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Evaluation of Aromatic hydrocarbons (PHAs) in some drinking water wells in Baghdad

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Abstract

Polycyclic Aromatic Hydrocarbons (PAHs), which are chemical molecules, have been causing numerous health and environmental issues in water supplies. This study investigated the levels of PAHs in groundwater samples collected from the Diyala Bridge and Al-Ahdamiyah districts between March and June 2023. Ten groundwater samples were collected from different locations; six wells were distributed in the Diyala Bridge area and four in the Adhamiya area. The results show that the average total amounts of PAHs in each water sample in Diyala Bridge and Al-Ahdamiyah districts ranged between 16.0 – 472.63 ppm with a mean of 213.13ppm, which is significantly higher than the ten ppm control. During the study period, Several locations reported noticeably elevated concentrations of one or both of the chosen PAHs. The highest concentration of PAHs was recorded for the chrysene compound at the Abu-Hassan site of 284ppm, followed by pyrene and acenophthylene, with a concentration of 167.8 and 131.7ppm, respectively. The lowest concentrations were for Naphthalene, which were 0.0213 and 0.041 in Qassim and Abu-Hassan wells, respectively. It also noted that high concentrations were recorded for all PAHs at the Mohammed, Ahmad, and Qassim wells, which exceeded significantly for other sites. This research advice focuses more on the risk evaluation of PAHs for well water sources when used for drinking.

Keywords: Polycyclic aromatic hydrocarbons; Wells; Groundwater; GC; Al-Ahdamiyah city.

تقييم المركبات الأروماتية في بعض الابار المستخدمة للشرب في مدينة بغداد

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الخلاصة

في الآونة الأخيرة، هناك العديد من المشاكل الصحية والبيئية في مصادر المياه التي تأتي من نوع واسع من المركبات الكيميائية واحدى هذه المركبات هي الهيدروكربونات العطرية متعددة الحلقات (PAHs). تمت في

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هذه الدراسة دراسة تراكيز الهيدروكربونات العطرية متعددة الحلقات في عينات المياه الجوفية في مدينتي جسر ديالى والاعظمية خلال الفترة من آذار إلى حزيران من عام 2023. تم جمع 10 عينات من المياه الجوفية من مواقع مختلفة توزعت 6 ابار في منطقة جسر ديالى و4 ابار في منطقة الاعظمية. أظهرت النتائج أن متوسط تركيزات PAHs في عشر عينات مياه مختلفة في منطقة جسر ديالى والأعظمية تراوح بين 16-472.63 جزء في المليون بمتوسط 213.13 جزء في المليون، وهي أكبر بكثير من التراكيز الموصى بها (10 جزء في المليون) بحسب منظمة الصحة العالمية WHO. خلال فترة الدراسة، لوحظت مستويات عالية وبشكل ملحوظ من واحد أو اثنين من الهيدروكربونات العطرية متعددة الحلقات المختارة في بعض المواقع. تم تسجيل أعلى تركيز لمركبات PAHs في موقع أبو حسين بواقع 284 جزء في المليون، يليه مركب البيرين والأسينوفثيلين بتركيز 167.8 و131.7 جزء في المليون على التوالي. وكان أدنى تركيز للنفثالين 0.0213 و 0.041 في بئر قاسم وأبو الحسن على التوالي. كما لوحظ أنه تم تسجيل تراكيز عالية لجميع الهيدروكربونات العطرية متعددة الحلقات في ابار محمد و احمد وقاسم والتي تجاوزت بشكل التراكيز المسجلة في المواقع الأخرى. ينبغي أن نولي المزيد من الاهتمام لتقييم مخاطر الهيدروكربونات العطرية متعددة الحلقات في مياه الآبار في المنطقة المدروسة عند استخدامها للاغراض الشرب.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a broad class of chemical compounds with two or more benzene rings in their structure. The primary sources of PAHs are anthropogenic activities, industrial emissions, incomplete combustion of fossil fuels, including coal and oil, and household activities. [1, 2]. These substances are extensively found in soils, sediments, water, and the aquatic environment. Even though there are over 100 distinct kinds of PAHs, [3] most analyses and data reports usually concentrate on between 14 and 20 specific PAHs on average. Two groups of PAHs may be distinguished: low molecular weight compounds, or 2- and 3-ring (molecular weight 200 g/mol), constitute the first group. According to [4], pure PAHs are typically colored, crystalline solids at room temperature with high melting and boiling temperatures, low vapor pressures, and extremely limited solubility in water. These substances are lipophilic and highly soluble in organic solvents.

Globally, numerous investigations of PAHs in soils, water, and sediment from many nations, including Germany [5], China [6], and the USA [7], have found PAHs in Chennai, Tamil Nadu, and India's groundwater. The behavior of PAHs in China's Yellow River's surface and groundwater has been studied by Li et al. [8,9]. In Bosnia and Herzegovina, there are few systematic investigations on PAH contamination in surface soil and sediments, and no studies have ever been done on PAHs at various soil depths.

Analyses of PAHs in soil, water, and sediment were done locally. Salah et al. [10] examined the sediment and water in the southern portion of Al-Hammar Marsh. PAHs were analyzed in the Tigris and Euphrates rivers [11, 12-13] and in the surface water of Al-Dalmaj Marsh, Al-Diwaniya Province, Iraq [14, 15]. Although there has been little research into PAHs in Iraqi groundwater resources, some have been conducted in Sulymaniya City [16] and Basrah [17]. This study investigated the levels of PAHs in groundwater in an agricultural and industrial area of Al Ahdamiyah City and the Diyala Bridge in Baghdad.

1.1Study area

The research area is located in the centre of Baghdad, namely in Diyala Bridge and Al-Ahdamiyah districts (Fig. 1). The average yearly temperature is 9.64 0C for the lowest and 35.39 0C for the highest. The potential evaporation and annual rainfall range from 0.04 to 24.6 mm and 66.85 to 530 mm [18], respectively. In Baghdad, groundwater serves as a backup water supply. From a geological perspective, the three main geological ages are Pleistocene, Quaternary deposits, and Holocene [19]. The sand and gravel aquifers were found 8 to 20 m deep in the study area [20].

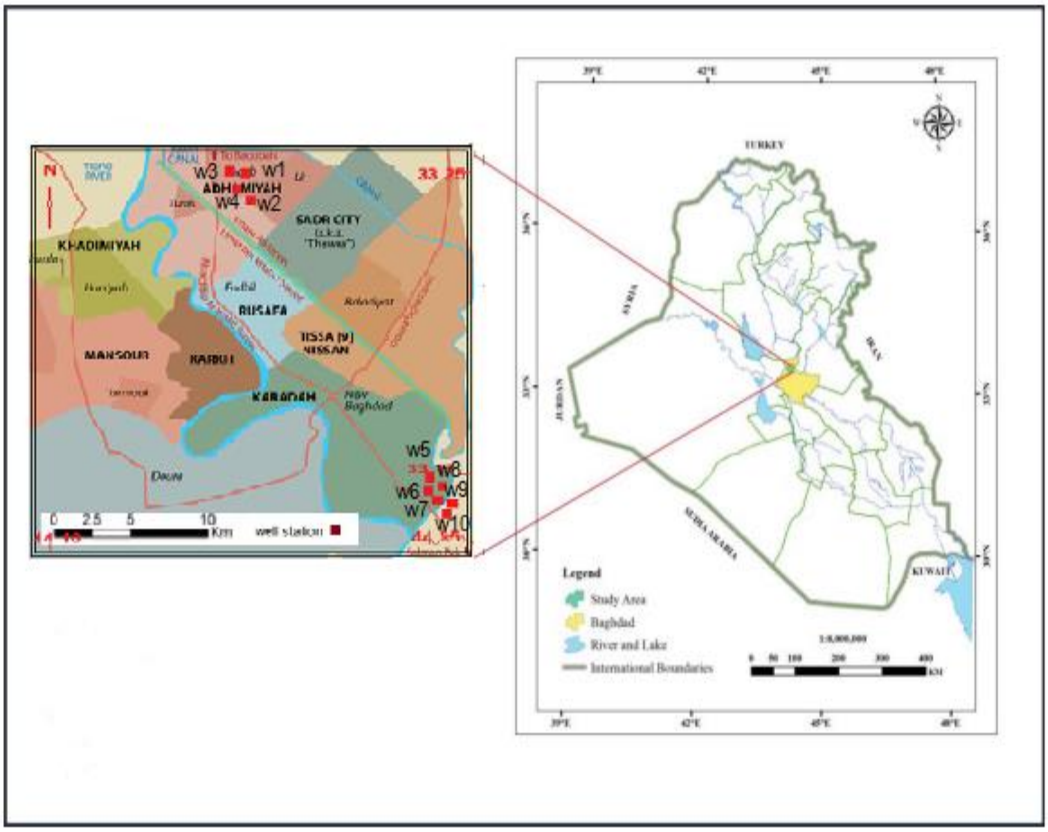

Figure 1: Map of the study area

2. Materials and methods

2.1Sampling

A total of 10 groundwater samples were collected from Diyala Bridge and Al-Ahdamiyah district in Baghdad City. The depth of the wells ranged from 17-28 m Table 1. The groundwater samples were collected during March-June 2023.

Table 1: Name, symbol and depth of wells in the study area.

Well name	Symbol	Well depth	Coordination	Well name	Symbol	Well depth	Coordination
Abu-Hassan	W1	18	33°23'56.4"N 44°21'00.8"E	Fish shop	W6	27	33°14'10.7"N 44°32'33.5"E
Haji Sadeq	W2	17	33°24'04.9"N 44°21'16.4"E	Abu-ali	W7	18	33°14'09.5"N 44°32'35.6"E
Abu-Zaid	W3	19	33°24'01.9"N 44°21'20.1"E	Mohammed	W8	19	33°14'09.2"N 44°32'37.0"E
Al-Basatine	W4	18	33°23'56.8"N 44°21'26.0"E	Ahmad Ro	W9	28	33°14'09.6"N 44°32'36.9"E
Abu-Hassan	W5	27	33°14'07.0"N 44°32'33.4"E	Qassim	W10	26	33°14'09.7"N 44°32'36.3"E

Gas chromatography was utilized to perform chemical tests for sixteen different forms of PAHs (GC). Acidity (pH), EC and Temp are measured at the site. Components of PAHs (Low and High molecular weight PAHs were analyzed as shown in (Fig 2).

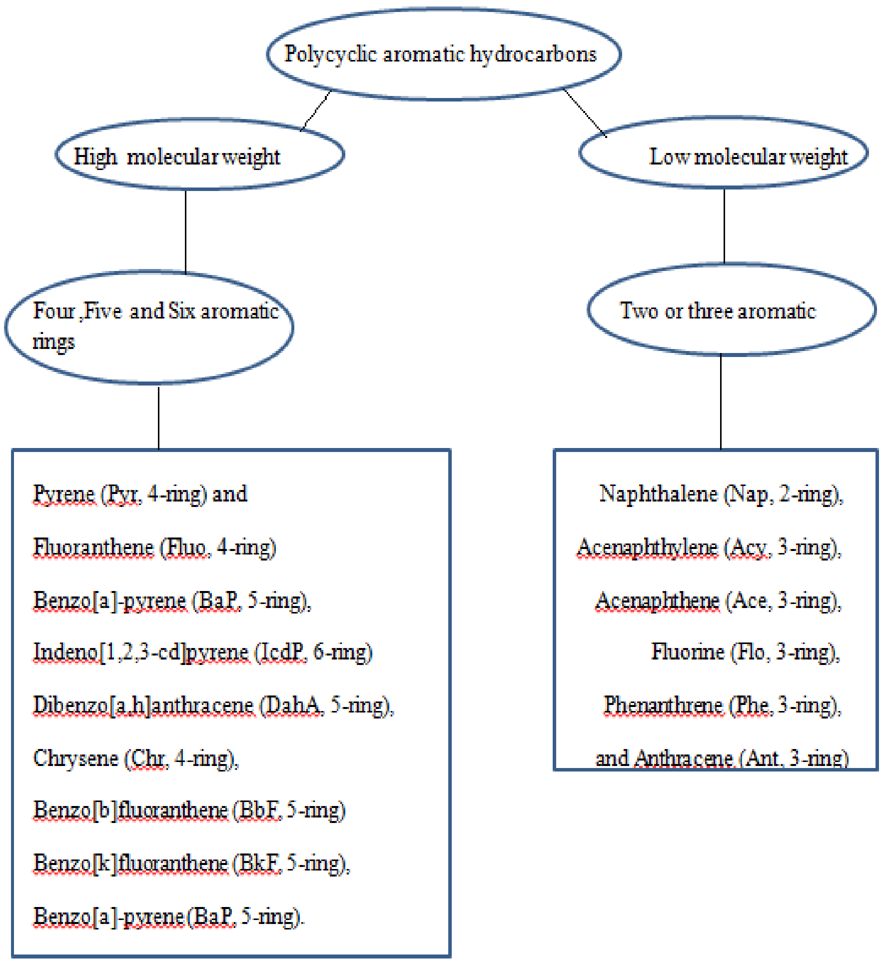

Figure 2: Low and High Low and High molecular weight PAHs.

2.2 Extraction

In this study, water samples were extracted using liquid-liquid extraction mode. After shaking the sample well, a volume of (100 ml) was taken from the active samples, and 50 ml hexane was added, then shaken well and left for an hour; after the samples were placed in the centrifuge for (10 minutes) at the highest rotation (10,000 revolutions per minute, then only the upper liquid is withdrawn, filtered, and injected into the GC to define the PAHs. The extraction and disintegration techniques were analyzed based on the principles described in standard methods [21, 22].

2.3 GC analytical conditions

The analyses were separated by liquid/liquid chromatographic separation using a Gas Chromatograph (Shimadzu, Japan). The quantities of PAHs were determined by utilizing the calibration curves of the standards and extrapolating the peak area.

The gas chromatography conditions are as follows:[23]

Colum :DN-5 (30 m * 0.32 mm) .

The Injection : (280 ^{0}C).

Carrier gas: N_2

Flow rate: 1.5ml/min.

FID (300^{0}C).

Thermal program: (110 C(1min)-190C@12C/min-210@6C/min-250C@3C/min).

2.4 Measurement

In the first step of measuring, the stability of gas pressure and different temperatures in the GC device is a very important issue. Ten microliters of the sample were injected into the syringe chamber using a laboratory glass syringe of 25 microliters at a temperature of 280 °C, after which evaporation of the sample occurred towards Colum, Which separates the organic compounds according to the degree of evaporation and within the above thermal program. Then, the separated organic compounds go to the detector (FID) (300m), which diagnoses all the organic compounds in the form and gives an electrical signal to the calculator screen to show all the compounds in the form of peaks and a unique table with its values. Concentrations are calculated according to the following mathematical equations:[24].

$$(1)\boldsymbol{C\ sample} = \frac{\boldsymbol{Area\ sample}}{\boldsymbol{Area\ St.}} * \boldsymbol{C\ ST}$$

3. Results and Discussion

1. Physical properties of studied locations

The physical characteristics of groundwater samples in the research region are shown in Figures 2,3and 4. Well (W9) was the deepest (28m) recorded well in the research region, while well (W2) had the shallowest reported depth of 17 m. The maximum values for ion hydrogen (pH), total dissolved solids (TDS), electrical conductivity (EC), and temperature (T) were 7.6, 7455 ppm, 9020 S/cm, and 23 C. Correspondingly, for wells W1, W4, W5, W9, and W10. TDS levels in water samples, the most measured component of electrical conductivity, were higher than WHO and Iraqi standards. High EC and TDS levels in water samples from the investigated wells may be due to rock weathering or anthropogenic sources such as sewage, industrial, or urban runoff.

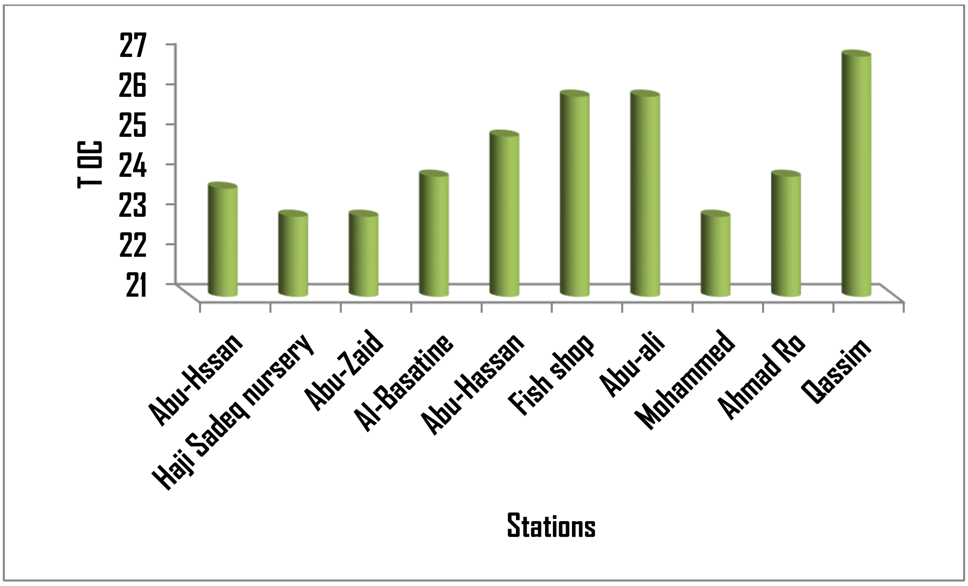

Figure 2: Distribution of temperature values in studied wells.

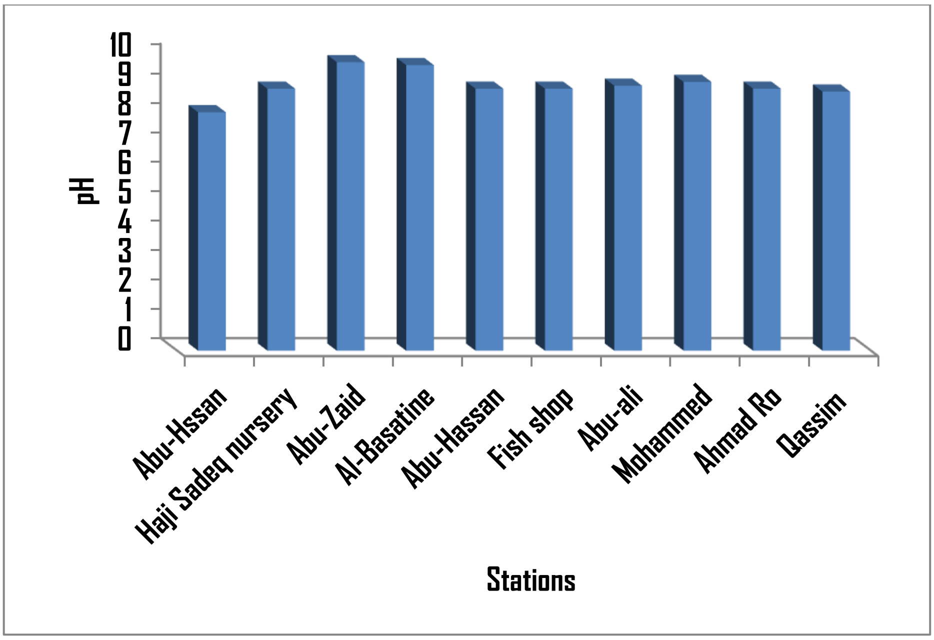

Figure 3: Distribution of pH values in studied wells.

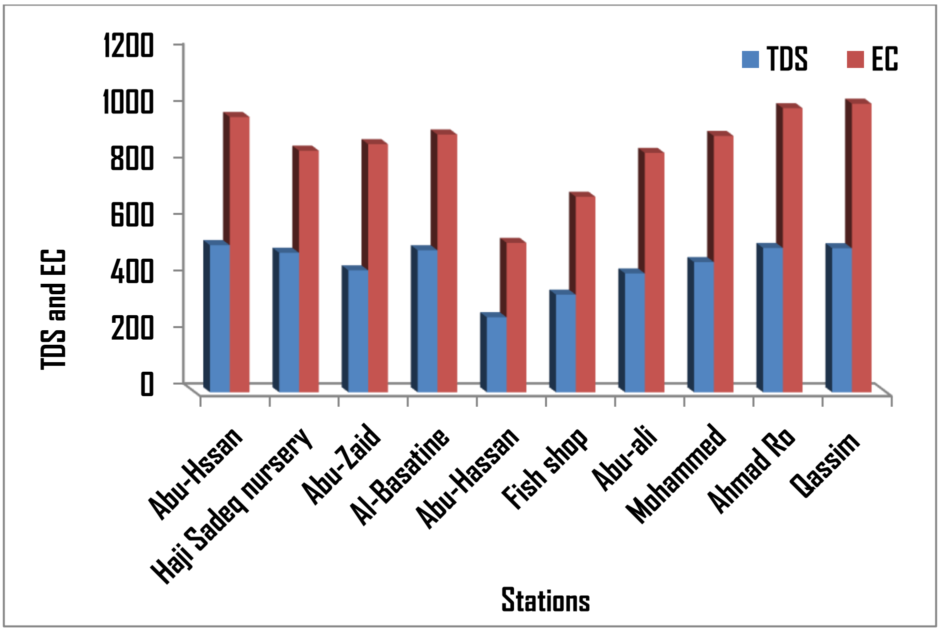

Figure 4: Distribution of Electrical conductivity (EC) and TDS values in studied wells.

2. Concentration of PAHs at various locations

The analytical results of the PAHs in groundwater samples from Al-Ahdamiyah and Diyala Bridge regions are presented in Tables 2 and 3.

Table 2: The concentration of PAHs in wells locations in Al-Ahdamiyah region in ppm.

PAHs ST.	Conc.	A st	Abu-Hssan	Haji Sadeq	Abu-Zaid	Al-Basatine
Naphthalene	10ppm	6825.07	0.041	0.0414	0.05	
Naththalene	10ppm	229.53				0.79
Flurobipheyl	10ppm	178.78				
acenopthene	10ppm	8.741				
acenophthylene	10ppm	29.926		2.61	4.69	
Fluorene	10ppm	22.77				
phenanthrene	10ppm	13.04		52.7	33.3	49.9
benzo [ghi] perylene	10ppm	139.58				
pyrene	10ppm	0.717	167.8			
benzo[a]anthracene	10ppm	138.337				6.43
benzo[k]fluomethene	10ppm	313.028				
chrysene	10ppm	2.983			71.7	
benzo[a] fluoranthene	10ppm	0.032				
benzo[a] pyrene	10ppm	22.212				
Di benzo[ah] anthracene	10ppm	3.349				
			167.841	55.3514	109.74	57.12

- **10ppm is the concentration of standard**

Table 3: The concentration of PAHs in wells locations in the Diyala Bridge region in ppm.

PAHs ST.	Conc.	A st	Abu-Hassan	Fish shop	Abu-Ali	Mohammed	Ahmad Ro	Qassim
Naphthalene	10ppm	6825.07			0.029	0.083	0.08	0.0213
Naththalene	10ppm	229.53			2.15	20.05	12.411	5.192
Flurobipheyl	10ppm	178.78					14.346	4.064
acenopthene	10ppm	8.741				53.54		10.87
acenophthylene	10ppm	29.926				131.7	73	
Fluorene	10ppm	22.77			12.53			
phenanthrene	10ppm	13.04				0.45	76	51.606
benzo [ghi] perylene	10ppm	139.58				44.603	25.456	20.81
pyrene	10ppm	0.717	53	165		3.471	55	81.478
benzo[a]anthracene	10ppm	138.337	3.63	1.2				1.198
benzo[k]fluomethene	10ppm	313.028				21.311	2.215	0.413
chrysene	10ppm	2.983		284		92.1	74.34	
benzo[a] fluoranthene	10ppm	0.032	5.97		1.295	60.81	50.79	4.089
benzo[a] pyrene	10ppm	22.212				41.49		1.342
Di benzo[ah] anthracene	10ppm	3.349		70.9		1.46	89	6.79
			62.6	521.1	16.004	471.068	472.638	187.8733

- **10ppm is the concentration of standard**

The average PAHs in each of the ten distinct water samples varied from 16.0 to 472.63 ppm with an average of 213.13 ppm, far greater than that in control (10 ppm). It suggested that the PAHs originated from non-point sources such as runoffs or industrial effluents from local industry units. This study has no clear pattern in the PAHs values due to differences in well depth and lithology.

Significantly elevated concentrations of one or both of the chosen PAHs were observed at several locations throughout the research period. The highest concentration of PAHs was recorded for the chrysene compound at the Abu-Hassan site at 284 ppm, followed by pyrene and acenophthylene with a concentration of 167.8 and 131.7 ppm, respectively. The lowest concentrations were for Naphthalene, 0.0213 and 0.041, in the Qassim and Abu-Hassan sites, respectively. It was also noted that high concentrations were recorded for all PAHs at Mohammed, Ahmad RO, and Qassim, which exceeded significantly for other sites. On the other hand, it can be seen from Table 2 that some of the PAH concentrations decreased with the depth of the wells in the studied area. A similar result was a decrease in the concentration of ∑16PAHs by reducing the depth in the study area.

The average concentration of ∑PAHs in the Diyala Bridge area exhibited the following trend: Fish shop > Ahmad Ro > Mohammed > Qassim > Abu-Hassan > Abu-Ali. In contrast, the average concentration of ∑PAHs in Al-Ahdamiyah region in the sites is in the order of Abu-Hssan> Abu-Zaid > Al-Basatine > Haji Sadeq.

The percentage of ∑PAHs in the studied area (Diyala Bridge and Al-Ahdamiyah regions) indicates the variation in total concentrations of PAHs due to the different sources of those concentrations (Figures 5 and 6).

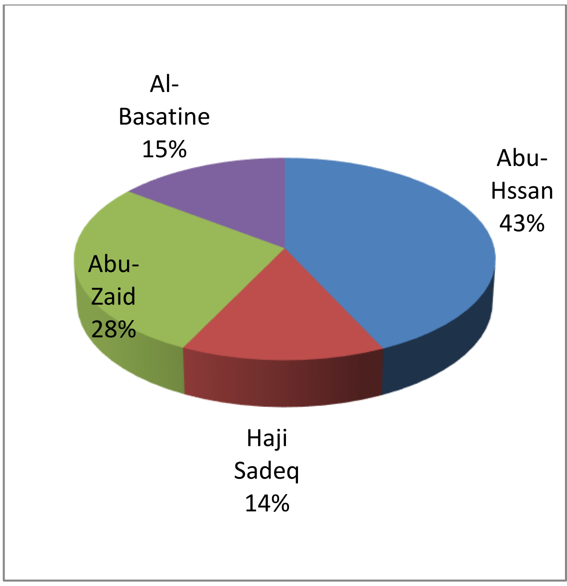

Figure 5: PAHs % in Jisser Diyala region.

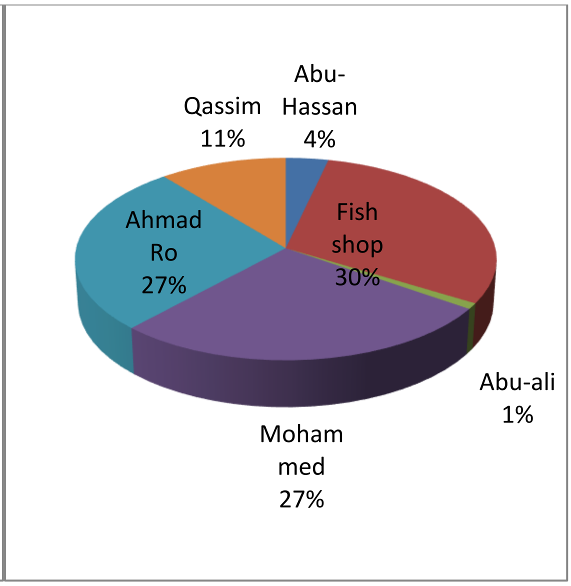

Figure 6 :PAHs % in Al-Ahdamiyah region.

The PAH levels in the groundwater under investigation, as shown in Table 4, were much higher than the maximum contaminant limits (MCLs) for drinking water set by the European Community (EC) [25] and the United States Environmental Protection Agency (USEPA) [26]. The results achieved in the current study were, for the most part, 100–1000 times greater than the established criteria.

Table 4: PAH standards in drinking water.

PAHs	MCL in µg/µL (EC)	MCL in µg/µL (USEPA)
Naphthalene	-	-
Acenaphthylene	-	-
Acenaphthene	-	-
Fluorene	-	0.0002
Phenanthrene	-	0.0002
Anthracene	-	0.0002
Fluoranthene	0.00003	-
Pyrene	-	0.0002
Benzo (a)anthracene	-	0.0002
Chrysene	-	0.0002
Benzo (b)fluoranthene	0.00003	0.0002
Benzo (k)fluoranthene	0.00003	0.0002
Benzo (a) pyrene	0.00003	0.0002
Indeno(1,2,3-cd)pyrene	0.00003	0.0002
Dibenzo(a,h)anthtracene	-	0.0002
Benzo (g,h,i) perylene	0.00003	-

MCL - Maximum contaminant level, EC - European Community, USEPA – United States Environmental Protection Agency.

The World Health Organization set 0.2 µg/L as the maximum permissible limit for total PAHs in drinking water while that of benzo(a) pyrene (0.1 µg/L).[27]
Al-Paruany [28] studied the groundwater in Baghdad and concluded that there is a mixing or interaction between groundwater and surface water with the Tigris River throughout Baghdad city. This mixing or interaction may be a major source of aromatic compounds in the groundwater wells adjacent to the Tigris River in the Dyala Bridge and Adhamiyah districts and other sources represented by human and industrial activities. In addition, other natural factors such as geology (lithology) and climate parameters (runoff, temperature, and humidity) are also included. Finally, the results of this study reflect the effects of industrial origin and may provide basic data for the remediation of PAHs in the location, especially in the Diyala Bridge district.

4. Conclusions

The results of this study showed that twelve PAHs were detected. The results indicated no discernible correlation between the occurrence or composition of PAHs found in the water samples and variations in well depth and lithology.
In this study, In most cases, the values obtained in this work were about 100 to 1000 times higher than the set standards. The mixing or interaction may be a major source of aromatic compounds in the groundwater wells adjacent to the Tigris River in the Adhamiyah region and adjacent to the Diyala River, as well as other sources represented by human and industrial activities, In addition, other natural factors such as geology (lithology) and the interaction between groundwater and surface water (Diyala River). Generally, The concentration of PAHs in groundwater sources in the Diyalal Bridge and Adhamiyah districts is high. So, more attention to PAHs risk assessment for the well water sources is recommended when used for drinking.

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