Indonesian Journal on Health Science and Medicine
Vol 2 No 1 (2025): January
ISSN 3063-8186. Published by Universitas Muhamamdiyah Sidoarjo

https://doi.org/10.21070/ijhsm.v2i2.98

Variability By Region and Season of Polycyclic Aromatic Hydrocarbons in Oil Field Soil in Southern Iraq's Basrah Governorate

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Abstract. Soil samples were gathered from 11' oil fields in the Basrah governorate, including (Seba, Safwan, Majnoon, Ratawi, Bergezia, West Qurna 1, West Qurna 2, Shuaaba, South and North Rumaila, and Zubair), at a depth of 0 to 20 cm. The aim was to determine the distribution and origin polycyclic aromatic hydrocarbons (PAHs), they were divided into two major groups according to their molecular weight. The first group included six low molecular weight (LMW) chemicals: naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene, each containing two to three fused aromatic rings. The second group consisted of nine high molecular weight (HMW) compounds with four or more fused aromatic rings: Fluoranthene, Pyrene, Benzo(a)anthracene, Chrysene, Benzo"(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)Pyrene, Indeno (1,2,3, c,d) Pyrene, and Benzo(g,h,i)perylene. Station 8 (Shuaaba) recorded the highest mean concentration of total PAHs at 2374.85 ng/g dry weight, while Station 3 (Majnoon) recorded the lowest at (370.672ng/g) dry weight. The PAHs origin was attributed to both pyrogenic and petrogenic sources, as determined by the ratios of LMW/HMW, Phenanthrene/Anthracene, and Fluoranthene/Pyrene. The PAHs compound came from pyrogenic and petrogenic organisms, as indicated by the ratios of LMW/HMW, Phenanthrene/Anthracene, and Fluoranthene/Pyrene. Seasonal mean concentrations of PAHs were in winter (1375.541 ng/g) and summer (529.496 ng/g), with autumn having the lowest concentration (304.486 ng/g), arranged in this order: (Winter > Spring > Summer > Autumn).

Highlights:

1. PAHs in Basrah Soil: Highest in Shuaaba (2374.85 ng/g), lowest in Majnoon (370.67 ng/g).
2. Source & Classification: PAHs from pyrogenic and petrogenic origins, classified by LMW/HMW ratios.
3. Seasonal Variation: Highest in winter (1375.54 ng/g), lowest in autumn (304.49 ng/g).

Keywords: PAHs,GClMS. Soil pollution, Oil fields, Basrah

Introduction

Aromatic hydrocarbons often contaminate aquatic environments and are frequently used to evaluate sediments pollution, which are either pyrogenic or oil pollution. [1]. These include monocyclic aromatic compounds such as Benzene, Tulane,

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and Xylene, as well as polycyclic aromatic hydrocarbons (PAHs), also referred to as polycyclic organic matter (POM), for example of PAHs include naphthalene, anthracene, benzo(a) pyrene, and phenanthrene, which are composed of two or more fused aromatic rings [2]. These compounds are particularly concerning due to their carcinogenic potential or their ability to become carcinogenic through microbial processes [3].

As a result, the US Environmental Protection Agency (US EPA) has classified these chemicals as priority pollutants [4]. The soil in Basrah is heavily contaminated due to the numerous oil field, increased drilling and exploration activities, oil extraction and refining operations, and frequent oil spills. These contaminants include hydrocarbon compounds, normal alkanes (n-alkanes), and polycyclic aromatic hydrocarbons (PAHs), which found, in both oil sites and nearby lands. Water and air are essential components of soil, so it is concerning that the soil also absorbs the pollutions from the air via precipitation and from water through leaching, in addition to direct contamination. Basrah faces a significant accumulation of pollutant residues each year, compounded by presence of oil fields.

Large-scale hydrocarbon emissions from power plants, industry, petrol stations, and private electrical generators contribute significantly to hydrocarbon pollution. These sources have caused substantial contamination, affecting both the environment and people of Basrah City. Exposure to polycyclic aromatic hydrocarbons (PAHs) primary occurs through skin contact, ingestion and inhaling of fine particles. Seven PAHs are known carcinogens, including benzo(a)anthracene, chrysene, benzo(b), benzo(k), benzo(a), pyrene, dibenzo(a), and indeno (1,2,3-c,d) are among the seven substances that are known to cause cancer. Benzo (g,h, i)perylene, pyrene, anthracene, fluoranthene, phenanthrene, acenaphthylene, acenaphthene, fluorene, and naphthalene are the nine non-carcinogenic chemicals but mutagenic species. Total petroleum hydrocarbons (TPH) are categorized as aliphatic, aromatic, resinous, or asphaltene, depending on their chemical structure. Aromatic hydrocarbons can be divided into two groups which are Low molecular weight (LMW) and high molecular weight (HMW). Traditional methods for determining TPH level involve extracting contaminants from a soil sample, followed by analysis using techniques like gravimetry, calibrated with an Environmental Protection Agency (EPA) and gas chromatography-mass spectrometry (GC-MS). In the fields of the Basra Governorate, eleven samples were gathered. Large

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geographic expanses, numerous extraction operations, proximity to the governorate, sizable people within, and the presence of river tributaries that supply water to the surrounding areas made these fields noteworthy.

Therefore, the research necessary to evaluate the prevalence of these pollutants in specific industries, as will help to establish a base for future studies focused on mitigating the environmental impact of oil pollution in the Basra Governorate.

This study specifically focuses on the distribution and source of polycyclic aromatic hydrocarbon in these 11 oil fields in the Basrah governorate, crucial area in Iraq with significant oil reserves nearby. The results could serve as a foundation for further research on this critical issue.

Methods

Eleven samples were taken near the oil field sites in Basrah city, '(Seba, Safwan, Majnoon, Ratawi, Bergezia, west Qurna2, west Qurna1, Shuaaba, South and North Ru"maila, 'and Al Zubair) as depicted in Figure (1). During the period from July 2023 to March 2024, ''soil samples were seasonally collected. After rolling the samples with ''aluminum foil, they were brought to the l'aboratory for analysis. To extract the hydrocarbons from the soil, the procedures described by [5] were followed. A 24-hour soxhlet extraction was carried out using 50 grams of dirt and 250 milliliters of methanol:benzen (1:1). ''In order to av'oid sulfur int'erferences during the gas chromatographic separation, elemental sulfur was removed from the extracts using activated elemental copper. A chromatography column was then used to split the extracts into aromatic and aliphatic hydrocarbons. In order to prevent the top layer from being disrupted when the solvent was poured, 1 g of anhydrous sodium sulphate wa'"s added t"o the surface" after 10 g of silica ''(100-200 mesh) and 10 g of alumina (100-200 mesh) were slurry packed. The silica and alumina were activated at 200° C for 4 hours and then partially deactivated with 5% water. To get the aromatic 'hydrocarbons, the extract was added to the head of the column," which eluted 25 milliliters of 'benzene. Using a rotary evaporator, the Aromatic fractions were concentrated and then transferred to a vial, where a stream of

The volume was accurately tuned to 1 ml using N2. An aliquot of a 1 l extract of aromatic hydrocarbons was subjected to analyses utilizing an ally capillary gas

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chromatography with a flash ionization detector (FID). The column's temperature (Agilent 19091J-101HP-5 5% phenyl methyl silicone with PAHs dimensions) was maintained at 80 °C for two minutes before rising to 280 °C for twelve minutes at a rate of 8 °C per minute. The various PAHs were detected using the retention duration of a real mixed standard that was acquired from Supelco in the United States. The standard calibration curve of the relevant standard chemicals was used to calculate the concentrations of PAH compounds. Recovery assays range from 80% to 92% for compounds that contain PAHs.

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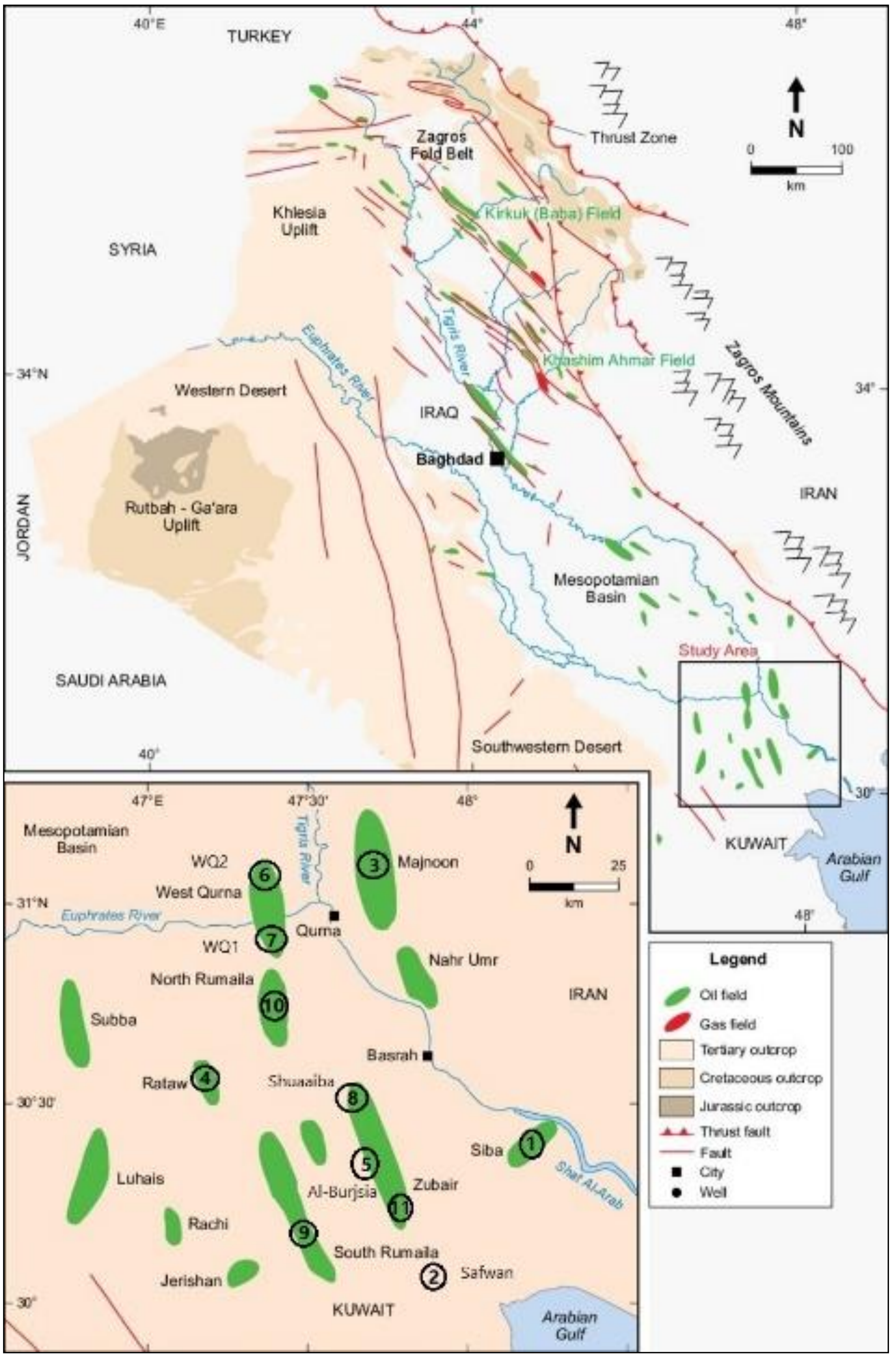

Figure (1) Samples Location

Result and Discussion

Soil samples from stations Seba, Safwan, Majnoon, Ratawi, Bergezia, West Qurna2, West Qurna1, Shuaaba, South and North Rumaila, and Al Zubair oil fields, respectively, contained fifteen PAH chemicals, according to the current study. Their molecular weight led to their classification into two main groupings. The first group

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consisted of six compounds: anthracene, fluorene, phenanthrene, acenaphthylene, naphthalene, and acenaphthene. These substances are light (low molecular weight) and have two to three fused aromatic rings. Benzo(a)anthracene, chrysene, benzo(b) fluoranthene, benzo(k) fluoranthene, benzo(a)pyrene, indeno (1,2,3, c,d)pyrene, and benzo(g,h, i)perylene were among the nine distinct compounds in the second group. As seen in Figure (2), these heavy (high molecular weight) molecules have four or more fused aromatic rings. The range of total PAH concentrations found in soil samples from eleven stations is as follows: Station Majnoon went from 82.99 ng/g in the summer to 733 ng/g in the spring, whereas Station Seba went from 145.64 ng/g in the summer to 929.1 ng/g in the winter and Station Safwan from 22.72 ng/g in the summer to 1133.6 ng/g in the spring. Stations Ratawi and Bergezia saw increases from 18.4 ng/g in the summer to 842 ng/g in the spring, from 324.1 ng/g in the summer to 1904 ng/g in the winter, from 24.7 ng/g in the summer to 1817.9 ng/g in the winter, from 361.5 ng/g in the fall to 2092.4 ng/g in the spring, from 225.7 ng/g in the fall to 4515 ng/g in the winter, and from 60.67 ng/g to According to the geographical PAH results for the current study, Ratawi Station has the lowest concentration of PAHs during the summer (18.4 ng/g to dry weight). In contrast, Shuaaba Station has the highest concentration during the winter (4515 ng/g dry weight). According to table (5), Shuaaba Station has the highest mean concentrations of total PAHs in soil (2374.85 ng/g) dry weight, whereas Majnoon Station has the lowest mean concentrations (370.672 ng/g) dry weight. The reasons for the rise in the overall concentration of PAH compounds in the fall and winter are the low rate of evaporation processes to the compounds and the declining efficiency of different microorganisms in the degradation processes of these compounds with low temperatures. Furthermore, bacteria, particularly those with low molecular weights, are encouraged to break down these compounds at high temperatures [6]. Also, the oxidation processes are caused by the extended duration of brightness and intensity of solar radiation [7]. Throughout this investigation, seasonal fluctuations in the total PAHs are noted. As shown in figure (3), the highest concentrations were found in the winter and spring, except West Qurna1 Station and North Rumaila, which were in the autumn. Conversely, the summer months saw lower concentrations, except West Qurna1 Station and North Rumaila, which were in the spring, Shuaaba Station in the fall, and Al Zubair

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Station in the winter. According to research on seasonal mean concentrations of PAHs, wintertime had the highest amounts.

ArcGIS version 10.7 software has been used to drawing the maps that represent the distribution of PAHs measured in studied area, the method used in distributing the data is the IDW, figure (5).

PAHs are organic compounds that are hydrophobic and are typically absorbed on the organic portion of soils [8]. When compared to natural sources, human activity is mostly responsible for environmental contamination with PAH chemicals [9]. The primary source of PAHs in soil is anthropogenic activity, which also "includes pyrogenic" inputs "from oil products and automobile emissions [10]. "90% of the polycyclic aromatic hydrocarbons in soil have a longer half-life than those in the air and in plants, making soil a sink for PAH compounds [11]. Groups of PAH compounds are based on the number of benzenes rings they contain [12] . Six rings (InP and Bghi), five rings (BbF, BkF, and BaP), four rings (Fla Pyr, BaA, Chr), and three rings (Acy, Ace, Flu, Phe, and Ant) are among these groups. HMW-PAHs build up in soil in most locations because of oil refineries, oil fields, and other operations that rely on the high-temperature burning of fuel, which generates massive amounts of PAHs and these pervasive pollutants deposited on the soil [13,11]. According to [14] , benzo [a] pyrene and benzo [a] anthracene are the most powerful carcinogens known to science. Most stations discovered that HMW-PAHs were higher than LMW-PAHs during the study period; this could be because of several microorganisms, including. The low levels of PAHs in some soils could be due to the existence of microbial flora that degrades these substances [15]. In addition to biodegradation, LMW-PAHs evaporate more quickly than HMW-PAHs due to their high vapor pressure. Compounds with five or more rings of PAHs are found in a solid state and attach to soil particles due to their lower volatility and solubility [16]. HMW-PAH molecules are therefore more stable and long-lasting in the environment because bacteria cannot break them down as readily [17] The results of another study [18, 19, 20] were in agreement with this one. The rainy season There are many sources of PAHs in the environment, such: With the potential to impact the air, water, soil, and eventually all living things in our area, the oil business poses a serious risk to the environment. One frequent and hazardous byproduct of the activities of the oil and gas sector is pollution. From exploration to refining, it has an impact on each stage of the production process

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[21]. This is explained by how the climate affects photo-oxidation, volatilization, and high deterioration during the hot season. Increasing the rate of evaporation also affects biodegradation because of the higher summer temperatures [22].

The highest rates of biodegradation often occur in the range of 20 to 30Cº" in environments, as the rate of biodegradation normally decreases with decreasing temperature and vice versa" [23]. High amounts of PAHs were introduced by the drilling processes to oil fields, oil exploration, and petroleum storage [24, 9]. As a result of the temperature decreasing during winter, there is less evaporation, which lowers the rate of biodegradation "[25,26,27]. According to numerous studies, PAHs are mostly released into the atmosphere, where they are transported over short and long distances in both gaseous and particulate forms before accumulating in soils as a result of both dry and wet atmospheric deposition [28]. If we compare the findings of the present study findings with those of previous studies as shown (table 6) and due to the location and level of pollution in the area where the samples were taken, it was found that they differed between certain studies and others according to of their levels.

At Shuaaba Station in the spring, the LMW/HMW ratio is 0.103, but at West Qurna1 Station in the summer, it is 2.333. Both pyrogenic and petrogenic sources are the main causes of PAH pollution. While higher concentrations of HMW-PAHs are linked to pyrogenic origin, or combustion origin, the presence of LMW-PAHs indicates a petrogenic origin [29].

The summertime phenanthrene/anthracene ratio at Majnoon Station is 0.047, whereas the wintertime ratio at Seba Station is 22.642. The phenanthrene/anthracene ratio has been utilized in numerous research (27,30,31, 32, 33] to determine the source of PAH chemicals in sediments. According to the current study, the phenanthrene/anthracene ratio is likely to have pyrogenic origins. The ratio values display

At Safwan Station in the summer, the fluoranthene/pyrene ratio is 0.250, while at Al Zubair Station in the winter, it is 3.250. Many writers [27, 30, 34, 33] employ the fluoranthene/pyrene ratio to identify the source of PAHs in sediment sample samples. At North Rumaila Station in the summer, the BaA/(BaA+Chry) ratio was 0.001, but at West Qurna1 Station in the fall, it was 0.865. As per Wang et al, 1330-1336, a ratio of benzo(a)anthracene/benzo(a)anthracene+chrysene < 0.20 signifies petroleum input,

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0.20 to 0.35 suggests oil and petroleum combustion and > 0.35 implies combustion. At Safwan Station in the spring, the Ant/(Ant+Phen) ratio is 0.020, while at Majnoon Station in the summer, it is 0.955. A petrogenic source is indicated by an anthracene/anthracene+phenanthrene ratio < 0.1, whereas a pyrolytic source is suggested by a ratio > 0.1.

Table1: The Concentration of PAHs Compounds dry wet in soil During summer seasons in The Studied Locations

NAPHTHALENE″	ND′	‘ND	1.2′	‘15	ND′	‘ND	40′	‘40	20′	6′0′	‘90
ACENAPHTHYLENE″	20′	‘ND	60′	‘10	18′	‘16	5′	‘16	ND′	0.4′7	1′.1
ACENAPHTHNEN″	20′	ND	ND′	N′D	ND′	N′D	10′	‘ND	ND′	10′	2′0
FLUORENE″	0.68′	‘ND	0.72′	‘10	22′	1′4	10′	‘3.9	ND′	20′	1′0
PHENANTHRENE″	40′	‘10	0.47′	1′5	12′	12′	1′10	‘80	10′	100′	7″0
ANTHRACENE″	50′	7′.3	10′	1′5	24′	13′	1′20	9′0	10′	120′	5.′1
FLUORANTHENE″	10′	2′0	10′	1′2	8′	0.3′	‘40	1′30	ND′	130′	40′
PYRENE″	20′	8′0	15′	30′	14′	0.4′	‘40	13′0	ND′	130′	60
BENZO(A)ANTHRAC″	10′	N′D	10′	15′	0.9′	4.1′	‘0.16	0′	0.6″	0.2′	0.9″
CHRYSENE″	10′	2.′7	20′	25′	8′0	10′	‘30	360′	7′	320′	60″
BENZO(B) FLUORA″	0.87′	0.86′	0.′9	23′	3′.2	4.3′	‘0.69	1.1′	1.9′	320′	20′
BENZO(K) FLUORA″	1.69′	0.86′	0.′9	1.3′	1′20	3.9′	‘70	460′	0.6′7	350′	20′
BENZO(A) PYRENE″	2.4′	1′	2′0	2.1′	1′00	1.7′	‘0.9	400′	0.′5	40″	3.2′
INDENO(1,2,3-CD)PYRENE″	30′	20′	N′D	ND′	‘10	5′	‘1.5	290′	‘	3.6′	0.5′
BENZO(G,H,I)PERYLEN″	53′	10′	‘20	ND′	‘10	4′	‘0.33	0.7′	‘10	680′	0.89′
∑ PAHs (ng.g-1)″	145.64′	22.72′	‘82.99	18.4′	‘324.1	24.7′	‘473.58	1985.′7	‘60.67	2284.2′7	401.6′9

Table2: The Concentration of PAHs Compounds dry wet in soil During autumn seasons in The Studied Locations

NAPHTHALENE	10	10	10	2.7	20	10	10	10	2.4	2.7	20
ACENAPHTHYLENE	4.2	1.6	4.1	0.7	3.4	1.6	1.4	1.4	5	0.9	1.9
ACENAPHTHNEN	10	10	10	4.2	20	10	10	10	10	10	10
FLUORENE	10	10	20	10	20	10	10	10	10	10	10
PHENANTHRENE	40	40	80	20	78	50	80	50	40	50	70
ANTHRACENE	10	3.1	10	10	70	40	10	30	2.8	20	30

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FLUORANTHENE	30	30	50	10	21	70	40	30	10	40	50
PYRENE	40	40	60	10	16	60	15	30	10	50	50
BENZO(A)ANTHRAC	20	20	20	10	45	20	90	1.2	0.2	30	10
CHRYSENE	40	50	10	10	81	60	14	20	10	50	30
BENZO(B) FLUORA	20	20	20	10	69	20	20	10	7.9	10	10
BENZO(K) FLUORA	20	20	20	10	73	20	20	10	4.3	10	10
BENZO(A) PYRENE	10	10	10	10	20	10	30	10	0.6	4.3	4.2
INDENO(1,2,3-CD) PYRENE	10	10	10	5.5	11	10	1.1	0.3	0.1	2	1.4
BENZO(G,H,I)PERYLEN	20	20	20	5.3	10	20	10	2.8	1.65	10	1.4
∑ PAHs (ng.g-1)	294.2	294.7	354.1	128.4	557.4	411.6	361.5	225.7	114.95	297.9	308.9

Table3: The Concentration of PAHs Compounds dry wet in soil During winter seasons in The Studied Locations

NAPHTHALENE	6	1.2	50	4.2	10	2.2	2	10	60	30	1
ACENAPHTHYLENE	6.5	1.4	3.3	3	120	2.3	1.3	10	10	5	1.1
ACENAPHTHNEN	4.3	0.1	10	2.9	160	1.2	10	10	20	10	1.4
FLUORENE	27	2.3	20	20	150	2.2	5	5	15	15	0.6
PHENANTHRENE	120	30	60	100	100	110	80	200	210	160	0.5
ANTHRACENE	5.3	1.6	3.1	5.3	160	10	4.6	10	10	10	0.7
FLUORANTHENE	90	20	30	100	120	320	270	670	390	290	1.3
PYRENE	70	20	50	90	180	270	210	530	430	270	0.4
BENZO(A)ANTHRAC	20	1.3	5.6	20	35	120	90	250	130	100	14.9
CHRYSENE	50	15	10	10	60	140	90	330	170	25	16.8
BENZO(B) FLUORA	90	10	20	100	180	230	190	520	240	260	2
BENZO(K) FLUORA	40	1.5	20	40	198	80	15	180	25	10	1.7
BENZO(A) PYRENE	20	10	0.6	10	39	100	80	390	200	140	1.3
INDENO(1,2,3-CD)PYRENE	160	4	10	70	183	210	150	600	210	250	1.7
BENZO(G,H,I)PERYLEN	220	4.2	20	110	209	220	170	800	430	340	1.8
∑ PAHs (ng.g-1)	929.1	122.6	312.6	685.4	1904	1817.9	1367.9	4515	2550	1915	47.2

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Table 4 shows the concentration of dry-wet PAH compounds in soil during the spring months in the locations under study.

NAPHTHALENE	10	10	10	10	10	10	10	10	10	10	30
ACENAPHTHYLENE	0.76	0.8	1	2	1.1	2.7	2.4	5.1	1.5	70	2.8
ACENAPHTHNEN	3.2	0.6	2	10	15	10	10	18	10	2.7	20
FLUORENE	10	0.4	10	30	0.69	20	30	10	30	20	40
PHENANTHRENE	20	90	110	170	50	100	120	170	100	150	120
ANTHRACENE	10	1.8	10	10	10	20	40	20	10	18	20
FLUORANTHENE	150	50	40	40	70	50	60	25	20	80	30
PYRENE	150	100	60	60	120	60	50	15	30	85	40
BENZO(A)ANTHRAC	30	20	20	30	20	50	40	120	20	130	20
CHRYSENE	100	130	80	80	30	90	220	320	3.5	300	110
BENZO(B) FLUORA	50	130	80	60	30	70	300	490	50	250	30
BENZO(K) FLUORA	10	10	10	10	10	70	300	9.9	25	250	30
BENZO(A) PYRENE	20	40	20	40	15	80	20	180	30	250	130
INDENO(1,2,3-CD)PYRENE	90	190	80	100	70	190	320	550	80	540	160
BENZO(G,H,I)PERYLEN	200	360	200	190	170	350	570	830	220	790	540
∑ PAHs (ng.g-1)	853.96	1133.6	733	842	621.79	1172.7	2092.4	2773	640	2945.7	1322.8

Table 5 shows seasonal changes in oil field polycyclic aromatic hydrocarbons (ng/g) with mean

Seba	145.64	294.2	929.1	853.96	555.725
Safwan	22.72	294.7	122.6	1133.6	393.405
Majnoon	82.99	354.1	312.6	733	370.672
Ratawi	18.4	128.4	685.4	842	418.55
Bergezia	324.1	557.4	1904	621.79	851.822
West Qurna2	24.7	411.6	1817.9	1172.7	856.725
West Qurna1	473.58	361.5	1367.9	2092.4	1073.845
Shuaaba	1985.7	225.7	4515	2773	2374.85
South Rumaila	60.67	114.95	2550	640	841.405
North Rumaila	2284.27	297.9	1915	2945.7	1860.717
Al Zubair	401.69	308.9	47.2	1322.8	520.147
S. Mean	529.496	304.486	1469.700	1375.541	919.806

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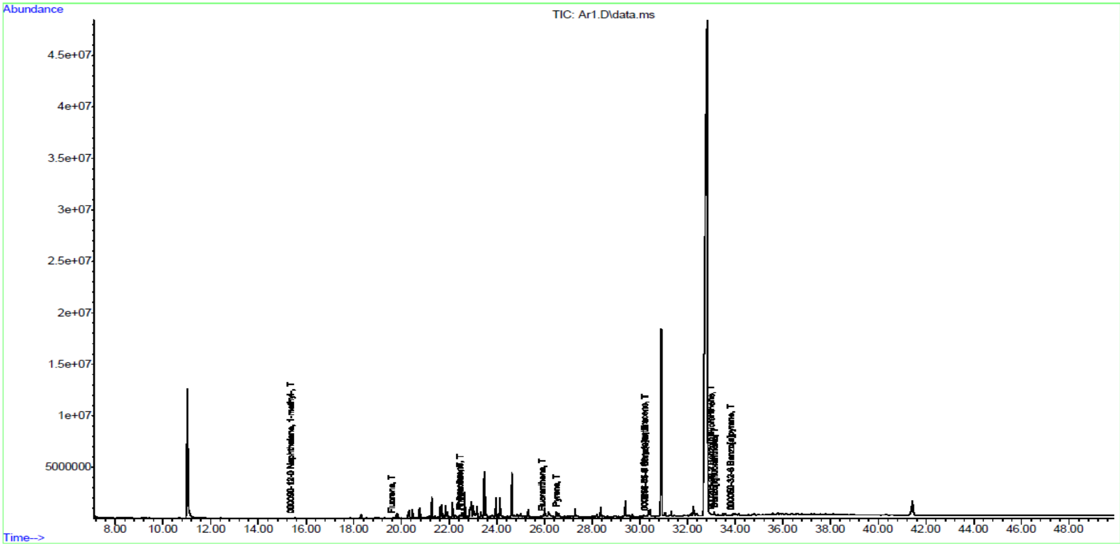
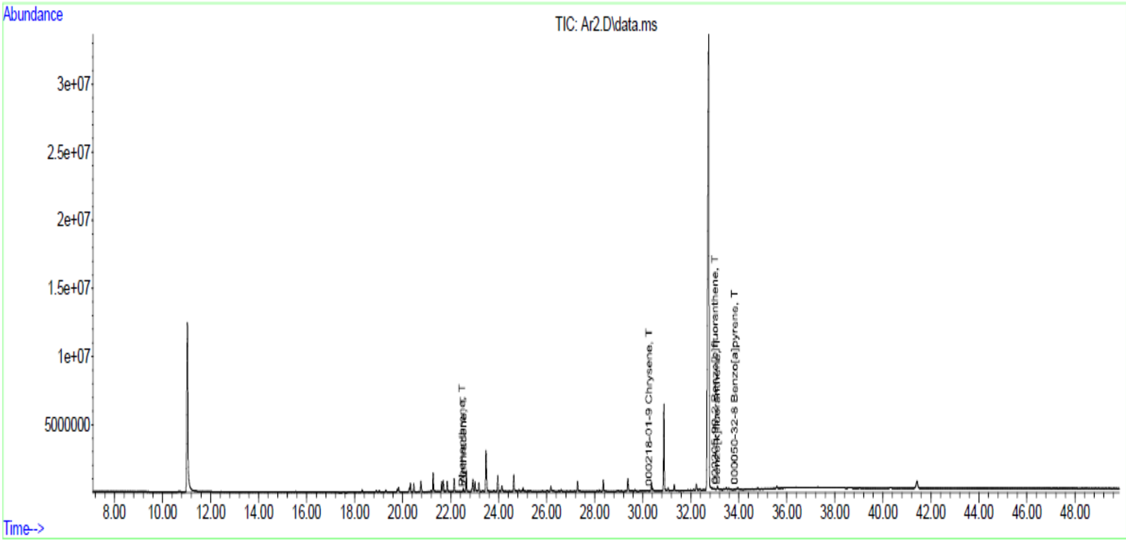
https://doi.org/10.21070/ijhsm.v2i2.98





Indonesian Journal on Health Science and Medicine
Vol 2 No 1 (2025): January
ISSN 3063-8186. Published by Universitas Muhamamdiyah Sidoarjo

https://doi.org/10.21070/ijhsm.v2i2.98

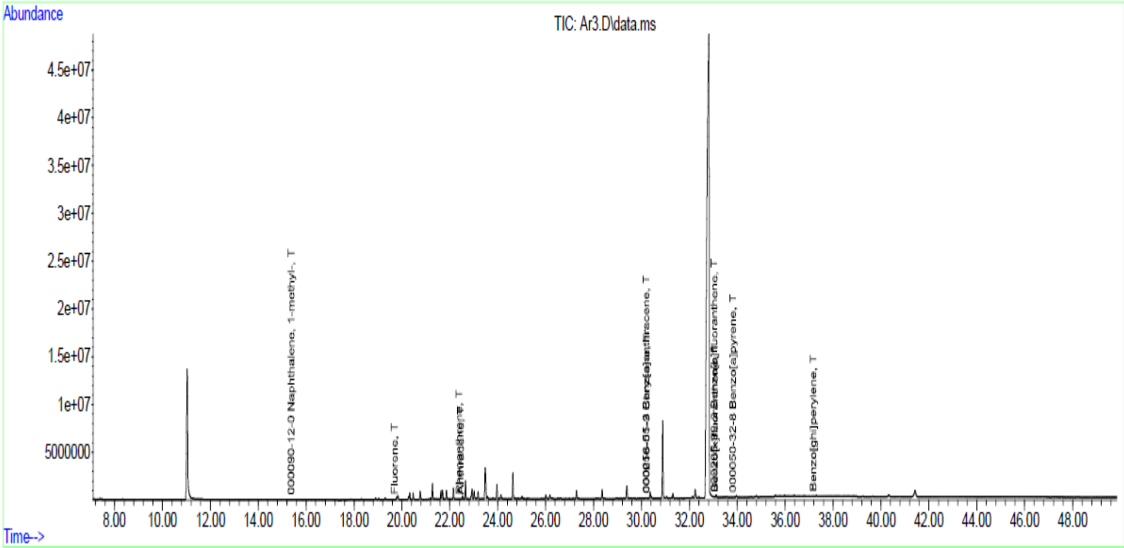


Figure 2 shows representative PAH chromatograms in soil samples from the locations under study at various times of the year.

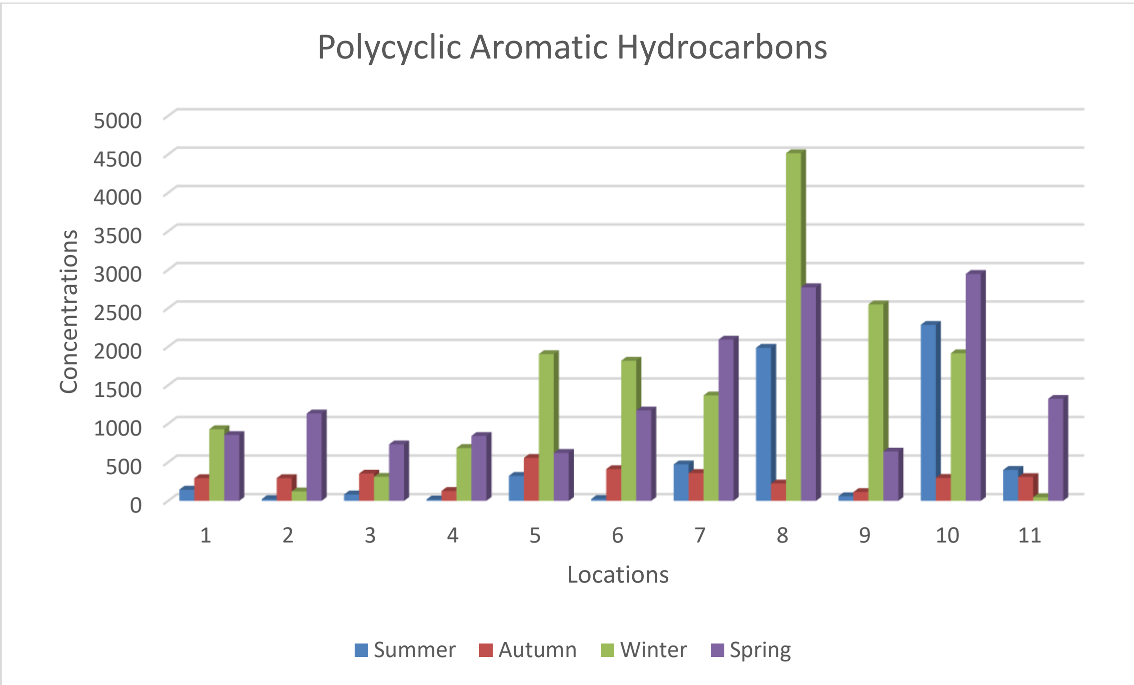


Figure 3: Polycyclic Aromatic Hydrocarbons (ng/g) at oil fields by season and average concentration.

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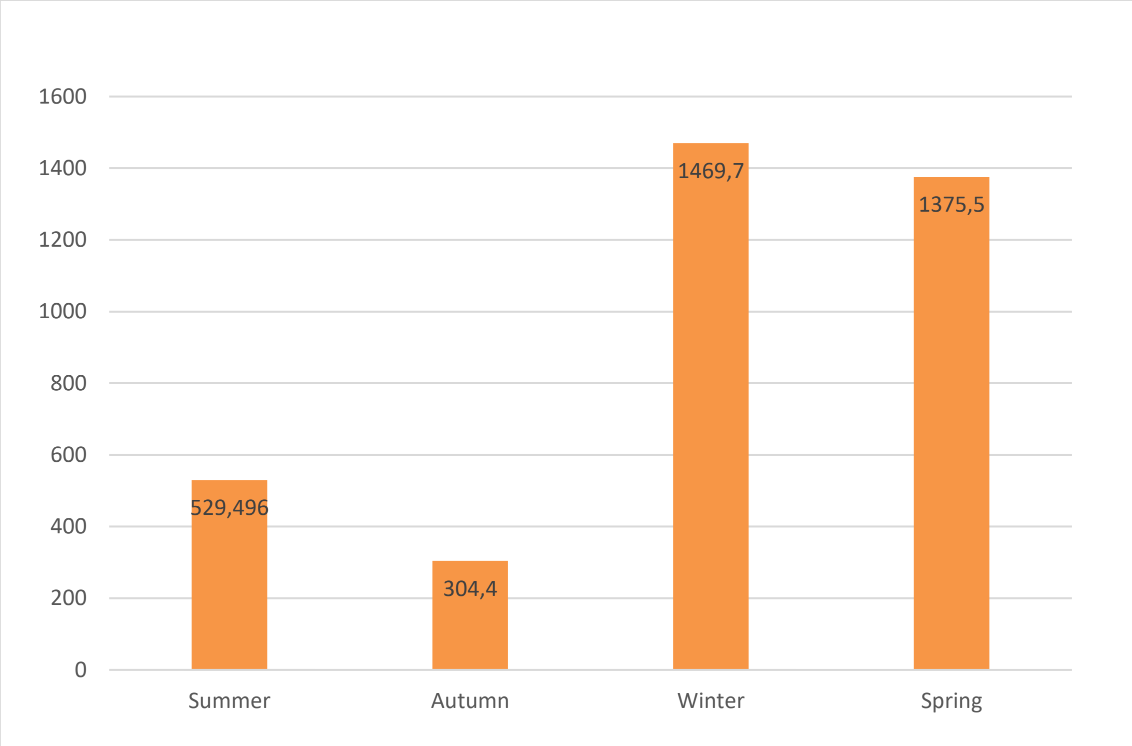

Figure 4: Seasonal Changes in Oil Field Polycyclic Aromatic Hydrocarbons (ng/g).

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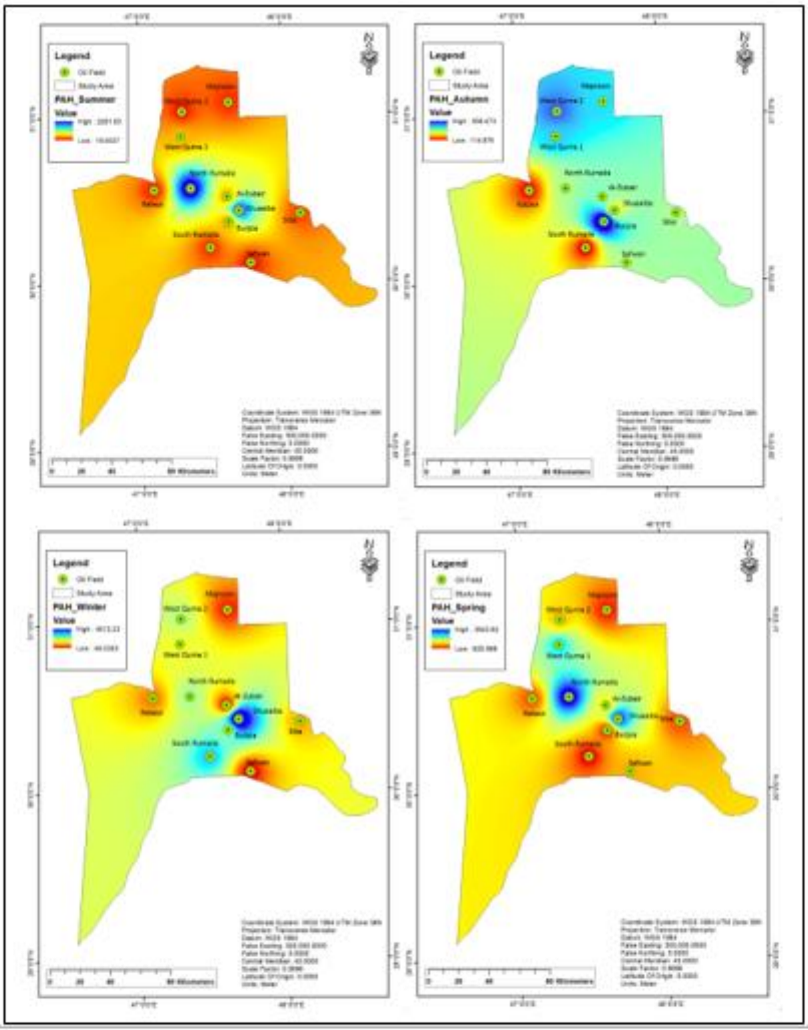

Figure (5): GIS' Maps of PAHs in The Studied Locations.

Table 6: Comparison of Current Surface Soil PAH Compound Concentrations (ng g-1 dw) with Prior Research in Iraq.

[35]	Kirkuk oil r'efinery	10.92 '- 26.92
[36]	industrial d'istrict Baiji - Kirkuk	94.9 – 4'16.3
[37]	Al-Ahdab 'oil field, Waset	19 – 855'
[38]	Nasiriyah' oil field	0.003 – 7'3.462
[39]	Agricult'ure fields in Baghdad	0.21 - 30.2'
[40]	Agricul'ture fields in Baghdad	99.1 – 322.'6
[41]	AL-na'hrawan bricks factory, Baghdad	64910 – 245'005

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[42]	AL –` zubaidiya Thermal Power Plant, Bag'hdad	22790 – 4555'0
[43]	Oil `refinery and petrol stations in Sul'aymaniyah	55300'
[11]	Ki'rkuk province	26.4 – `42.79
[44]	B'asrah city	531.21 `- 5737.23
Current study'	`selected station	18.4-451'5

Conclusion

In summary, this work established a baseline of the PAH compound pollution that results from natural gas combustion and crude oil spills in the Basrah oil field. Their molecular weight led to their classification into two main groupings. The first group consisted of six compounds: anthracene, fluorene, phenanthrene, acenaphthylene, and naphthalene. These light (low molecular weight) compounds have two to three fused aromatic rings. Flouranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b), benzo(k), benzo(a), indeno(1,2,3,c,d), and benzo(g,h, i)perylene are the nine compounds that make up the second group. These substances were hefty (high molecular weight) and had more than four fused aromatic rings. Ratawi Station has the lowest concentration of PAHs in the summer (18.4 ng/g to dry weigh). In contrast, Shuaaba Station has the greatest concentration in the winter (4515 ng/g dry weigh), per the regional PAH results for the current study. Furthermore, the mean concentrations of total PAHs in soil are lowest at Majnoon Station (370.672 ng/g dry weight) and greatest at Shuaaba Station (2374.85 ng/g dry weight).

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