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 these 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.

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

© The Author(s) 2022
This is an open access article under the Creative Commons CC BY license

How to cite
Salem, Z. A., Mohammed, A. H., Al-Saad, H. T. (2022). Origin and sources of polycyclic aromatic hydrocarbons (PAHs) in sediments core from Tigris, Euphrates and Shatt Al-Arab rivers. Technology Audit and Production Reserves, 5 (3 (67)), 20–28. doi: https://doi.org/10.15587/2706-5448.2022.266459

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 km² 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, Fluoranthen, Benz(a)anthracene are the lowest average for station No. 1 concentrations (Fig. 2). While the compounds of 1_Methylnaphthalene, Acenaphthen, Phenanthrene, Pyrene, Chrysene, B(b)fluoranthene, B(k)fluoranthene, 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)fluoranthene, 2_Methylnaphthalene, 1_Methylnaphthalene. The compounds with the highest concentration in that station are Naphthalene, Acenaphthyene, Fluorene, Anthracene, Fluoranthen, Benz(a)anthracene, Acenaphthen, Phenanthrene, Pyrene, Chrysene, B(b)fluoranthene, Benzo(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene.
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  |
| Acenaphthene             | 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)fluoranthene         | 1.481  | 6.947  | 2.913  | 5.761  | 2.357  | 4.357  |
| B(k)fluoranthene         | 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  | 3.280  | 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)fluoranthene while the compounds with highest average concentrations are 2-Methylnaphthalene, 1-Methylnaphthalene, Naphthalene, Acenaphthyene, Fluorene, Anthracene, Acenaphthlen, Phenanthrene, Pyrene, Chrysene, B(b)fluoranthene, Benz(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene. The compounds with the highest concentration in that station B(b)fluoranthene, Benz(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene. The compounds with the lowest concentration for station No. 4 concentrations (Table 2).

While the compounds of B(b)fluoranthene, B(k)fluoranthene, 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, Acenaphthlen, Phenanthrene, Pyrene, Chrysene, Benz(a)anthracene, B(k)fluoranthene, Benzo(g,h,i)perylene. The compounds with the highest concentration in that station B(b)fluoranthene, Benz(a)pyrene, Indeno(1,2,3-cd)pyrene, Benzo(g,h,i)perylene. The compounds with the lowest concentration for station No. 6. While the compounds of B(b)fluoranthene, Benz(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  

| 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  | 0.985                   | 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   | 0.862                   | Petrogenic  | 0.326                                      | Petrogenic  |
| 2         | 0–5                | 0.030                | Petrogenic  | 0.939                   | 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   | 1.049                   | Pyrogenic   | 0.162                                      | Petrogenic  |
|           | 5–10               | 0.516                | Petrogenic  | 1.961                   | 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                   | Petrogenic  | 0.584                                      | Petrogenic  |
|           | 20–25              | 0.454                | Petrogenic  | 0.129                   | Petrogenic  | 1.331                                      | Pyrogenic   |
|           | 25–30              | 0.030                | Petrogenic  | 0.683                   | 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              | 4.683                | Pyrogenic   | 1.148                   | Pyrogenic   | 0.431                                      | Petrogenic  |
|           | 35–40              | 1.378                | Pyrogenic   | 0.298                   | Petrogenic  | 0.756                                      | Petrogenic  |
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   | 0.980          | 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   | 0.555          | 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   | 0.822          | 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   | 0.877          | Pyrogenic   | 0.386          | Petrogenic or pyrogenic |
| 4         | 0–5               | 0.488          | Pyrolytic   | 0.855          | Pyrogenic   | 0.535          | Pyrogenic |
|           | 5–10              | 0.349          | Pyrolytic   | 0.336          | 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 |
|           | 30–35             | 0.774          | Pyrolytic   | 0.211          | Pyrogenic   | 0.531          | Pyrogenic |
|           | 35–40             | 0.538          | Pyrolytic   | 0.421          | Pyrogenic   | 0.201          | Petrogenic or pyrogenic |
| 5         | 0–5               | 0.452          | Pyrolytic   | 0.648          | Pyrogenic   | 0.262          | Petrogenic or pyrogenic |
|           | 5–10              | 0.722          | Pyrolytic   | 0.484          | Pyrogenic   | 0.223          | Petrogenic or pyrogenic |
|           | 10–15             | 0.382          | Pyrolytic   | 0.455          | Pyrogenic   | 0.683          | Pyrogenic |
|           | 15–20             | 0.275          | Pyrolytic   | 0.090          | Pyrogenic   | 0.499          | Petrogenic or pyrogenic |
|           | 20–25             | 0.872          | Pyrolytic   | 0.074          | Pyrogenic   | 0.285          | Petrogenic or pyrogenic |
|           | 25–30             | 0.394          | Pyrolytic   | 0.125          | Pyrogenic   | 0.557          | Pyrogenic |
|           | 30–35             | 0.754          | Pyrolytic   | 0.570          | Pyrogenic   | 0.469          | Petrogenic or pyrogenic |
|           | 35–40             | 0.359          | Pyrolytic   | 0.434          | Pyrogenic   | 0.543          | Pyrogenic |
| 6         | 0–5               | 0.231          | Pyrolytic   | 0.352          | Pyrogenic   | 0.241          | Petrogenic or pyrogenic |
|           | 5–10              | 0.157          | Pyrolytic   | 0.546          | Pyrogenic   | 0.246          | Petrogenic or pyrogenic |
|           | 10–15             | 0.353          | Pyrolytic   | 0.435          | Pyrogenic   | 0.222          | Petrogenic or pyrogenic |
|           | 15–20             | 0.498          | Pyrolytic   | 0.438          | Pyrogenic   | 0.402          | Petrogenic or pyrogenic |
|           | 20–25             | 0.465          | Pyrolytic   | 0.421          | Pyrogenic   | 0.511          | Pyrogenic |
|           | 25–30             | 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 pyrogenic, 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-Howaida 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                            | 0.379–9.966 | (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·g⁻¹) | ERM39 (ng·s⁻¹) | Sampling locations |
|-------------------|----------------|---------------|--------------------|
|                   | 1   | 2   | 3   | 4   | 5   | 6   |
| Naphthalene       | 160 | 2100| 3.158| 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| 18.73 |
| A0                | 44  | 640 | –    | –   | 5.480| 1.912| 15.76 | 19.55 |
| Pyrene            | 665 | 2800| 17.296| 6   | 4.272| 5.752| 55.29 | 21.17 |
| Fluoranthene      | 600 | 5100| 5.44 | 0.976| 2.264| 4.52  | 8.664 | 29.16 |
| Benzo(a)/pyrene   | –   | –   | 11.85| 55.58| 23.304| 46.09| 18.86 | 34.86 |
| Benzo(b)/fluoranthene | – | – | 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·g⁻¹·dw, weakly contaminated 200–600 ng·g⁻¹·dw, moderately contaminated 600–1000 ng·g⁻¹·dw, and heavily contaminated >1000 ng·g⁻¹·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.

Financing

The study was performed with financial support from University of Basrah, College of Science and College of Marine science, Iraq.

Presentation of research in the form of publication through financial support in the form of a grant from SUES (Support to Ukrainian Editorial Staff).

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., Madhala, N. R., Moglaha, 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 Qurna 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., Atek, A. A., Sultan, A. W., Ghan, A. A., Mahdi, S. (2015). N-Alkanes in surficial soils of Basrah city, Southern Iraq. International Journal of Marine Science, 5 (32). doi: https://doi.org/10.5376/ijms.2015.05.0052
7. Jordan River Basin Inventory. Shared of 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/10.18356/30674338-en
8. Goutx, M., Salot, 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., Zahraa-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.envirobotjhournals.com/PR/v40i121/Pol%20Res-14.pdf
12. Al-Handi, 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.