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Zainab A. Salem,
Abbas H. Mohammed,
Hamid T. Al-Saad

ORIGIN AND SOURCES OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHs) IN SEDIMENTS CORE FROM TIGRIS, EUPHRATES AND SHATT AL-ARAB RIVERS

Due to the important area of the Tigris, Euphrates and Shatt Al-Arab rivers in Iraq, and the effect of pollutant to theses rivers, the object of study is the origin and sources of PAHs compounds in sediment core samples which collected in 2021 from six important stations that are (Tigris1, Tigris2, Euphrates1, Euphrates2, Shatt Al-Arab1, and Shatt Al-Arab2). Polycyclic aromatic hydrocarbons (PAHs) were analyzes by using capillary gas chromatography. The results of PAHs shown in two pattern low and high molecular weight. The total PAHs ranged between 79.141 ng/g at station No. 6 to 3.830 ng/g at station No. 3. The rush to develop industries across the globe accelerates environmental damage brought on by many contaminants, including PAHs. Organic compounds in the PAHs class have two or more aromatic rings. PAHs can be pyrogenic, petrogenic, or biogenic depending on how they develop. Pyrogenic PAHs are produced when various fuels, oil and gas, waste, or other organic materials like fume from oil industries in the area. The investigation showed two patterns of sources petrogenic and pyrogenic with the petrogenic source predominating according to the ratios (low molecular weight/high molecular weight), anthracene/(anthracene+phenanthrene) and fluoranthene/(fluoranthene+pyrene). Additionally, findings indicated that sediment pollution is of a moderate pollution. By adhering to sedimentary particles, PAHs get into the sediments. Based on the physicochemical characteristics of each fraction and the surrounding environment, sediments also serve as a source for some contaminants that re-enter the water column. Lighter PAHs predominated in water samples, while heavier compounds predominated in sediment samples, according to several studies. In addition, it is difficult to remove the high concentrations of PAHs in riverine sediments brought on by industrial activity. While other research indicated significant PAHs pollution in a variety of global environments. Due to the fact that such research helps to lessen the obvious shortage of information regarding such pollutants in Iraqi rivers, this study gives as the baselines for coming research.

Keywords: *polycyclic aromatic hydrocarbons (PAHs), sediment pollution, Tigris, Euphrates, Shatt Al-Arab, gas chromatography.*

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1. Introduction

One of the major issues that have attracted a lot of attention globally is the contamination of sediment and aquatic environments with hydrocarbons. These compounds, which are derived from crude oil and products like diesel, gasoline, lubricating oil, and others, have been shown to be highly toxic, genotoxic, and carcinogenic in nature [1, 2]. One large class of chemical compounds, known as hydrocarbons, have carbon and hydrogen as its basic building blocks, along with a variety of heteroatoms like oxygen, nitrogen, chlorine, sulfur, and others. Aliphatic, alicyclic, and aromatic compounds are the three main classes that can be used to categorize the hydrocarbon molecules [3, 4].

There are two types of polycyclic hydrocarbons: low molecular and high molecular. Low molecular polycyclic hydrocarbons have two to three fused rings and are soluble in water and volatile, making them susceptible to degradation processes. High molecular polycyclic hydrocarbons have more than four fused rings and are less soluble, less volatile, and more lipophilic than low molecular polycyclic hydrocarbons [5].

After the confluence of the Euphrates and the Tigris Rivers, the Shatt Al-Arab River is formed near the city of Al-Qurna in southern Iraq [6]. The territory flowing to the Shatt Al-Arab region downstream of Al-Qurna is shared by Iran and Iraq. The Shatt Al-Arab River, which runs for 192 kilometers, widens along the way, from 250–300 meters near the Euphrates-Tigris confluence to about 700 meters around Basrah and more than 800 meters as it approaches the river mouth. A total of 145,190 km^2 of land flows directly into the Shatt Al-Arab region downstream of the Euphrates-Tigris confluence, excluding the Euphrates and Tigris Basins [7].

This rivers is the most important source of fresh water in Iraq, and influenced by freshwater discharges from agricultural runoff, industrial activities, and untreated domestic sewage.

Thus, *the object of study* is the origin and sources of PAHs (polycyclic aromatic hydrocarbons) compounds in sediment core samples which collected in 2021 from six important stations that are (Tigris1, Tigris2, Euphrates1, Euphrates2, Shatt Al-Arab1, and Shatt Al-Arab2).

2. Research methodology

Sediment cores pipe of (120 cm length and 5 cm diameter) were collected from six stations in 4 December 2021 which represent different sites of the Euphrates and Tigris Rivers and the Shatt Al-Arab River (Fig. 1) for analyzing and estimating the concentration of polycyclic aromatic hydrocarbons (PAHs) in these sediment core.

The cores were inserted into the water-sediment interface and pushed to ensure that they reached maximum depth. The cores were slowly retrieved back, closed with its cover immediately and marked as to which is the upward direction.

The samples were dried in an air grinded in an electrical stainless steel mortar and sieved. Through 63 μm sieve, 25 gm of sieved sediments were placed in cellulose thimble and soxhlet. Extracted using soxhlet intermittent extraction [8] with mixed solvents (120 ml) methanol:benzene (1:1 v/v) for 24–36 hrs. at temperature doesn't exceed 40 °C. At the end of this period, the combined extracts were saponification for 2 hrs. by adding (15 ml) 4M MeOH (KOH) at the same temperature, then cooled to room temperature, using separator funnel to extracted the un saponification matter with (40 ml) *n*-hexane. The upper un saponification matter with hexane was taking and passed through chromatographic column provided with glass wool at the bottom then a layer of silica gel and a layer of alumina, in the top, a layer of anhydrous sodium sulfate was placed to collect the aliphatic fraction, then 40 ml of benzene added to collect the aromatic fraction, analysis were done by using capillary gas chromatography.

3. Research results and discussion

At six stations, the total concentration of polycyclic aromatic hydrocarbons in sediment ranged from 79.141 ng/g at station No. 6 to 3.830 ng/g at station No. 3. The total averages of aromatic compounds concentrations in the regions were calculated in Table 1 and Fig. 2 and Fig. 3.

It is evident from Table 1 that the compounds of Naphthalene, 2_Methylnaphthalene, Acenaphthyene, Fluorene, Anthracene, Fluoranthene, Benz(a)anthracene are the lowest average for station No. 1 concentrations (Fig. 2). While the compounds of 1_Methylnaphthalene, Acenaphthnen, Phenanthrene, Pyrene, Chrysene, B(b)fluoronthene, B(k)fluoronthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene are the highest average for the same station. While in station No. 2, the compounds that recorded the lowest concentrations were B(k)fluoronthene, 2_Methylnaphthalene, 1_Methylnaphthalene. The compounds with the highest concentration in that station are Naphthalene, Acenaphthyene, Fluorene, Anthracene, Fluoranthene, Benz(a)anthracene, Acenaphthnen, Phenanthrene, Pyrene, Chrysene, B(b)fluoronthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene.

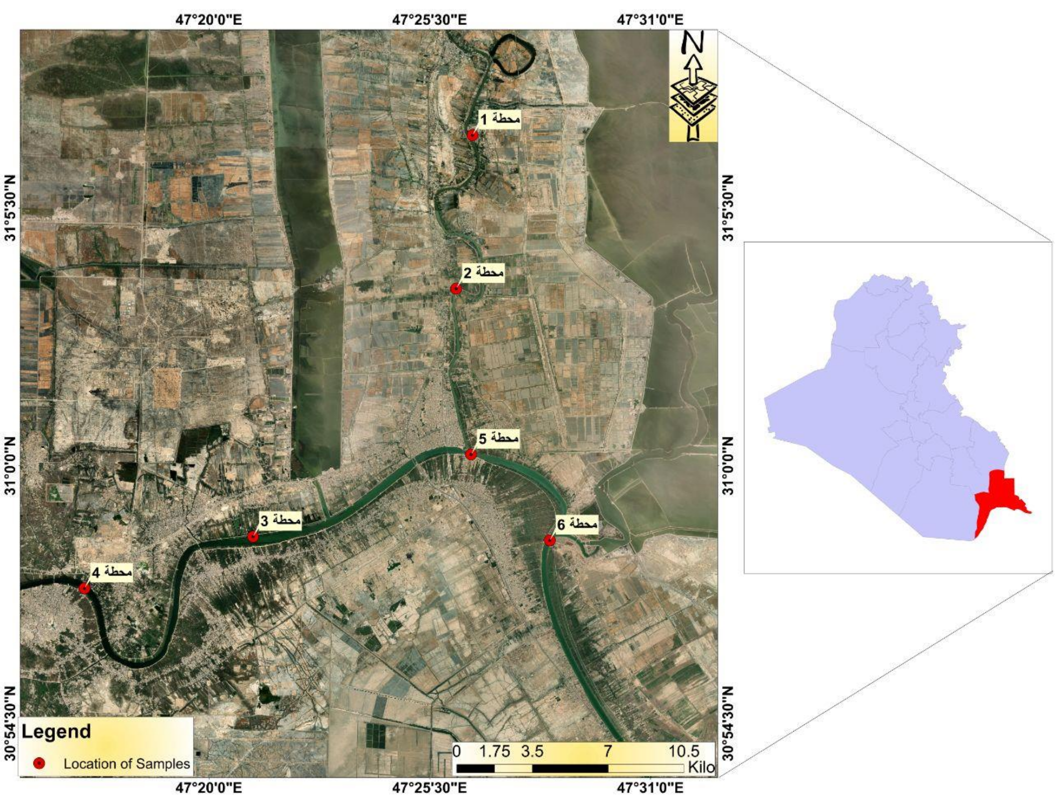

Fig. 1. Sampling locations

Table 1

Averages of the concentration values of aromatic compounds in the study areas

PAHs Compounds	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6
Naphthalene	0.392	0.105	0.127	0.431	1.719	2.163
2_Methylnaphthalene	0.312	0.149	0.171	0.409	2.326	1.045
1_Methylnaphthalene	1.264	0.264	0.145	0.251	2.514	1.602
Acenaphthyene	0.686	0.239	0.253	0.305	1.970	2.444
Acenaphthnen	1.131	0.355	0.324	0.226	1.801	2.091
Fluorene	0.961	0.278	0.257	0.423	2.288	3.753
Phenanthrene	6.185	0.307	0.329	0.307	0.918	3.495
Anthracene	0.773	0.335	0.505	0.499	2.370	2.16
Pyrene	2.162	1	0.534	0.719	6.911	2.646
Fluoranthene	0.680	0.122	0.283	0.565	1.083	3.645
Benz(a)anthracene	0.64	1.951	0.128	0.638	0.842	2.505
Chrysene	1.272	1.625	0.216	0.470	1.366	2.717
B(b)fluoronthene	1.481	6.947	2.913	5.761	2.357	4.357
B(k)fluoronthene	1	0.345	0.327	1.972	0.473	0.365
B(a)pyrene	2.020	3.895	2.251	0.448	1.475	2.518
Indeno(1,2,3-cd)pyrene	2.482	7.043	4.757	2.770	3.260	4.356
Benzo(g,h,i)perylene	2.432	3.815	0.639	1.302	5.134	5.936

Station No. 3 compounds with lowest average concentrations are Phenanthrene, Benz(a)anthracene, B(k)fluoronthene while the compounds with highest average concentrations are 2_Methylnaphthalene, 1_Methylnaphthalene, Naphthalene, Acenaphthyene, Fluorene, Anthracene, Acenaphthnen, Phenanthrene, Pyrene, Chrysene, B(b)fluoronthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene. The compounds of 2_Methylnaphthalene, 1_Methylnaphthalene, Naphthalene, Acenaphthyene, Fluorene, Anthracene, Fluoranthene, Acenaphthnen, Phenanthrene, Pyrene, Chrysene, Benzo(a)pyrene, Benz(a)anthracene are the lowest average for station No. 4 concentrations (Table 2).

While the compounds of B(b)fluoronthene, B(k)fluoronthene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene are the highest average for the same station. While in station No. 5, the compounds that recorded the lowest concentrations were 2_Methylnaphthalene, Fluorene, 1_Methylnaphthalene, Naphthalene, Acenaphthyene, Anthracene, Fluoranthene, Acenaphthnen, Phenanthrene, Pyrene, Chrysene, Benz(a)anthracene, B(k)fluoronthene, Benzo(g,h,i)perylene. The compounds with the highest concentration in that station B(b)fluoronthene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene. The compounds of Naphthalene, 2_Methylnaphthalene, 1_Methylnaphthalene, Acenaphthyene, Acenaphthnen, Fluorene, Phenanthrene, Anthracene, Pyrene, Fluoranthene, Benz(a)anthracene, Chrysene, B(k)fluoronthene are the lowest average for station No. 6. While the compounds of B(b)fluoronthene, Benzo(a)pyrene, Indeno(1,2,3-cd) pyrene, Benzo(g,h,i)perylene are the highest average for the same station. There are six indices that can be used to determine the origin sources of PAHs, as shown in Tables 2, 3.

In all stations, the source of PAHs was petrogenic, as shown by the first of them, Low Molecular Weight/High Molecular Weight – PAHs in the (Table 2). The source of PAHs was pyrogenic according to Anthracene (Anthracene+Phenanthrene) indices.

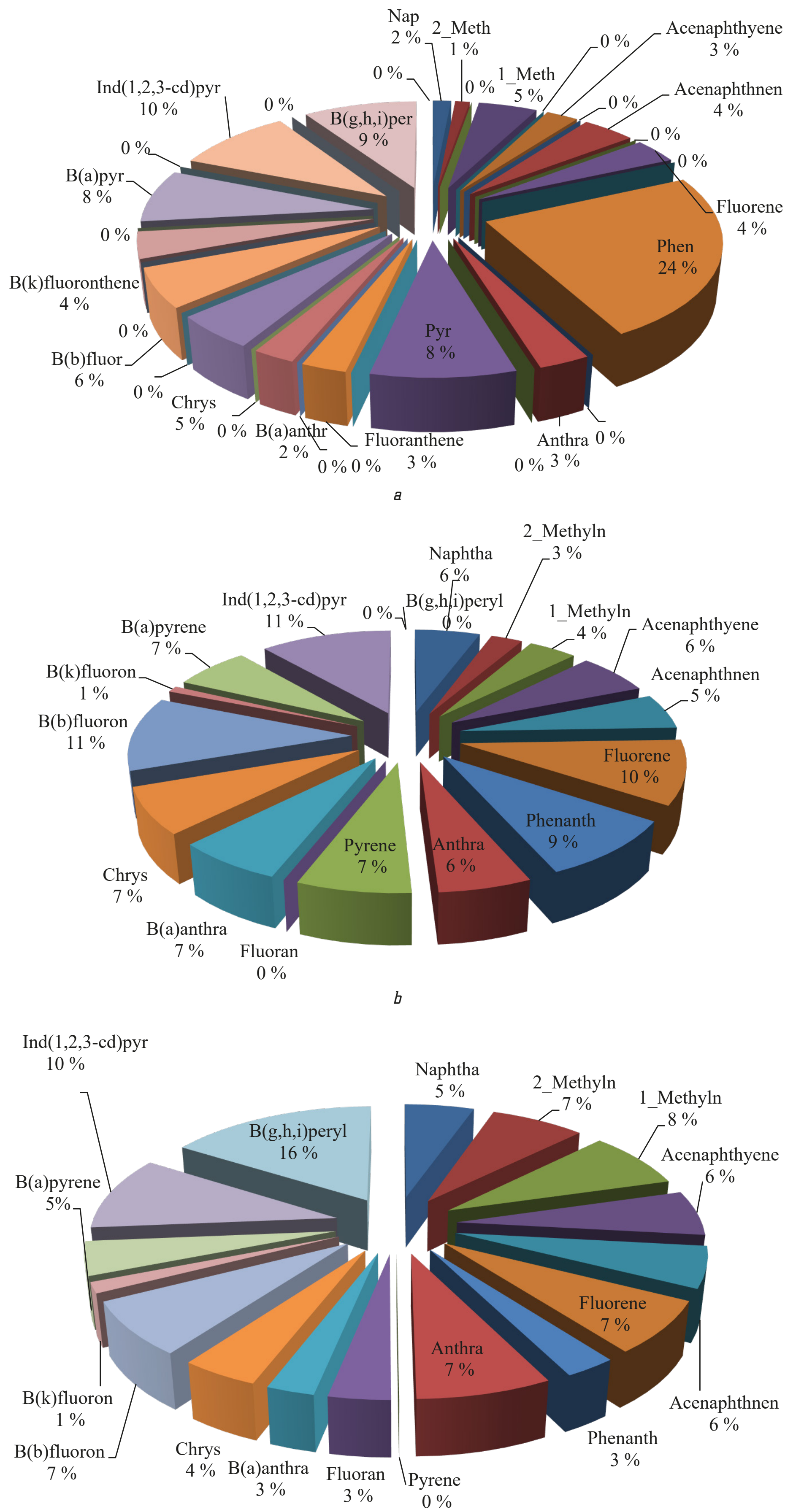

Fig. 2. Average concentrations of polycyclic aromatic compounds in the study areas: *a* – Station No. 1; *b* – Station No. 2; *c* – Station No. 3

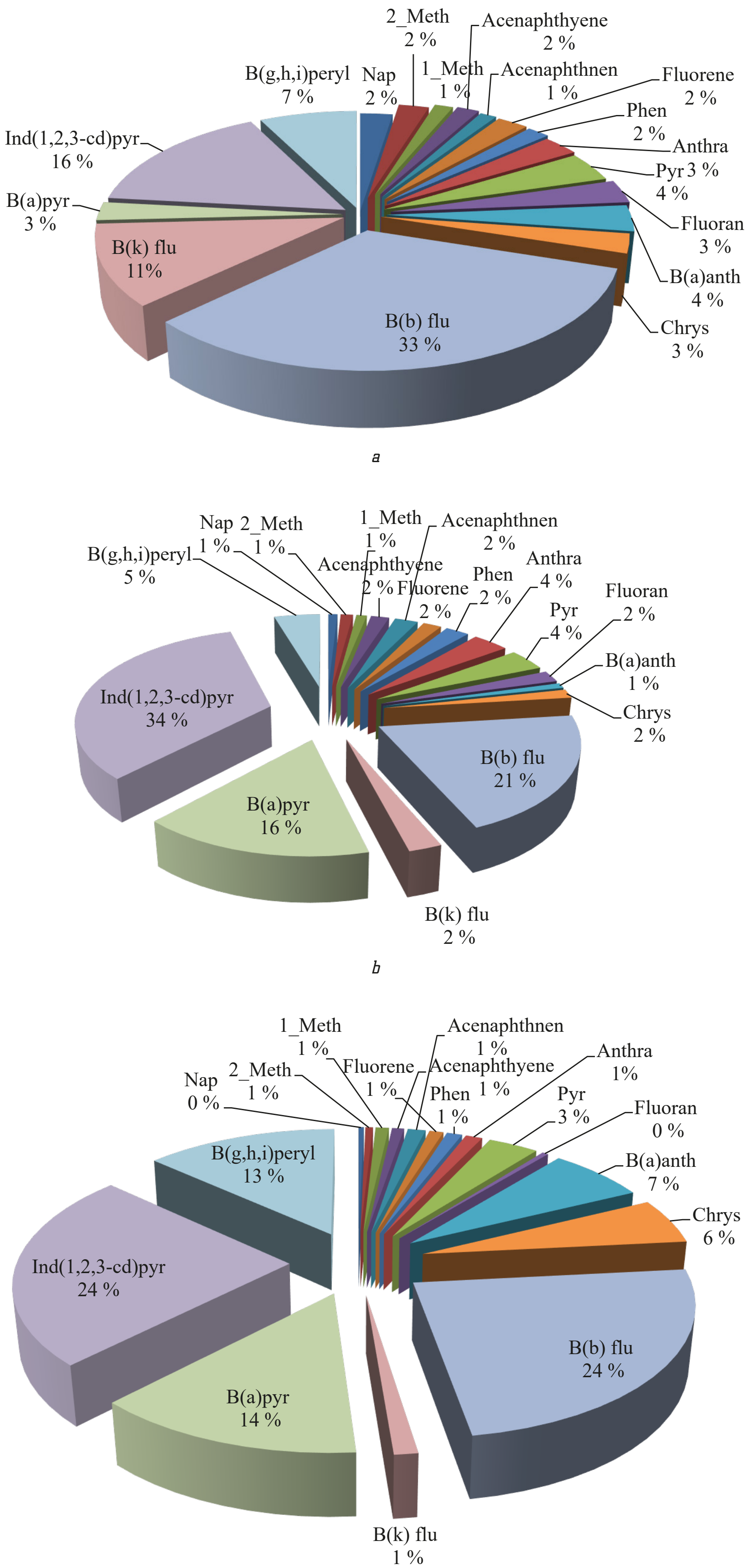

Fig. 3. Average concentrations of polycyclic aromatic compounds in the study areas: *a* – Station No. 4; *b* – Station No. 5; *c* – Station No. 6

Table 2

PAHs pollution indices values in sediment samples at the studied Locations

Locations	Depth (centimeter)	Fluoranthene/ Pyrene	Description	Phenanthrene/ Anthracene	Description	Low molecular weight/ High molecular weight	Description
1	0–5	0.118	Petrogenic	3.197	Pyrogenic	0.346	Petrogenic
	5–10	0.301	Petrogenic	0.986	Petrogenic	0.445	Petrogenic
	10–15	0.649	Petrogenic	1.918	Pyrogenic	0.528	Petrogenic
	15–20	0.265	Petrogenic	0.257	Petrogenic	1.298	Pyrogenic
	20–25	0.023	Petrogenic	2.503	Petrogenic	0.329	Petrogenic
	25–30	0.416	Petrogenic	0.340	Petrogenic	0.291	Petrogenic
	30–35	0.213	Petrogenic	0.870	Petrogenic	0.911	Petrogenic
	35–40	1.068	Pyrogenic	0.882	Petrogenic	0.326	Petrogenic
2	0–5	0.030	Petrogenic	0.938	Petrogenic	1.265	Pyrogenic
	5–10	0.139	Petrogenic	1.409	Pyrogenic	0.050	Petrogenic
	10–15	0.091	Petrogenic	2.479	Pyrogenic	0.068	Petrogenic
	15–20	0.375	Petrogenic	0.743	Petrogenic	0.028	Petrogenic
	20–25	0.082	Petrogenic	0.523	Petrogenic	0.124	Petrogenic
	25–30	0.081	Petrogenic	1.486	Pyrogenic	0.076	Petrogenic
	30–35	0.155	Petrogenic	2.243	Pyrogenic	0.033	Petrogenic
	35–40	0.135	Petrogenic	1.011	Pyrogenic	0.388	Petrogenic
3	0–5	0.321	Petrogenic	0.291	Petrogenic	0.168	Petrogenic
	5–10	0.083	Petrogenic	0.855	Petrogenic	0.197	Petrogenic
	10–15	0.134	Petrogenic	1.162	Pyrogenic	0.222	Petrogenic
	15–20	1.883	Pyrogenic	0.384	Petrogenic	0.599	Petrogenic
	20–25	0.411	Petrogenic	1.613	Pyrogenic	0.080	Petrogenic
	25–30	0.673	Petrogenic	2.630	Pyrogenic	0.791	Petrogenic
	30–35	0.521	Petrogenic	0.145	Petrogenic	0.113	Petrogenic
	35–40	0.298	Petrogenic	1.537	Pyrogenic	0.732	Petrogenic
4	0–5	1.231	Pyrogenic	1.048	Pyrogenic	0.162	Petrogenic
	5–10	0.516	Petrogenic	1.861	Pyrogenic	0.075	Petrogenic
	10–15	0.128	Petrogenic	1.897	Pyrogenic	0.132	Petrogenic
	15–20	0.129	Petrogenic	0.219	Petrogenic	0.216	Petrogenic
	20–25	0.705	Petrogenic	0.421	Petrogenic	0.722	Petrogenic
	25–30	1.011	Pyrogenic	1.691	Pyrogenic	0.211	Petrogenic
	30–35	2.357	Pyrogenic	2.757	Pyrogenic	0.272	Petrogenic
	35–40	0.188	Petrogenic	0.302	Petrogenic	0.204	Petrogenic
5	0–5	0.451	Petrogenic	0.181	Petrogenic	1.004	Pyrogenic
	5–10	0.019	Petrogenic	1.446	Pyrogenic	0.457	Petrogenic
	10–15	0.134	Petrogenic	0.829	Petrogenic	0.293	Petrogenic
	15–20	0.101	Petrogenic	1.296	Pyrogenic	0.564	Petrogenic
	20–25	0.454	Petrogenic	0.129	Petrogenic	1.331	Pyrogenic
	25–30	0.030	Petrogenic	0.663	Petrogenic	0.508	Petrogenic
	30–35	0.166	Petrogenic	0.928	Petrogenic	0.641	Petrogenic
	35–40	1.055	Pyrogenic	2.444	Pyrogenic	1.197	Pyrogenic
6	0–5	2.159	Pyrogenic	0.325	Petrogenic	0.107	Petrogenic
	5–10	3.793	Pyrogenic	1.779	Pyrogenic	0.432	Petrogenic
	10–15	1.020	Pyrogenic	3.324	Pyrogenic	1.219	Pyrogenic
	15–20	1.356	Pyrogenic	5.367	Pyrogenic	0.538	Petrogenic
	20–25	0.890	Petrogenic	1.832	Pyrogenic	1.201	Pyrogenic
	25–30	0.639	Petrogenic	1.005	Pyrogenic	0.634	Petrogenic
	30–35	4.693	Pyrogenic	1.148	Pyrogenic	0.431	Petrogenic
	35–40	1.378	Pyrogenic	0.298	Petrogenic	0.756	Petrogenic

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Table 3

Another PAHs pollution indices values in sediment samples at the studied Locations

Locations	Depth (centimeter)	Ant/(Ant+Phen)	Description	BaA/(BaA+Chry)	Description	InP/(InP+BghiP)	Description
1	0–5	0.238	Pyrolytic	0.023	Pyrogenic	0.438	Petrogenic or pyrogenic
	5–10	0.503	Pyrolytic	0.390	Pyrogenic	0.472	Petrogenic or pyrogenic
	10–15	0.342	Pyrolytic	0.517	Pyrogenic	0.342	Petrogenic or pyrogenic
	15–20	0.795	Pyrolytic	0.495	Pyrogenic	0.264	Petrogenic or pyrogenic
	20–25	0.285	Pyrolytic	0.525	Pyrogenic	0.501	Pyrogenic
	25–30	0.746	Pyrolytic	0.455	Pyrogenic	0.615	Pyrogenic
	30–35	0.534	Pyrolytic	0.272	Pyrogenic	0.413	Petrogenic or pyrogenic
	35–40	0.531	Pyrolytic	0.490	Pyrogenic	0.784	Pyrogenic
2	0–5	0.515	Pyrolytic	0.922	Pyrogenic	0.844	Pyrogenic
	5–10	0.415	Pyrolytic	0.990	Pyrogenic	0.629	Pyrogenic
	10–15	0.287	Pyrolytic	0.394	Pyrogenic	0.225	Petrogenic or pyrogenic
	15–20	0.573	Pyrolytic	0.350	Pyrogenic	0.535	Pyrogenic
	20–25	0.656	Pyrolytic	0.346	Pyrogenic	0.993	Pyrogenic
	25–30	0.402	Pyrolytic	0.343	Pyrogenic	0.572	Pyrogenic
	30–35	0.308	Pyrolytic	0.520	Pyrogenic	0.959	Pyrogenic
	35–40	0.497	Pyrolytic	0.580	Pyrogenic	0.934	Pyrogenic
3	0–5	0.846	Pyrolytic	0.156	Pyrogenic	0.882	Pyrogenic
	5–10	0.408	Pyrolytic	0.089	Pyrogenic	0.959	Pyrogenic
	10–15	0.546	Pyrolytic	0.468	Pyrogenic	0.981	Pyrogenic
	15–20	0.435	Pyrolytic	0.692	Pyrogenic	0.955	Pyrogenic
	20–25	0.885	Pyrolytic	0.419	Pyrogenic	0.972	Pyrogenic
	25–30	0.594	Pyrolytic	0.883	Pyrogenic	0.864	Pyrogenic
	30–35	0.518	Pyrolytic	0.079	Pyrogenic	0.429	Petrogenic or pyrogenic
	35–40	0.290	Pyrolytic	0.677	Pyrogenic	0.386	Petrogenic or pyrogenic
4	0–5	0.488	Pyrolytic	0.855	Pyrogenic	0.535	Pyrogenic
	5–10	0.349	Pyrolytic	0.936	Pyrogenic	0.683	Pyrogenic
	10–15	0.345	Pyrolytic	0.602	Pyrogenic	0.820	Pyrogenic
	15–20	0.819	Pyrolytic	0.924	Pyrogenic	0.852	Pyrogenic
	20–25	0.703	Pyrolytic	0.842	Pyrogenic	0.608	Pyrogenic
	25–30	0.371	Pyrolytic	0.425	Pyrogenic	1.885	Pyrogenic
5	0–5	0.774	Pyrolytic	0.211	Pyrogenic	0.531	Pyrogenic
	5–10	0.538	Pyrolytic	0.421	Pyrogenic	0.201	Petrogenic or pyrogenic
	10–15	0.462	Pyrolytic	0.648	Pyrogenic	0.262	Petrogenic or pyrogenic
	15–20	0.722	Pyrolytic	0.484	Pyrogenic	0.223	Petrogenic or pyrogenic
	20–25	0.382	Pyrolytic	0.455	Pyrogenic	0.683	Pyrogenic
	25–30	0.275	Pyrolytic	0.090	Pyrogenic	0.499	Petrogenic or pyrogenic
	30–35	0.872	Pyrolytic	0.074	Pyrogenic	0.285	Petrogenic or pyrogenic
	35–40	0.394	Pyrolytic	0.125	Pyrogenic	0.557	Pyrogenic
6	0–5	0.754	Pyrolytic	0.570	Pyrogenic	0.469	Petrogenic or pyrogenic
	5–10	0.359	Pyrolytic	0.434	Pyrogenic	0.543	Pyrogenic
	10–15	0.231	Pyrolytic	0.352	Pyrogenic	0.241	Petrogenic or pyrogenic
	15–20	0.157	Pyrolytic	0.546	Pyrogenic	0.246	Petrogenic or pyrogenic
	20–25	0.353	Pyrolytic	0.435	Pyrogenic	0.222	Petrogenic or pyrogenic
	25–30	0.498	Pyrolytic	0.438	Pyrogenic	0.402	Petrogenic or pyrogenic
	30–35	0.465	Pyrolytic	0.421	Pyrogenic	0.511	Pyrogenic
	35–40	0.770	Pyrolytic	0.487	Pyrogenic	0.593	Pyrogenic

Notes: Ant/(Ant+Phen) – Anthracene/(Anthracene+Phenanthrene); BaA/(BaA+Chry) – Benzo(A)/(Benzo(A)+Chrysene); InP/(InP+BghiP) – Indeno(1,2,3-cd)pyrene/(Indeno(1,2,3-cd)pyrene+Benzo(g,h,i)perylene)

The study found that the sources of polycyclic aromatic hydrocarbons were both petrogenic and pyrogynic, with the predominance of Flouren and Phenanthrene in high concentration indicating a Petrogenic source and the presence of Anthracene in most stations indicating a pyrogenic origin. This finding is consistent with those of [9–11]. If to compare received data with other studies in the area let's find that it is within the range (Table 4).

Table 4

Comparison of PAHs values of previous studies with the current study

Studied Areas	PAHs (μg/g)	References
Khor Al Zubair and the North-Western Arabian Gulf	6.88–39.85	[12]
Shatt Al-Arab River and North-Western Arabian Gulf	8.42–70.56	[13]
Al-Howaiza Marsh	0.1–145.8	[14]
Iraqi Coast Region	12.15–47.38	[9]
Al-Azeem Marsh	0.252–10.363	[15]
Shatt Al-Arab River	4.318–28.48	[16]
Al-Kahla River	2.391–35.479	[17]
Shatt Al-Arab River	1.630–60.362	[18]
West Qurna-2 Oil Field	0.378–9.966	[19]
Al-Hammar Marsh	342.82–434.438	[11]
Tigirs, Euphrates and Shatt Al-Arab Rivers	3.830–79.141	Current Study

Table 5

Concentrations of PAHs in Sediment Compared with US National Oceanic Sediment Quality Guidelines

PAHs	ERL39 ($ng \cdot g^{-1}$)	ERM39 ($ns \cdot s^{-1}$)	Sampling locations					
			1	2	3	4	5	6
Naphthalene	160	2100	3.138	0.84	1.016	3.448	13.75	17.302
Anthracene	85	1100	6.184	2.68	4.04	3.992	18.96	17.28
Fluorene	19	540	7.688	2.224	2.056	3.384	18.304	30.03
Phenanthrene	240	1500	49.48	2.456	2.632	2.456	7.344	27.96
Acenaphthene	16	500	9.048	2.84	2.592	1.808	14.408	16.73
AQ	44	640	–	–	5.488	1.912	15.76	19.55
Pyrene	665	2600	17.296	8	4.272	5.752	55.29	21.17
Fluoranthene	600	5100	5.44	0.976	2.264	4.52	8.664	29.16
Benzo(b)fluoranthene	–	–	11.85	55.58	23.304	46.09	18.86	34.86
Benzo(a)pyrene	430	2800	16.16	31.16	18.01	3.584	11.8	20.144

Notes: ERL – effective range low; ERM – effective range median

The PAHs concentration in the sediments was compared with US National Oceanic sediment quality guidelines (Table 5) [20]. The recommended effect range low (ERL) and effect range median (ERM) target values were used to determine toxic effects in the sampling locations. When PAH concentrations vary between ERL and ERM values, a mild toxic effect is expected. In addition, no negative effect is expected for PAH concentrations lower than ERL values. All PAH compounds were below ERL, ERM values in all sampling locations, indicating no mild toxic effect.

According to [21] classification which depending on the concentration of total PAHs in the sediment is classified as non-contaminated with the total PAHs <200 $ng \cdot g^{-1} \cdot dw$, weakly contaminated 200–600 $ng \cdot g^{-1} \cdot dw$, moderately contaminated 600–1000 $ng \cdot g^{-1} \cdot dw$, and heavily contaminated >1000 $ng \cdot g^{-1} \cdot dw$. According to this classification, most samples in the current study were weakly contaminated by PAHs including (oil areas, roads, petrol stations, power plants and electrical generators) samples.

4. Conclusions

1. The study found that there are two main sources of polycyclic aromatic hydrocarbons, petrogenic and pyrogenic, with petrogenic dominating because of the predominance of low molecular weight polycyclic aromatic hydrocarbons and this agree with [9]. In addition to [10, 11].

2. The limits and conditions for applying this research indicated that Sediment pollution in the research locations is classified as moderate pollution by [22].

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has associated data in a data repository.

References

1. Zhou, H. W., Luan, T. G., Zou, F., Tam, N. F. Y. (2008). Different bacterial groups for biodegradation of three- and four-ring

PAHs isolated from a Hong Kong mangrove sediment. *Journal of Hazardous Materials, 152 (3),* 1179–1185. doi: https://doi.org/10.1016/j.jhazmat.2007.07.116
2. Kuppusamy, S., Maddela, N. R., Megharaj, M., Venkateswarlu, K. (2020). *Total Petroleum Hydrocarbons. Environmental Fate, Toxicity, and Remediation.* Springer Cham, 264. doi: https://doi.org/10.1007/978-3-030-24035-6
3. Reeves, G. (2000). *Understanding and monitoring hydrocarbons in water.* Available at: https://www.environmental-expert.com/articles/understanding-and-monitoring-hydrocarbons-in-water-6508
4. Al-Saad, H. T., Al-Ali, B. S., Al-Anber, L. J., Al-Khion, D. D., Hantoush, A. A., Saleh, S. M., Alaial, A. H. (2017). Total Petroleum Hydrocarbon in Selected Fish of Shatt Al-Arab River, Iraq. *International Journal of Marine Science.* doi: https://doi.org/10.5376/ijms.2017.07.0001
5. Al-Talal, E. A., Talal, A. A., Al-Saad, H. T. (2019). Regional and seasonal variation of polycyclic aromatic hydrocarbons in water and mollusca at Quarna north of Shatt Al-Arab River. *Journal of Natural Sciences Research, 9 (14),* 31–48. doi: https://doi.org/10.7176/jnsr/9-14-05
6. Al-Saad, H. T., Farid, W. A., Ateek, A. A., Sultan, A. W., Ghani, A. A., Mahdi, S. (2015). N-Alkanes in surficial soils of Basrah city, Southern Iraq. *International Journal of Marine Science, 5 (52).* doi: https://doi.org/10.5376/ijms.2015.05.0052
7. Jordan River Basin. Inventory of shared water resources in Western Asia. United Nations Economic and Social Commission for Western Asia (2013). *Federal Institute for Geosciences and Natural Resources.* Beirut, 169–221. doi: https://doi.org/10.18356/50674358-en
8. Goutx, M., Saliot, A. (1980). Relationship between dissolved and particulate fatty acids and hydrocarbons, chlorophyll a and zooplankton biomass in Villefranche Bay, Mediterranean Sea. *Marine Chemistry, 8 (4),* 299–318. doi: https://doi.org/10.1016/0304-4203(80)90019-5
9. Al-Khion, D. D. (2012). *Sources and distribution of polycyclic aromatic hydrocarbons compounds in water, sediments and some biota of Iraqi coast regions.* College of Agriculture, University of Basrah, 171.
10. Rinawati, R., Takada, H. (2017). Distribution and Source of Sedimentary Polycyclic Aromatic Hydrocarbon (PAHs) in River Sediment of Jakarta. *Indonesian Journal of Chemistry, 17 (3),* 394. doi: https://doi.org/10.22146/ijc.26837
11. Saleh, S. M., Farhan, F. J., Khwedem, A. A., Al-Saad, H. T., Hantoush, A. A., Zahraal-Hello, A. (2021). Assessment of polycyclic aromatic hydrocarbons (PAHs) in water and sediments at South Part of AlHammer Marsh, Southern Iraq. *Pollution Research Paper, 40 (1),* 79–87. Available at: http://www.envirobiotechjournals.com/PR/v40i121/Poll%20Res-14.pdf
12. Al-Hamdi, M. M. S. (1989). *Hydrocarbons: Sources and vertical distribution in sediment from Khor Al-Zubair NW Arabian Gulf.* Marine Science Centre, Basrah University, 130.
13. Al-Saad, H. T. (1995). *Distribution and sources of hydrocarbons in Shatt Al-Arab estuary and NW Arabian Gulf.* Basrah University, 186.
14. Al-Khatib, F. M. (2008). *Determination the concentrations, origin and distribution of hydrocarbon compounds in water, sediments and some biota of Hor Al-Howaiza, south of Iraq and their sources.* University of Basrah, College of Science, Biology Department, 228.
15. Al-Taie, E. O. A. (2013). *Evaluation of Pollution in the Hor Al-Azim Sediments by hydrocarbons and Heavy Metals, Missan Government, South of Iraq.* College of Science, University of Basrah, 125.
16. Al-Hejuje, M. M. (2014). *Application of water quality and pollution indices to evaluate the water and sediments status in the middle part of Shatt Al-Arab River.* College of Science, University of Basrah, 239.
17. Jazza, H. S. (2015). *The status of hydrocarbons compounds pollution of water, sediments and some aquatic biota in Al-Kahlaa River Missan Province, Iraq.* University of Basrah, 137.
18. Al-Mahana, D. S. (2015). *Distribution and sources of Total Hydrocarbons, N-Alkane and Poly Cyclic Aromatic compounds in sediments cores of Shatt Al-Arab coast, Khor Al-Zubair and Um-Qaser.* College of Science, University of Basrah, 124.
19. Karem, D. S. A. (2016). *Environmental Impact Assessment of air, noise and petroleum hydrocarons pollution in soil of west qurna-2 oil field at Basrah city, southern Iraq.* University of Basrah, 165.
20. Long, E. R., MacDonald, D. D. (1998). Recommended Uses of Empirically Derived, Sediment Quality Guidelines for Marine and Estuarine Ecosystems. *Human and Ecological Risk Assessment: An International Journal, 4 (5),* 1019–1039. doi: https://doi.org/10.1080/10807039891284956
21. Maliszewska-Kordybach, B. (1996). Polycyclic aromatic hydrocarbons in agricultural soils in Poland: preliminary proposals for criteria to evaluate the level of soil contamination. *Applied Geochemistry, 11 (1-2),* 121–127. doi: https://doi.org/10.1016/0883-2927(95)00076-3
22. Baumard, P., Budzinski, H., Garrigues, P. (1998). Polycyclic aromatic hydrocarbons in sediments and mussels of the western Mediterranean sea. *Environmental Toxicology and Chemistry, 17 (5),* 765–776. doi: https://doi.org/10.1002/etc.5620170501

Zainab A. Salem, *Department of Geology, College of Sciences, University of Basrah, Basrah, Iraq, ORCID: https://orcid.org/0000-0003-3799-0100*

Abbas H. Mohammed, *Department of Geology, College of Sciences, University of Basrah, Basrah, Iraq, ORCID: https://orcid.org/0000-0003-4314-1535*

✉***Hamid T. Al-Saad,*** *College of Marine Science, University of Basrah, Basrah, Iraq, e-mail: htalsaad@yahoo.com, ORCID: https://orcid.org/0000-0002-3350-0752*

✉*Corresponding author*