

## Assessment of Polycyclic Aromatic Hydrocarbons Contamination in Water, Sediment and Fish of *Temsah* Lake, Suez Canal, Egypt

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### ABSTRACT

The nature, origin and distribution of the listed reference US Environmental Protection Agency (EPA) priority pollutants; 16 polycyclic aromatic hydrocarbons (PAHs) were investigated in water, sediment and fish of Temsah Lake (Suez Canal, Egypt) using high performance liquid chromatography (HPLC). The compositions of PAHs determined in all samples were measured in order to use them as chemical markers for identifying different sources of PAHs pollution in the studied region. Qualitative and quantitative distribution of PAHs detected in all investigated samples have followed no particular pattern, but rather irregular. Quantitative determination of PAHs show that their concentration ranged from 52.46–3393 $\mu\text{g/L}$ , 585.9–8592.8 $\mu\text{g/L}$  and 1696.4–4785.7 $\mu\text{g/L}$  for water, sediment and fish samples, respectively. Data show that these values are considered to be alarmingly high and the studied areas have values high enough to cause lethal toxicity effect to the surrounding environment and consequently to the human health. All samples are characterized by low concentration of low molecular weight PAHs compared to high molecular weight PAHs. Sediment and fish samples are characterized by relatively high concentration of six membered rings PAHs. The origin of PAHs in collected samples is either petrogenic, biogenic or mixed petrogenic and biogenic.

**Key words:** Polycyclic aromatic hydrocarbons; water, sediment, fish, pollution and Temsah Lake.

### INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are classified as environmentally hazardous organic compounds due to their known hydrophobic and mutagenic characteristics in addition to its toxicity and carcinogenicity (Hatch and Burton, 1999). PAHs are included in the European Community (EC) and US Environmental Protection Agency (EPA) priority pollutant list (Anayakora *et al.*, 2005). They are ubiquitous in the environment largely due to the extensive use of fossil fuels. Investigation of polycyclic aromatic hydrocarbons (PAHs) in the water bodies is a very important part of environmental quality assessment which

determines the status of contamination and the impacts it may cause to the ecosystem. Despite the limited water solubility of PAHs, it has been shown that contact of water with PAH-contaminated sediment can lead to tetragenicity and toxicity of the water. Contaminated sediment in surface waters also represents a continuing source of contamination in the aquatic food chain. The toxicity of PAHs to fish is of a particular interest since fish occupy an elemental position in relation to man and his food chain. Even minor concentration of many PAHs could be accentuated through fish, posing a potential threat to man, being at the top of the atrophic hierarchy (Samanta *et al.*, 2002 and Maskaoui *et al.*, 2002).

EPA currently regulates 16 PAH compounds as priority pollutants in water and generally considers these same compounds as "total PAHs" in

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contaminated soils and sediments (Liu *et al.*, 2001 and Moustafa<sup>a</sup>, 2004). These PAHs can be divided according to the number of rings into low and high molecular weights PAHs. The low molecular weight (L) PAHs consists of two and three aromatic rings which are 6 LPAHs. While the high molecular weight (H) PAHs consists of tetra-, penta- and hexa-aromatic rings, they are 10 HPAHs (Viguri *et al.*, 2002). The nomenclatures, chemical structure and abbreviations of the 16 PAHs according to number of rings are shown in Fig. (1).

PAHs contamination may result from either pyrogenic source (incomplete combustion of organic matter, emission sources and exhausts) or from the release of petroleum into the environment; petrogenic source (Moustafa<sup>a</sup>, 2004). After entering the environment, PAHs are widely dispersed by atmospheric transport or through stream pathways

and eventually accumulate in soil and aquatic sediments (Samanta *et al.*, 2002).

Temsah Lake, one of the water bodies that constitute the Bitter Lakes located North of Suez Canal is a land engulfed embayment with a total area of 15 km<sup>2</sup>. The lake is bounded by Ismailia. This lake is the main water body that supports fishing and tourism, employ a large number of local citizens and provide a significant portion of the district revenues. Temsah Lake is the main wet dock of the city, a small port that also supports a variety of marine works, including maintenance work of the Suez Canal Authority and its allied maritime works.

The quality of life, contamination level and its source in the lake has been a major concern for the local authorities for the last few years because

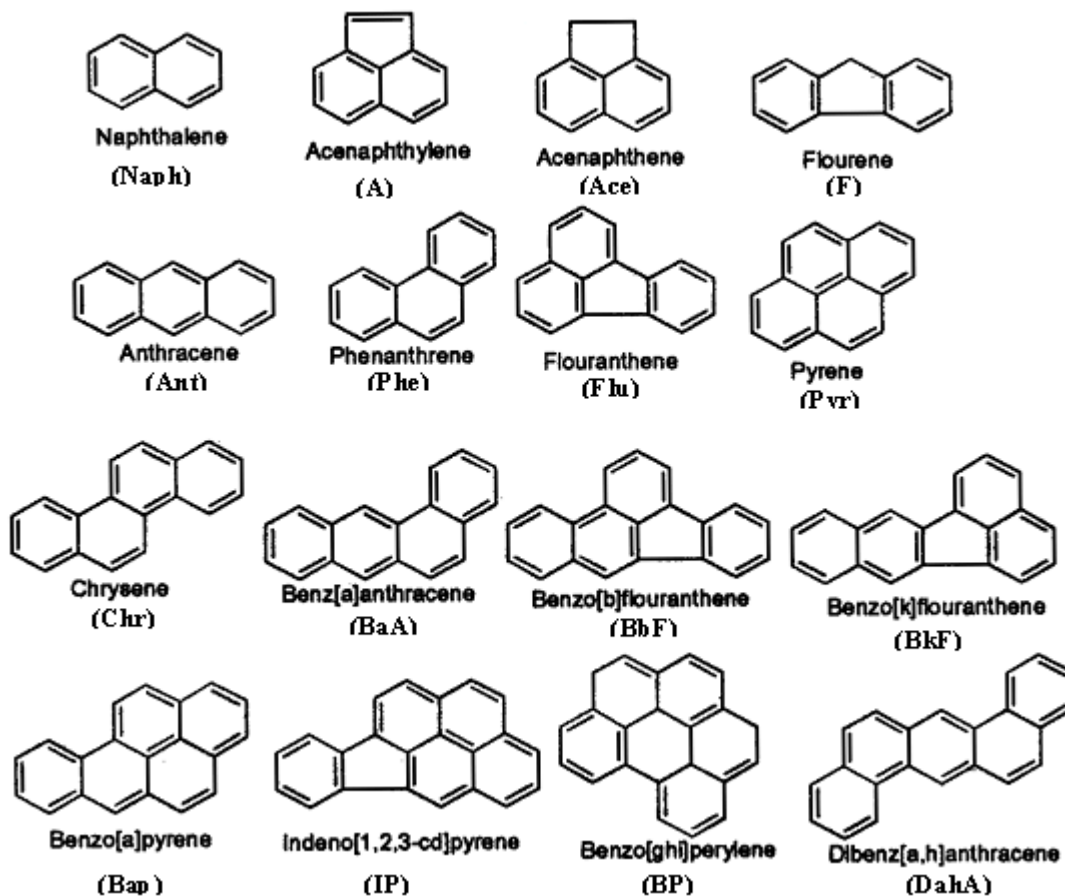


Fig. (1): The nomenclatures, chemical structure and abbreviations for 16 priority PAHs.

of the noticed sharp decline in the biodiversity and fish quality harvested from the lake (Tundo *et al.*, 2005).

Several reports have rerecorded the contamination level of a variety of pollutants in Temsah lake and its marine organisms, including dioxins (Tundo *et al.*, 2004 and 2005) chlorinated hydrocarbons, polychlorinated biphenyl and PAHs (Ahmed *et al.*, 2001 and Said and Agroudy, 2006). Temsah Lake is exposed to a variety of aliphatic and aromatic hydrocarbons that originate from shipping activities, ballasting water, maintenance and maritime works in the several clocks around (Tundo *et al.*, 2005).

There is still a lack of information in the levels and distribution of PAHs in Temsah Lake

sediment and four fish samples were collected from different sites all over the Temsah Lake in August 2005 for this study. The names and geographic locations of these sites are represented in table (1) and Fig. (2).

**Samples Collection**

Surface water samples were collected using narrow neck borosilicate glass bottles with Teflon lined caps. The samples were acidified to pH2 using 10% HCl to preserve them against bacterial action during transportation and storage. Surface sediment (0-2cm) samples were collected using a Van Veen grab sampler. Sediments from individual stations were well mixed and stored at refrigerator in pre-cleaned jars until analysis (Readman *et al.*, 2002). Fish samples were collected from different sites to represent various zones of territorial water, wrapped in clean

**Table - 1: Sampling sites**

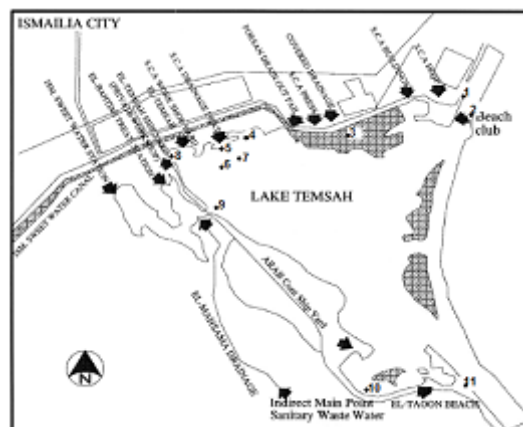
Sites	Type of sample		
	Water	Sediment	Fish
1	W1	S1	F1
2	W2	Rock area	Not represented
3	W3	S3	F3
4	W4	S4	Not represented
5	W5	Rock area	Not represented
6	W6	Rock area	Not represented
7	W7	S7	Not represented
8	W8	S8	Not represented
9	W9	S9	F9
10	W10	S10	Not represented
11	W11	S11	F11

water, sediment and fish. The purpose of the present work is to survey the major sources of PAHs and identify its levels in addition to the distribution of individual PAHs in order to establish an up to date PAHs environmental monitoring to be useful as a reference for future studies and conservation programs about contamination levels in Temsah Lake.

**MATERIAL AND METHODS**

**Samples Locations**

Eleven surface water, eight surface



**Fig. -2: Temsah Lake map and sampling sites**

aluminum foil and then they were frozen at -20°C until analysis.

**Extraction of oil  
Water samples**

Oil was extracted from water samples using carbon tetrachloride (CCl<sub>4</sub>) according to the method described by Moustafa<sup>a</sup>, (2004). The TPH concentration in the extract was determined gravimetrically (El-Tokhi and Moustafa, 2001).

**Sediment samples**

Sediment dry mass (dm) was determined from

the weight loss after heat treatment (20h at 105°C) (Margesin *et al.*, 2003). Extraction of dried sediment sample in a soxhlet extractor apparatus using a mixture of n-hexane and dichloromethane (1:1 v/v) was done (Viguri *et al.*, 2002). The TPH concentration in the extract was determined gravimetrically (El-Tokhi and Moustafa, 2001).

### Fish samples

Fish samples were thawed before gills, muscles and skins were cut down into small pieces, each sub-sample was ground in a pestle and mortar with 2 g anhydrous sodium sulphate. The cake was then extracted with 60 ml mixture hexane/dichloromethane (1:1) v/v. The mixture was filtered and the tissue was extracted twice more. Organic solvent fractions were combined and filtered through filter paper with 2g anhydrous sodium sulphate. The extract was then reduced to about 2 ml using a rotary evaporator.

Saponification; The concentrated fish extract (2 ml) was transferred to a round-bottom flask and 100 ml aqueous methanolic KOH was added. The mixture was refluxed for 3h.

Saponified material was transferred to a separating funnel. The round-bottom flask was quantitatively rinsed with 150-200 ml mixture of methanol-distilled water 4:1 v/v. The mixture was transferred to a separating funnel and 100ml of n-

hexane was added and then funnel shaken for 3min. Layers were allowed to separate and then organic layer was collected in another beaker. The extraction of the aqueous layer was repeated with 50ml n-hexane and layers were allowed to separate and the aqueous layer discarded. Organic layers were collected and carefully evaporated in a rotary evaporator to about 1ml. (Meddleditch *et al.*, 1977).

### High Performance Liquid Chromatographic analysis

PAHs identification and quantification in the extracted oil of all samples was performed using HPLC model Waters 600E equipped with auto sampler Waters 717 plus and dual wavelength absorbance detector Waters 2487 set at 254 nm. PAHs standards were obtained from Supelco. The condition of operation is as follows (Lai *et al.*, 1996): Column: Supelcosil LC-PAH, 15 cm x 4.6mm ID, 5 µm particles size.

Mobile phase: Acetonitrile/water HPLC grades, gradient from 50:50 to 100% acetonitrile.

Flow rate: Gradient program; 0-2min, 0.2 ml/min then 2-45min, 1.0 ml/min.

## RESULTS AND DISCUSSION

The distribution and separation of individual PAHs of the reference 16 PAHs listed by the US EPA (Ke *et al.*, 2002) using HPLC is shown in fig. (3).

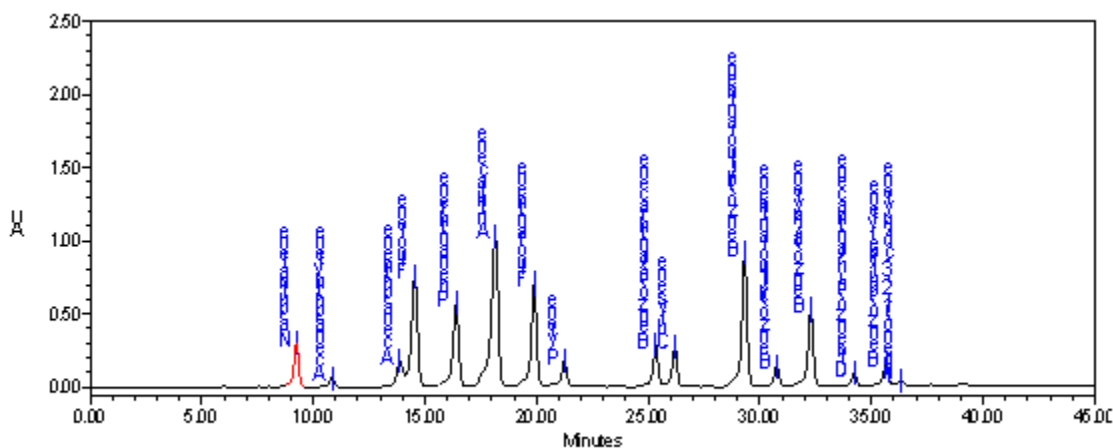
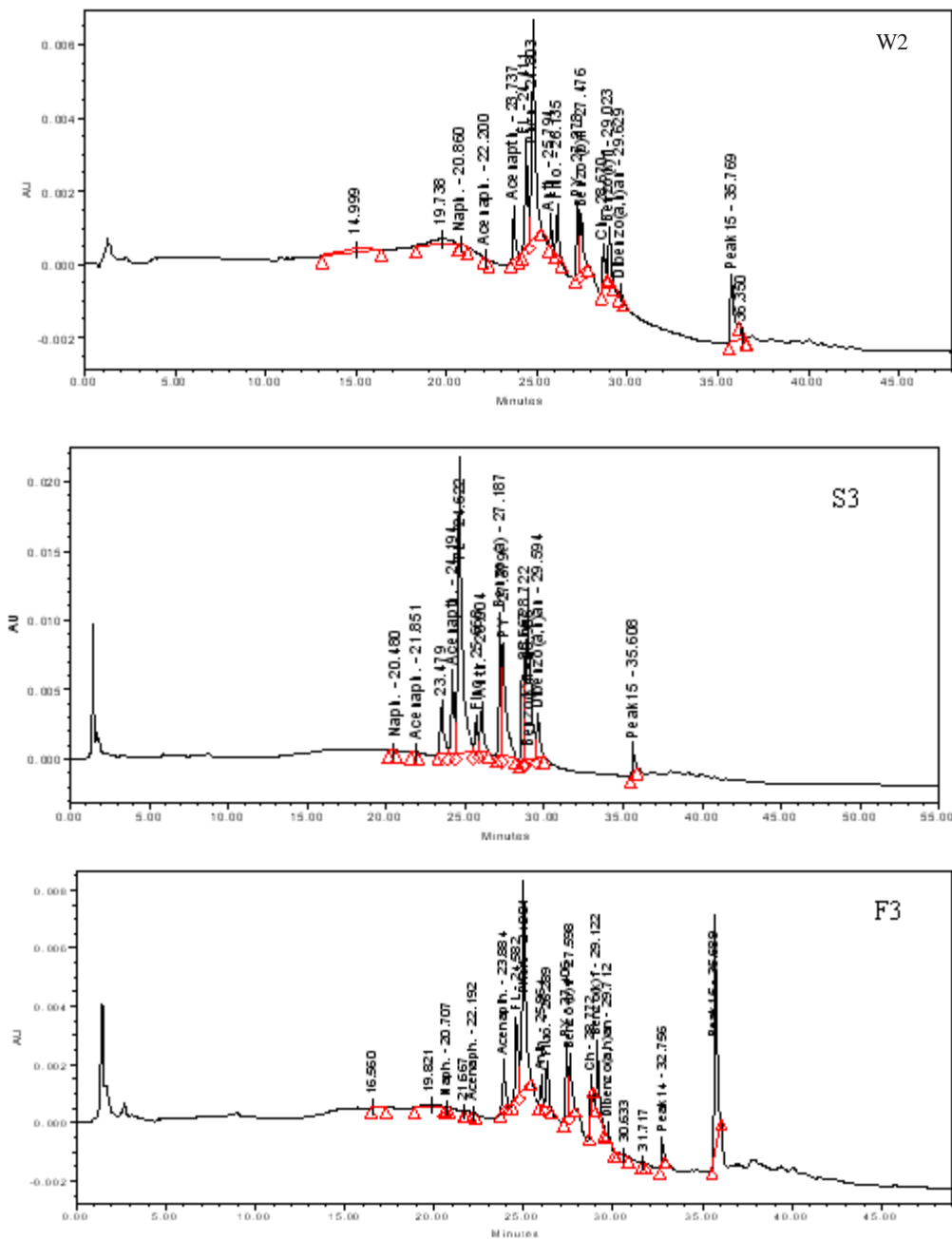


Fig. - 3: The distribution of individual PAHs of the reference 16 PAHs as listed by the US-EPA using HPLC

Qualitative and quantitative estimation of the individual PAHs for the extracted oils from water, sediment and fish samples of Temsah Lake were done and representative model samples are shown in fig. (4).

Careful examination of the HPLC chromatograms show that, each sample has its own distribution pattern and all have most of the target compounds. The brief identification of the present PAHs as shown in tables (2, 3 and 4) reveal the



**Fig. (4): Representative HPLC chromatograms of the PAHs in oil extracted from; water, sediment and fish samples of Temsah Lake**

presence of both LPAHs and HPAHs. Generally in all the water, sediment and fish samples there is a higher concentration of HPAHs compared to that of LPAHs. It is well known that the most important anthropogenic sources of PAHs are petrogenic and Pyrolytic, the latter type is usually prevalent in aquatic environments (Zakaria *et al.*, 2002 and Stout *et al.*, 2004).

Some molecular indexes play a major role in establishing the origin of PAHs, in particular; the

ratios between low and high molecular weight PAHs (Magi *et al.*, 2002), or the ratio of some isomers; e.g. phenanthrene/anthracene and flourantherene/Pyrene. They were chosen according to their thermodynamic stability (Tolosa *et al.*, 2004), among the three-ring isomers; Phen. is thermodynamically more stable and its prevalence over Ant. supports petrogenesis. Indeed, petroleum usually exhibits a quite high Phen/Ant ratio, among the four-ring isomers; Flu. is thermodynamically less stable than Pyr. Flu/Pyr>1; indicates Pyrolytic and

**Table (2-a): Individual PAHs distribution and their concentrations ( $\mu\text{g/l}$ ) in water samples**

Ring No.	PAHs	Water samples										
		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
2	Naph	1.3	1.1	0.66	3.3	11	5.12	7	0.34	29.7	93	123
	<b>Total</b>	<b>1.3</b>	<b>1.1</b>	<b>0.66</b>	<b>3.3</b>	<b>11</b>	<b>5.12</b>	<b>7</b>	<b>0.34</b>	<b>29.7</b>	<b>93</b>	<b>123</b>
	A	0.22	0.76	4	26.7	1.02	5.1	7.7	2	1.1	0	0
	Ace	0.084	3.9	16.8	0	0	0.21	0	0	2.9	0.08	0
	F	3.9	18.6	46.2	3.1	0	0	0	0	14	0	0
3	Phe	2	9.3	23.8	2.2	0	0	0.402	0.34	4.9	0.41	0.42
	Ant	57	8	14.5	0	0.44	3.3	0	2.6	4.2	0	0
	<b>Total</b>	<b>63.204</b>	<b>40.56</b>	<b>105.3</b>	<b>32</b>	<b>1.46</b>	<b>8.61</b>	<b>8.102</b>	<b>2.94</b>	<b>27.1</b>	<b>0.49</b>	<b>0.42</b>
	Flu	3.4	5.4	19.1	1.07	2.9	2.7	3.3	0	2.7	2.7	2
	Pyr	0.36	19.5	15.2	0	0	0.016	0	0	8.9	0	0
4	BaA	5.1	0	2.8	2.2	8	0.011	6.6	5.7	2	4.1	2.4
	Chr	0.018	6.2	0	5	0	0	0	0	0.53	0	0
	<b>Total</b>	<b>8.878</b>	<b>31.1</b>	<b>37.1</b>	<b>8.27</b>	<b>10.9</b>	<b>2.727</b>	<b>9.9</b>	<b>5.7</b>	<b>14.13</b>	<b>6.8</b>	<b>4.4</b>
	BbF	8.7	8.7	5.1	4.6	0	4.5	0	0	4.6	0	0
	BkF	3.9	1.5	1.8	0	0	4.5	0	0	1.02	0	0
5	BaP	-	-	-	-	-	-	-	-	-	-	-
	DahA	15.8	1.3	0	0.59	0	0.037	0	1.9	0.54	0.187	0.109
	<b>Total</b>	<b>28.4</b>	<b>11.5</b>	<b>6.9</b>	<b>5.19</b>	<b>0</b>	<b>9.03</b>	<b>0</b>	<b>1.9</b>	<b>6.16</b>	<b>0.187</b>	<b>0.109</b>
	BP	93.11	0	0	0	1430.3	11.75	404.3	0	77.29	50.85	1.58
6	IP	2960.8	3308.9	501	3083.5	584.6	15.22	1064	764.87	1493.6	388.4	909.5
	<b>Total</b>	<b>3053.9</b>	<b>3308.9</b>	<b>501</b>	<b>3083.5</b>	<b>2015</b>	<b>26.97</b>	<b>1468.3</b>	<b>764.87</b>	<b>1570.9</b>	<b>439.3</b>	<b>911.12</b>
	Total PAHs	3155.7	3393	650.98	3132.3	2038.4	52.46	1493.3	777.75	1648	539.77	1039

**Table (2-b): PAHs parameters used to distinguish petrogenic from pyrogenic origin of PAHs**

Parameters	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11
Phe/Ant	0.035	1.163	1.64	$\infty$	0	0	$\infty$	0.13	1.16	$\infty$	$\infty$
Flu/Pyr	9.44	0.28	1.26	$\infty$	$\infty$	168.8	$\infty$	0	0.3	$\infty$	$\infty$
$\Sigma$ LPAHs:											
$\Sigma$ HPAHs	1:48	1:80	1:5	1:88	1:163	1:3	1:98	1:236	1:28	1:5	1:7

Phen/Ant<1 indicates Pyrolytic origin and Phen/Ant >1 indicates petrogenic origin  
Flu/Pyr<1 indicates petrogenic origin and Flu/Pyr>1 indicates Pyrolytic origin

Flu/Pyr < 1 indicates petrogenic genesis of PAHs. Baumard<sup>a,b</sup> *et al.*, (1998) suggested that only the evaluation of both the ratios Phen/Ant and Flu/Pyr could prevent a misleading estimate of PAH sources. According to De Luca *et al.*, (2005); petrogenic contamination is characterized by the predominance of the LPAHs (with three and four fused rings), while the HPAHs prevail in Pyrolytic PAHs. But ratio of LPAHs : HPAHs is usually used as indices of weathering (Bernard *et al.*, 1996; Zakaria *et al.*, 2001; Moustafa<sup>b</sup>, 2004 and Hwang and Foster, 2006).

### Water samples

Qualitative and quantitative distribution of PAHs detected in water samples have followed no particular pattern, but were rather irregular. Their levels are high, ranging between 52.46-3393 µg/l which are alarmingly high. Generally the samples are characterized by high concentration of the six membered ring; Indeno(1,2,3-cd)Pyrene, ranging between 501-3308.9 µg/l except for sample W6 which is characterized by low concentration of IP of 15.22 µg/l. It can be observed also that water samples are generally characterized by low ratios of  $\Sigma$  6LPAHs :  $\Sigma$  10HPAHs, as shown in table (2-b) which might be presumably because of the relatively higher volatility of these LPAHs compounds which restrict their residence in water, especially in warm weather (Ahmed *et al.*, 1998 and Zakaria *et al.*, 2001).

This may also indicates high pyrogenic genesis of PAHs in Tamsah Lake (Magi *et al.*, 2002). Regarding to Phe/Ant ratio, samples W4, W7, W10 and W11 have values of infinity due to the absence of anthracene indicating purely petrogenic origin, In contrary; regarding to Flu/Pyr ratio of these four samples have the value of infinity which is due to the absence of Pyrene indicating purely petrogenic origin. This misleading in results may be due to weathering or the presence of both pyrogenic and petrogenic genesis of PAHs due to the different outlets of effluents discharged into the lake and the accessibility of Tamsah Lake to different sources of potential contaminates and pollutants. For samples W5 and W6 Phe/Ant ratio is zero due to the absence of Phe indicating purely pyrogenic origin, which is confirmed by the ratio of Flu/Pyr; which are infinity and 169 for W5 and W6, respectively. But, for

sample W1; Phe/Ant value is < 1 and Flu/Pyr > 1, indicating pyrogenic genesis of PAHs. For samples W2 and W9; Phe/Ant value > 1 and Flu/Pyr < 1, indicating petrogenic genesis of PAHs. For sample W3; Phe/Ant and Flu/Pyr values are close to one, indicating a mixture of petrogenic and pyrogenic origin of PAHs. On the other hand, sample W8 has a zero value for Flu/Pyr ratio and Phe/Ant value is close to zero, indicating also a mixture of petrogenic and pyrogenic genesis of PAHs. In conclusion, there are some discrepancies between the results obtained using the different parameters. The petrogenic genesis in Tamsah Lake may result from the presence of some potential pollutants such as dry docks and ships and tankers passing through the Suez Canal, also they may be due to the presence of dockyards and ship-maintenance works for example S.C.A. workshop yard Lake Tamsah, El-Tamsah Ship yard (private workshop) and Arab Cont. ship yard (Tamsah Lake map, fig., 2). The high pyrogenic genesis is probably the result of the massive discharge of industrial effluents into the lake (Tundo *et al.*, 2004) and the surrounding Forsain drain out fall, covered drainage and El-Mahmasa drainage, which is an indirect main point for sanitary waste water (Tamsah Lake map, fig., 2) (Tundo *et al.*, 2004).

### Sediment samples

Qualitative and quantitative distribution of PAHs detected in sediment samples have followed no particular pattern, but were rather irregular and their level are alarmingly high, ranging between 585.9-8592.8 µg/kg, the presence of such high concentrations are considered to be toxic (Moustafa<sup>b</sup>, 2004).

PAHs are contaminants of marine coastal sediments because of their hydrophobic character (water solubility between  $10^{-10}$  and  $10^{-13}$  mol/l) they are easily sorbed onto suspended particulate (Raoux *et al.*, 1999 and De Luca *et al.*, 2005). In this form they are more persistent to biodegradation in comparison to dissolved PAHs (Chiou *et al.*, 1998; Soclo *et al.*, 2000 and De Luca *et al.*, 2005). This explains why their concentration in sediments could be higher than that in the overlaying water column as in samples of S3, S8 and S9. Generally all the collected sediment samples are characterized by high concentrations of the six membered ring;

Indeno(1,2,3-cd)Pyrene, ranging between 408.5-8373.3 $\mu\text{g}/\text{kg}$ . Sample S3 has high concentration of Fluorene and Pyrene; 230 $\mu\text{g}/\text{kg}$  and 158 $\mu\text{g}/\text{kg}$ , respectively. Samples S8 and S9 are characterized by high concentration of Benzo[ghi]perylene; 700 $\mu\text{g}/\text{kg}$  and 185.99 $\mu\text{g}/\text{kg}$ , respectively. Generally all the collected sediment samples are characterized by low concentration of diaromatic ring compound; naphthalene except for sample  $\Sigma 11$  of concentration 137 $\mu\text{g}/\text{L}$  and also they are characterized by low concentration of triaromatic

ring compounds except for samples S3 and S10 of concentration; 321.5 $\mu\text{g}/\text{kg}$  and 130.3 $\mu\text{g}/\text{kg}$ , respectively. Weathering causes considerable changes in the chemical and physical properties of spilled oils as well as the PAHs (Zakaria *et al.*, 2001). Due to evaporation, dissolution and biodegradation, low molecular weights PAHs are thought to be selectively disappeared. As weathering increases the summation of the 6LPAHs decreased which makes the  $\Sigma 6\text{LPAHs} : \Sigma 10\text{HPAHs}$  parameter not useful to detect the origin. On the

**Table (3-a): Individual PAHs distribution and their concentrations ( $\mu\text{g}/\text{Kg}$ ) in sediment samples**

Ring No.	PAHs	Sediment samples							
		S1	S3	S4	S7	S8	S9	S10	S11
2	Naph	0.147	0.68	0.071	0.173	39	21	0	137
	Total	0.147	0.68	0.071	0.173	39	21	0	137
	A	0.4	3.2	0.099	0.039	0	0.023	59	0
	Ace	0.012	21.3	0.03	0.077	0	0	30	0
3	F	0.17	230	0.031	0	0.32	0	23	0
	Phe	0.02	0	0	0.4	0.18	0.37	9.3	0.81
	Ant	0.28	67	3.6	0	0	6.1	9	0
	Total	0.882	321.5	4.039	0.516	0.5	6.493	110.3	0.81
	Flu	0.74	12	0.18	0.49	2.3	0	0	0.9
	Pyr	0.23	158	0.046	0.001	0	0	29	0
4	BaA	0.062	41	0	0.019	6.3	6	26	6
	Chr	0.06	35	0.027	0.14	0	0	0	0
	Total	1.092	246	0.253	0.65	8.6	6	55	6.9
	BbF	0	0	2.8	0	0	0	16	0
	BkF	0.002	30	0.023	0.015	0	0	4.9	0
5	BaP	-	-	-	-	-	-	-	-
	DahA	0.018	36	0	0.009	0.01	0	0	0.18
	Total	0.02	66	2.8	0.024	0.01	0	20.9	0.18
	BP	4.06	0	0	0	700	185.99	0	32.54
6	IP	790.48	2109.6	927	792	2054.6	8373.3	4027.5	408.5
	Total	794.5	2109.6	927	792	2754.7	8559.3	4027.5	441
	TotalPAHs	796.6	2744.7	933.9	793.3	2802.8	8592.8	4233.7	585.9

**Table (3-b): PAHs parameters used to distinguish petrogenic from pyrogenic origin of PAHs**

Parameters	S1	S3	S4	S7	S8	S9	S10	S11
Phe/Ant	0.07	0	0	$\infty$	$\infty$	0.06	1.03	$\infty$
Flu/Pyr	3.22	0.076	3.91	490	$\infty$	0	0	$\infty$
$\Sigma\text{LPAHs}:\Sigma\text{HPAHs}$	1:773	1:8	1:226	1:1150	1:70	1:312	1:37	1:3

Phen/Ant<1 indicates Pyrolytic origin and Phen/Ant >1 indicates petrogenic origin  
Flu/Pyr<1 indicates petrogenic origin and Flu/Pyr>1 indicates Pyrolytic origin



other hand it could be useful in the comparison of the weathering effects on the samples (Zakaria *et al.*, 2001). Data obtained show low ratios of  $\Sigma 6\text{LPAHs} : \Sigma 10\text{HPAHs}$  as listed in table (3-b) indicating that all the sediment samples were subjected to weathering in different degrees. Based on this; weathering could explain the decrease of Naph concentration in all samples and also sample S11 could be considered as the least affected by weathering. Considering the different origins of PAHs; these sources induce a different chemical behavior in marine sediments; e.g. the interaction with sediments and resistance to biodegradation is higher for Pyrolytic than for petrogenic PAHs (Gustafsson *et al.*, 1997 and Wang *et al.*, 2006), this could explain the high concentration of the HPAHs in all the collected sediment samples compared to that of the LPAHs. Regarding to Phe/Ant ratio; samples S1 and S4 are  $< 1$  with Flu/Pyr  $> 1$ , indicating pyrogenic genesis of PAHs. But for samples; S3 and S9 Phe/Ant ratio is  $< 1$  with Flu/Pyr  $< 1$ , indicating a mixture of petrogenic and pyrogenic genesis of PAHs. For samples S7, S8 and S11; regarding to Phe/Ant ratio they have values of infinity due to the absence of anthracene indicating purely petrogenic origin, but in contrary; regarding to Flu/Pyr ratio of these samples S8 and S11 they also have the value of infinity which is due to the absence of Pyrene and for sample S7 Flu/Pyr ratio is 490; indicating purely petrogenic origin. This misleading in results may be due to weathering or the presence of both pyrogenic and petrogenic genesis of PAHs due to the different outlets of effluents discharged into the lake.

**Fish samples**

Qualitative and quantitative distribution of PAHs detected in fish samples have also followed no particular pattern, but were rather irregular. Various reports have pointed to such irregularity in PAHs detected in fish (Cocchieri *et al.*, 1990; Al-Yakoob *et al.*, 1993 and Ahmed *et al.*, 1998). Varanasi *et al.*, (1989) explained these irregularities in view of PAHs uptake by fish as well as levels and routes of exposure, environmental factors, salinity and differences in species, age and sex. Moreover, laboratory studies have been shown that the extraction and analytical methods used can overestimate or underestimate the concentrations in fish samples (May *et al.*, 1982 and Ahmed *et al.*,

1998). Generally, the concentration of PAHs in fish samples involved in this study is high, which could explain the decline of fish population in Tamsah Lake. Similar observations were listed by Ahmed *et al.*, 2001 and reported that high contamination level is the main cause behind the decline in the

**Table (4-a): Individual PAHs distribution and their concentrations ( $\mu\text{g/Kg}$ ) in Fish samples**

Ring No.	PAHs	Fish samples			
		F1	F3	F9	F11
2	Naph	0.04	1.1	1.5	1.5
	Total	0.04	1.1	1.5	1.5
	A	0.63	2.8	5.1	0.65
	Ace	4.4	17	2.9	5.1
3	F	18	53	18	19
	Phe	11.9	27	0	0
	Ant	10	31.2	13	11.2
	Total	44.93	131	39	35.95
	Flu	6.5	17	2.4	2.1
4	Pyr	27	36	9.3	11
	BaA	0	12.9	3.8	3.8
	Chr	3.5	11.8	2.8	0
	Total	37	77.7	18.3	16.9
	BbF	10	12.3	0	10
5	BkF	3.49	32	1.8	0.748
	BaP	-	-	-	-
	DahA	2.9	2	1.98	0
	Total	16.39	46.3	3.78	10.74
6	BP	1224.2	0	600.9	0
	IP	1013.9	2577.9	4122.2	1631.4
	Total	2238	2577.9	4723	1631.4
Tota					
IPAHS		2336.36	2834	4785.7	1696.4

**Table (4-b): PAHs parameters used to distinguish petrogenic from pyrogenic origin of PAHs**

Parameters	F1	F3	F9	F11
Phe/Ant	1.19	0.865	0	0
Flu/Pyr	0.24	0.47	0.26	0.19
$\Sigma\text{LPAHs}:\Sigma\text{HPAHs}$	1:51	1:20	1:117	1:44

Phen/Ant $<1$  indicates Pyrolytic origin and Phen/Ant  $>1$  indicates petrogenic origin  
 Flu/Pyr $<1$  indicates petrogenic origin and Flu/Pyr $>1$  indicates Pyrolytic origin

lake biodiversity and fish quality harvested from the lake. All of the collected fish samples are characterized by the presence of high concentration of the six membered ring compound Indeno(1,2,3-cd)Pyrene; ranging between 1013.9 $\mu\text{g}/\text{kg}$  and 4122.2 $\mu\text{g}/\text{kg}$ . Samples F1 and F9 are characterized by the presence of high concentration of the six membered ring compound Benzo[ghi]perylene; 1224.2 $\mu\text{g}/\text{kg}$  and 600.0 $\mu\text{g}/\text{kg}$ , respectively, but it is not found in samples F3 and F11. Regarding to Phen/Ant ratio, samples F1 and F3 have value close to 1 indicating a mixture of petrogenic and pyrogenic origin of the PAHs. The Flu/Pyr<1 indicates that the petrogenic genesis of PAHs are higher than that of pyrogenic one. But for samples F9 and F11; Phen/Ant ratio is zero due to the absence of Phen, indicating purely petrogenic origin this is confirmed by the Flu/Pyr ratio which is <1 this may be due to their proximity to a dockyard and a ship-maintenance works (Temsah Lake map, fig., 2) where oil and other contaminants spills are likely could be the reason for such high concentration of PAHs (Tundo *et al.*, 2004).

It can be observed also that fish samples are generally characterized by low ratios of

$\Sigma 6\text{LPAHs} : \Sigma 10\text{HPAHs}$ , as shown in table (4-b) which is considered as a very serious alarm for the sever toxicity of these ten HPAHs. Several PAHs are known to be potential human carcinogen; these include benz[a]anthracene, chrysene, benzo[b]flouranthene, benzo[a]pyrene and benzo[ghi]perylene (Guillen *et al.*, 2000 and Anyokora,2005). The health hazards posed by these compounds have been studied extensively by several authors (Perera *et al.*, 1988 and Schoket *et al.*, 1993). The presence of these compounds in the environmental samples (sediment, water and fish) has also been studied by numerous authors (Xu and Fang 1988 and Speer *et al.*, 1990).

### Conclusion

The qualitative and quantitative assessment of PAHs in water, sediments and fish samples of Temsah Lake indicated that they are highly affected by PAHs contamination which is problematic due to their propensity to initiate carcinogenic and or mutagenic effects in terrestrial as well as aquatic biota. These results contribute to better information of PAHs distribution, to a field validation, providing a technical basis to evaluate and pursue pollution abetments in Temsah Lake.

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