum) except location III during spring (>1) was related to a pyrolytic origin (combustion sources). While, at Ismailia sector the ratio of (FL/PY) was <1 at all locations suggested that the origin of PAHs was attributed to petrogenic inputs (petroleum) except locations

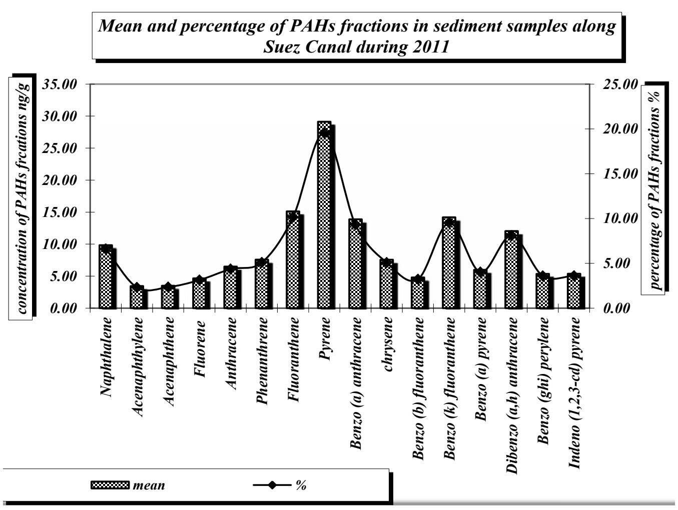

Figure 3c Mean and percentage % of PAHs fractions in sediment samples along Suez Canal area of investigation during 2011.

(VI and VIII) during winter, (V, VI and VIII) during spring (>1) were related to a pyrolytic origin (combustion sources). Suez sector the ratio of (FL/PY) was <1 at all locations suggested that the origin of PAHs was attributed to petrogenic inputs (petroleum) except locations (IX, X and XI) during winter and (X and XI) >1 were related to a pyrolytic origin (combustion sources) **(Table 4)**.

PH/AN <10 at all sectors which indicates that these are directly affected by the land based and sea based activities from combustion of fossil fuel [17, 22, 28, 33, 34] **(Table 4)**.

In the present study, the ratio in sediment samples showed (Σ LPAHs/Σ HPAHs) ratio <1 that means pyrolytic origin. The predominance of HMW-PAHs may be due to the fact that LMW-PAHs are preferentially degraded during PAH transport and burial into sediments [35] **(Table 5)**.

Large PH/AN ratio (>10) were ranged from (0.63-1.46) at locations (XII, IX and X) and (1.74 and 1.75) at locations (I and V) indicating that they were petrogenic. This ratio is agreed with that PH/AN (0.56-1.47) due to Urban runoff and (1.27-3.57) due to coke oven emissions **(Table 6)**.

(FL/PY) ratio in the present study ranged from (0.30-1.26) at locations (III and IX), less than 1 was attributed to petrogenic sources and values greater than 1 were obviously related to a pyrolytic origin. This ratio is agreed with that FL/PY (0.25-1.38) due to diesel exhausts particles, whereas 1.26 due to wood burning emission and diesel engine soot. Also, agreed with which said combustion of coal and wood gave FL/PY ratio of 1.4 and 1 respectively, while crude oil and fuel oil had values of 0.6-0.9 [28] **(Table 6)**.

The obtained results showed that the source could come from petroleum, combustion petroleum, and combustion mixture organic material. However, the main sources of the observed PAHs are considered to be petroleum and petroleum combustion [17, 22, 28, 33, 36, 37].

Conclusion and Recommendation

We concluded PAHs in Suez Canal were range more or less similar to the other neighboring studies **(Tables 7 and 8)**. In which changes related to variable environments. This may be due to the heavy oil tanker traffic along the shipping route, industrial discharge, refinery discharge, urban runoff, river discharges, ocean dumping and fishing vessels operating in the localized area.

The probabilities of sources of PAH at all locations are pyrogenic source represented by (Auto exhaust particles, Auto exhaust soot (gasoline), coke oven emission and urban runoff. But some locations as (I, III, VII, X and XI) showed probability of petrogenic sources represented by diesel fuel, crude oil and coal. Sector A and C petrogenic source was more existence than other sector B this is may be due to loading unloading operation of petroleum ships and Throw ballast water at Port said and Suez ports but less exist in sector B because there is a transit area for ships.

Our recommendation is to avoid as far as possible the discharge of oil spills, sewage and agriculture wastes into the waters of Suez Canal, especially at Manzalah, Temsah Lake and Bitter Lakes, which are considered a good source of fishes and tourist area for the people of canal cities.

Table 4 Ratio of PH/AN and FL/PY in water samples PAHs collected from Suez Canal during 2011.

	%	Winter				Spring				Summer				Autumn			
Port Said	PH/AN	0.83	0.61	0.24	0.32	0.94	0.80	1.90	--	0.46	0.46	0.39	0.33	0.85	0.82	1.01	1.06
	FL/PY	0.86	0.61	--	0.91	0.45	--	2.29	--	0.67	0.44	0.39	0.87	0.25	0.24	0.30	0.23
Ismailia	PH/AN	0.32	1.06	1.58	1.19	0.84	2.18	2.38	2.00	0.33	0.50	0.25	0.36	0.83	0.77	0.88	1.02
	FL/PY	0.48	13.30	0.86	6.22	1.90	57.44	4.58	--	0.40	0.41	0.73	0.95	0.17	0.25	0.38	0.32
Suez	PH/AN	0.51	0.21	0.32	0.27	1.02	1.06	1.75	1.51	0.22	0.13	0.12	0.25	0.70	0.51	0.52	0.85
	FL/PY	1.50	1.29	1.06	0.42	0.69	1.03	13.01	0.53	0.53	0.50	0.58	0.75	0.39	0.34	0.32	0.23

Table 5 The annual variations of % of LMW/HMW in Suez Canal sediment samples collected from Port Said, Ismailia and Suez sectors during 2011.

	Fractions	Port Said	Ismailia	Suez	Mean ± SD	%
1	Naphthalene	40.32	37.73	40.05	39.37	27.72
2	Acenaphthylene	19.23	11.19	10.88	13.77	9.70
3	Acenaphthene	18.92	10.83	12.20	13.98	9.84
4	Fluorene	34.14	11.16	10.61	18.64	13.12
5	Anthracene	27.49	22.31	28.08	25.96	18.28
6	Phenanthrene	33.54	31.38	26.05	30.32	21.35
	ΣLMW	**173.63**	**124.59**	**127.86**	**142.03 ± 10.13**	
7	Fluoranthene	63.24	61.70	56.49	60.48	13.33
8	Pyrene	134.33	89.17	125.90	116.47	25.68
9	Benzo (a) anthracene	63.75	45.15	57.51	55.47	12.23
10	Chrysene	40.90	26.90	22.90	30.23	6.66
11	Benzo (b) fluoranthene	26.43	13.00	18.16	19.20	4.23
12	Benzo (k) fluoranthene	69.37	49.39	51.49	56.75	12.51
13	Benzo (a) pyrene	27.45	24.50	19.87	23.94	5.28
14	Dibenzo (a,h) anthracene	63.81	36.84	43.90	48.18	10.62
15	Benzo (ghi) perylene	25.26	18.89	20.15	21.43	4.72
16	Indeno (1,2,3-cd) pyrene	37.34	12.21	14.82	21.46	4.73
	ΣHMW	**551.87**	**377.73**	**431.21**	**453.60 ± 29.89**	
	% of LMW/HMW	0.31	0.33	0.30	0.31	

Table 6 Ratio of PH/AN and FLY/PY in Suez Canal in sediment samples collected from Port Said, Ismailia and Suez during 2011.

	Port said sector				Average mean	Ismailia sector				Average mean	Suez sector				Average mean
	I	II	III	IV		V	VI	VII	VIII		IX	X	XI	XII	
% of PH/AN	1.74	1.07	1.10	0.98	1.22	1.75	0.96	1.43	1.28	1.41	1.46	1.46	1.02	0.63	0.93
% FLY/PY	0.70	0.46	0.30	0.58	0.47	0.56	0.83	1.00	0.55	0.69	1.26	0.37	0.35	0.43	0.45

Table 7 Comparison between levels of PAHs in water samples (ng/l) from different regions.

Locations	Range	References
Suez Canal	**86.22-235.30**	**Present Study, 2011**
Drainage Basin, Suez	64.79-2338412	**Ahmed et al., 2015 [21]**
Alexandria Sea	52811-559096	**Farid et al., 2013 [32]**
Timor Sea, Malaysia	54.46-213.70	**Falahudin et al., 2012 [37]**
Northern Part, Suez Gulf	26.40-1514	**Mostafa, 2011 [29]**
Kor River, Iran	29.14-157.80	**Kafilzadeh et al., 2011**
El Monofia	226.90-1492.20	**Nasr et al., 2010 [36]**
Bahia Balance Estuary, Argentina	ND-4000	**Arias et al., 2009 [24]**
Adriatic Sea, Gulf of Rijeka	ND-305	**Bihari et al., 2007**
Timsah and Bitter Lakes, Suez Canal	0.28-39.57	**Said and Al-Agroudy, 2006 [17]**
Gulf Suez	0.033-2.41	**Al-Agroudy et al., 2006**
LakeTimsah, Suez Canal	52.46-3393	**Ali et al., 2006**
Alexandria Coastal Area	113-952	**El Deeb and Emara, 2005**

Table 8 Comparison between levels of petroleum hydrocarbons in sediments (ng /g) in different regions of the marine environments.

Area	Site	Range	Mean	Analysis	References
Suez canal	Suez Canal	103.41-238.76	148.91	GC	**Present Study**
Persian Gulf	Persian Gulf	113.50-3384.34		HPLC	**Zaki et al., 2014 [3]**
Alexandria sea Coast		558.25-2924.27		HPLC	**Farid et al., 2013 [32]**
Bushehr Coastal Zone	Iran	844.90-4972.00			**Mahmoodi et al., 2012 [30]**
Northern Part	Gulf Suez	14.43-2268.6			**Mostafa, 2011 [29]**
Mediterranean coast		13.5-22600			**Barakat et al., 2011 [19]**
Orbetello, Central	Italy	0.92-279.38			**Perra et al., 2009**
Mediterranean coast		88-6338	154		**El- Nemr et al., 2007 [28]**
Adriatic Sea	Gulf of Rijeka	213-695			**Bihari et al., 2007**
Rodrigo de Freitas Lagoon		405-1173			**Stefens et al., 2007**
Suez Gulf		158-1043	234		**El Nemr et al., 2007 [28]**
Suez Canal	Temsah lake	585.9-8592.8		HPLC	**Ali et al., 2006**

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