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Distribution and sources of PAHs in Wheat (*Triticum aestivum*) and Barley (*Hordeum vulgare*) Cultivated in northern Basrah Governorate, Iraq

Fatimah I.AL-Zubaidi Widad M.T. Al-Asadi* Frias M.H. Al-Khatib
Department of Ecology, College of Science, University of Basrah, Basrah,Iraq
* Corresponding author: widad.taher@uobasrah.edu.iq

Abstract
Polycyclic aromatic hydrocarbons (PAHs) are persistent environmental pollutants with carcinogenic and mutagenic properties, and often enter the food chain through contaminated soil and crops. This study examined the distribution and sources of polycyclic aromatic hydrocarbons (PAHs) in wheat and barley crops grown at three stations in Al-Qurna District, north of Basra Governorate. The first station was Nahr Al-Ezz, the second station was Al-Turaba, and the third station was Umm Al-Shuwaij. The results showed the presence of different concentrations of total PAHs in wheat and barley crops at all study stations, as follows: the first station was 0.0738 and 0.1012, the second station was 0.0220 and 0.1070, and the third station was 0.1341 and 0.1400, respectively. When comparing the pollution levels and sources with global data, the third station recorded the highest level of pollution. Significant similarities were found between the PAH content in the two crops and the dispersion patterns. When analyzing wheat and barley samples from three stations for PAHs, benzo[a]pyrene and other hazardous PAHs were present in varying quantities. Despite differences in the concentration levels and distributions of the compounds, the data show that PAH contamination is present in both crops.
Keywords: wheat, barley, PAHs, gas chromatography-mass spectrometry, *Triticum aestivum, Hordeum vulgare*

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Introduction

PAHs are formed during incomplete combustion of organic matter and petroleum products, posing health risks through food contamination. Cereals like wheat and barley are staple foods in Basrah and may accumulate PAHs from polluted soils and atmospheric deposition. Previous studies in Basrah soils revealed mixed petrogenic and pyrogenic PAH sources linked to oil industry emissions and vehicular traffic. (Karem,2016)

A common class of chemical molecules made u p of two or more fused benzene rings are know n as polycyclic aromatic hydrocarbons, or PAH s.Both natural (such as forest fires and volcanic activity) and manmade (such as the burning of f ossil fuels, industrial processes, home heating, a nd cooking) sources contribute to their extensiv e distribution in the environment. They are mai nly formed by the incomplete combustion or py rolysis of organic matter (Kadhim, 2019).

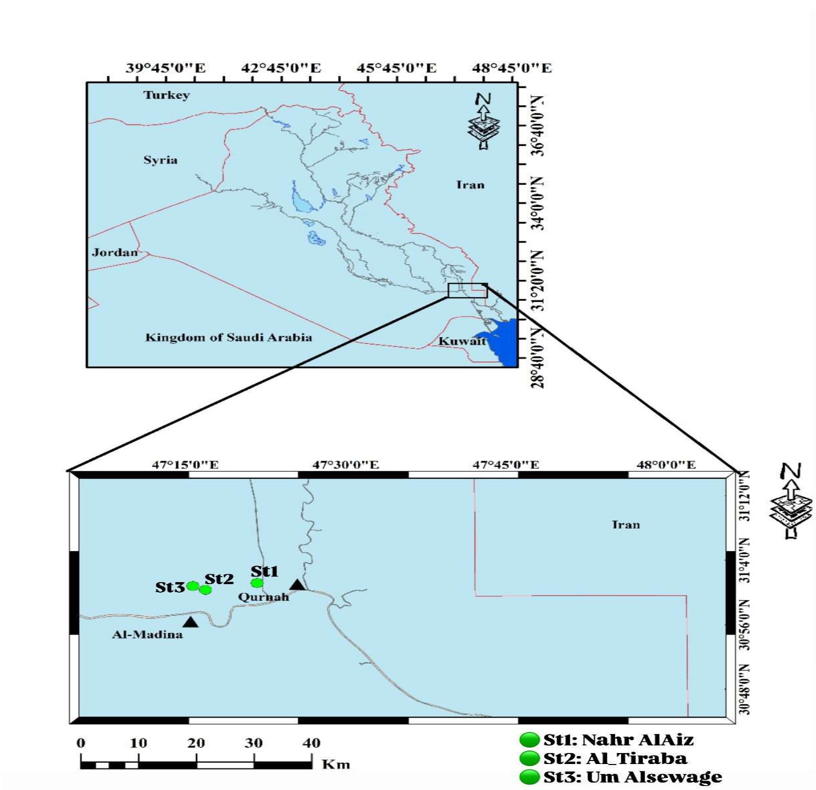
PAHs are classified as persistent organic polluta nts (POPs) because of their low water solubility , hydrophobicity, and chemical stability. These pollutants can build up in soil, water, and air, ca using serious problems for both human health a nd the environment (Resem,2024). Many PAHs are known for their mutagenic, genotoxic, and carcinogenic properties, making their presence in the food chain a critical food safety issue (Zhang *et al*.,2024).

Among agricultural crops, cereals like wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) are staple foods globally, making their contamination by PAHs a direct pathway for human exposure (Kobayashi *et al*., 2008) The presence of PAHs in these grains can result from several routes. Atmospheric deposition of airborne PAHs, originating from both distant and local emission sources, is a significant contributor, with plants capable of absorbing these compounds through their leaves and other aerial parts (Zhao *et al*., 2024). Soil contamination, stemming from long-term deposition or direct application of contaminated materials, also plays a crucial role, as PAHs can sorb to soil organic matter and subsequently be taken up by plant roots, although foliar uptake is

often considered more significant (Mackiewicz *et al*., 2022). Additionally, post-harvest processing methods, particularly those involving direct drying or smoking, can introduce or increase PAH levels in grains (Zhao *et al*., 2022). Understanding the distribution patterns and identifying the primary sources of PAH contamination in wheat and barley is therefore essential for developing effective strategies to mitigate risks to food safety and human health.
Environmental pollution by hydrocarbons, particularly polycyclic aromatic hydrocarbons (PAHs) and n-alkanes, is a growing concern in agricultural ecosystems near industrial zones. Basrah, located in southern Iraq, is a region heavily influenced by oil extraction and refinery operations. These activities contribute to air, water, and soil contamination, posing significant risks to crop safety and public health. Cereal crops such as wheat and barley are staples in the Iraqi diet. These crops can absorb pollutants from contaminated soil and atmospheric deposition. PAHs are recognized for their mutagenic and carcinogenic properties, can serve as biomarkers for hydrocarbon pollution.
This study aims to assess PAH levels in wheat and barley grains from Basrah, identify their sources, and compare findings with soil contamination data and international reports.

Materials and Methods

Sample Collection: Wheat and barley crop samples were collected from three selected stations in Al-Qurna District, north of Basra Governorate, during the growing season for both plants, from March to May 2024. Three selected stations were selected: Nahr Al-Ezz, Al-Turaba, and Umm Al-Shuwaija (Figure 1). After collection, the samples were brought to the laboratory, cleaned, and air-dried at laboratory temperature. They were left to dry completely, then ground with a ceramic mortar and sieved through a 63-micron sieve.



Fig(1) Sample location

After sample preparation, petroleum hydrocarbons (aliphatic and aromatic) were determined using the coxswale extraction method, as described in Grimalt and Oliver (1993).

To detect polycyclic aromatic hydrocarbon (PAH) components, all plant samples were confirmed using gas chromatography-mass spectrometry (GC-MS) using an Agilent/USA 7890B GC coupled with a 5977A mass-selective detector (MSD). The presence of some polycyclic aromatic hydrocarbons has been verified in each of them**.**

Results and Disscussion

The distribution and sources of PAHs in wheat and barley cultivated in 3 stations(St1: Nahr AlAiz, St2: Al-Tiraba, and St3: Um Alsewage) at Quarna in Basrah, Iraq, The total PAH concentrations are identical for wheat as shown in table 1 and figers (2,3,4,5) at each station:(St1: 0.0738, St2: 0.0220 , St3:0.1341) and for barley at St1: 0.1012 , St2: 0.1070 , St3: 0.1400 at shown in table 3 and fingers (6,7,8,9).The highest contamination occurs at St3 (Um Alsewage),

The presence of PAHs in wheat Table (1) and barley Table (2) reflects environmental contamination from Basrah's oil industry, vehicular emissions, and combustion processes. The lower PAH levels in grains suggest limited uptake or surface deposition. The mixed petrogenic and pyrogenic sources align with Basrah's industrial profile. PAH levels in Basrah cereals are within a similar range but vary with local pollution intensity (Mihai, 2024)

The main sources of PAHs in wheat and barley in Basrah are predominantly pyrogenic and petrogenic in origin. Pyrogenic sources, which are dominant, arise from combustion-related activities such as vehicle emissions, fuel combustion in power plants, electrical generators, waste incineration, and gas flaring associated with oil fields. Petrogenic sources stem from crude oil spills and petroleum-related pollution typical of Basrah's oil industry. These mixed sources contribute to PAH contamination in soils, which subsequently affects wheat and barley grown in the region (Saleem *et al*., 2023) While oil refineries and power plants contribute to PAH emissions, they are not the sole or primary sources in Basrah's wheat and barley fields. PAH emissions from industrial activities like oil refining, power generation, and municipal incineration are significant stationary sources (Saleem *et al*., 2023). However, PAHs in the environment, including in crops, arise from a broader range of sources.

In Basrah, the dominant sources are pyrogenic, resulting from incomplete combustion, and petrogenic, related to petroleum. Specific contributors include vehicle emissions, general fuel combustion, electrical generators, waste incineration, and gas flaring associated with the oil fields (Saleem *et al*., 2023). Workers in oil refining and related industries are exposed to PAHs, and these industrial activities contribute to the overall environmental burden (Resen, 2024). PAHs can be deposited onto plants through dry or wet deposition processes from the atmosphere and can also be absorbed by plant roots from contaminated soil.

The main sources of PAHs in wheat and barley as shown in tables (2 and 4) respectively in Basrah are predominantly:

Pyrogenic sources: Combustion-related activities such as vehicle emissions, fuel combustion in power plants, electrical generators, waste incineration, and gas flaring associated with oil fields.

Petrogenic sources: Crude oil spills and petroleum-related pollution typical of Basrah's oil industry.

These sources contribute to PAH contamination in soils and atmospheric deposition, which subsequently affect cereal crops.Oil refineries and power plants are significant contributors to PAH emissions in Basrah, but they are not the sole or primary sources affecting wheat and barley fields. Other important sources include:Vehicle emissions,Fuel combustion in electrical generators,Waste incineration and Gas flaring in oil fields Diagnostic ratios of PAHs in Basrah soils and environmental samples confirm this mixed source pattern, with a dominance of pyrogenic signatures in many locations, reflecting the extensive combustion-related activities in the region. Since wheat and barley are grown in these soils and exposed to atmospheric deposition, their PAH contamination reflects these combined sources. Compared our data of PAH leve in Wheat (*Triticum aestivum*) and Barley *(Hordeum vulgare*) are within a similar range but vary with local pollution intensity as shown in Table (5).

Table (1) Concentration of PAH compound (ng/g) in Wheat (*Triticum aestivum*)

Compound	**St1**	**St2**	**St3**
Naphthalene	0.0066	0.0005	0.0121
Naphthalene, 2-methyl-	0.0084	0.0012	0.0403
Naphthalene, 1-methyl-	0.0077	0.0017	0.0315
Acenaphthylene	0.0018	0.0003	0.0020
Acenaphthene	0.0066	0.0012	0.0062
Fluorene	0.0080	0.0037	0.0064
Phenanthrene	0.0203	0.0060	0.0123
Anthracene	0.0012	0.0002	0.0010
Fluoranthene	0.0051	0.0016	0.0076
Pyrene	0.0035	0.0016	0.0069
Benz[a]anthracene	0.0000	0.0000	0.0000
Chrysene	0.0004	0.0009	0.0032
Benzo[b]fluoranthene	0.0007	0.0004	0.0002
Benzo[k]fluoranthene	0.0014	0.0011	0.0028
Benzo[a]pyrene	0.0013	0.0002	0.0012
Indeno[1,2,3-cd] pyrene	0.0001	0.0000	0.0000
Dibenz[a,h]anthracene	0.0003	0.0005	0.0004
Benzo[ghi]perylene	0.0003	0.0007	0.0001
Total	0.0738	0.0220	0.1341

Table (2) Concentration of Indices PAH compound (ng/g) in Wheat (*Triticum aestivum*)

LPAHs	0.0606	0.0150	0.1119
HPAHs	0.0132	0.0070	0.0222
L/H	4.604556817	2.131315275	5.034883258
Phenanthrene/Anthracene	16.82577833	24.73609584	12.29734831
Fluoranthene/Pyrene	1.460319918	0.987171692	1.105728915
Indeno[1,2,3-cd] pyrene/Benzo[ghi]perylene	0.341419698	0	0

Benz[a]anthracene/Chrysene	0	0	0

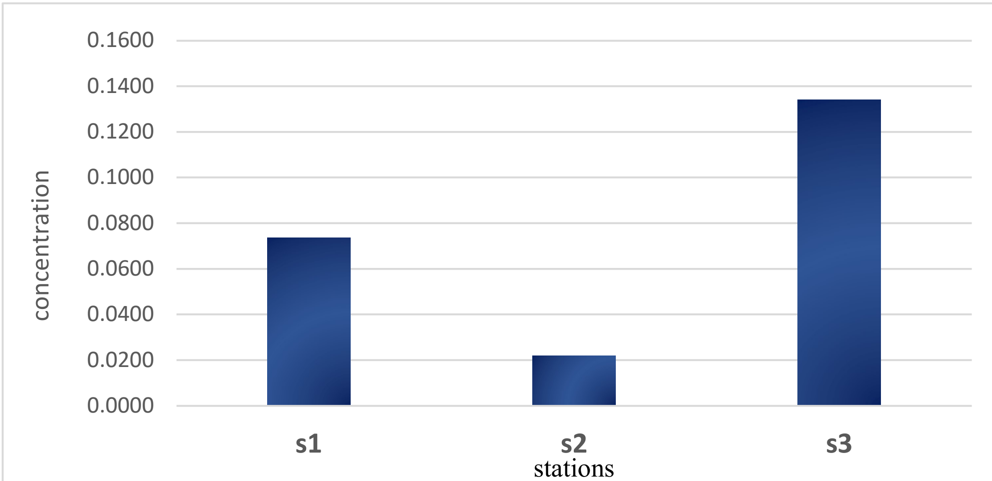


Fig (2) Total Concentration of Aromatic Compounds in Wheat

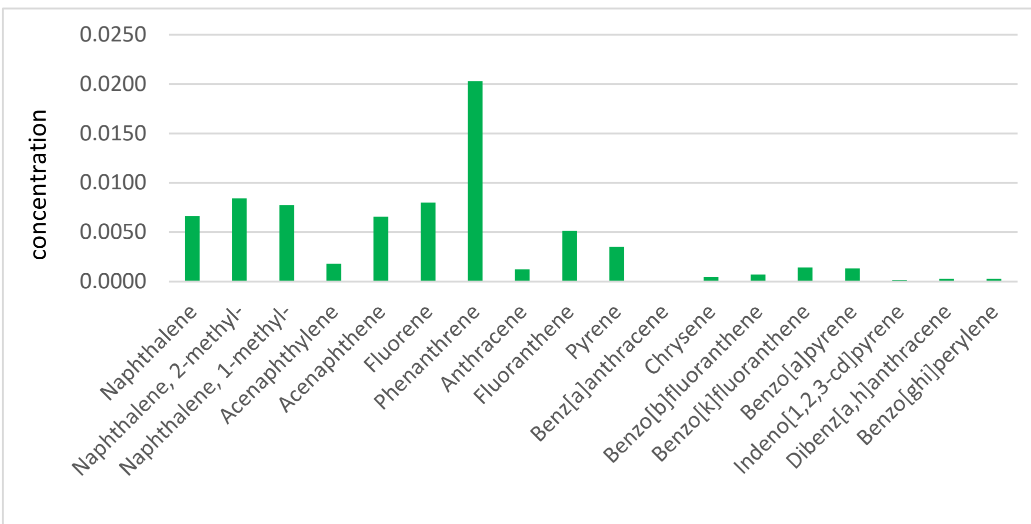


Fig (3) Concentration of Aromatic Compounds in the station 1

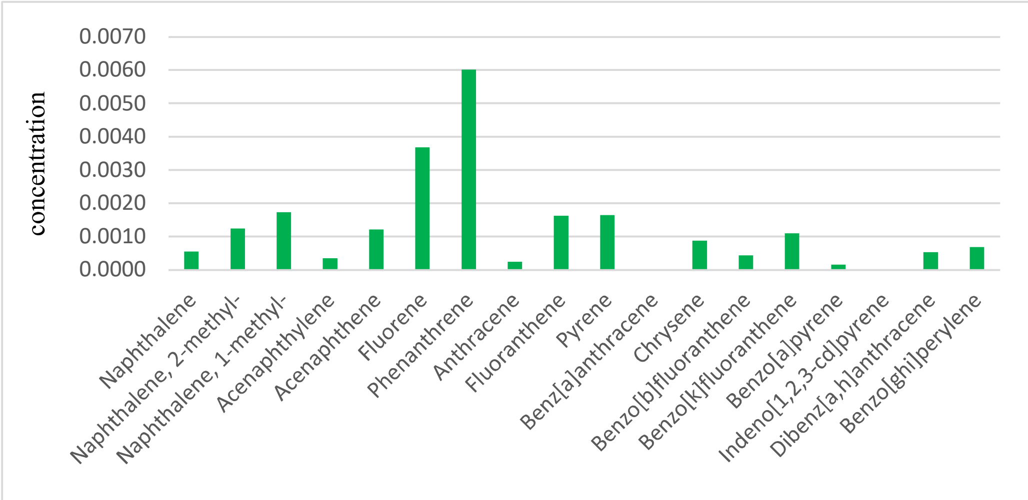


Fig (4) Concentration of Aromatic Compounds in the station 2

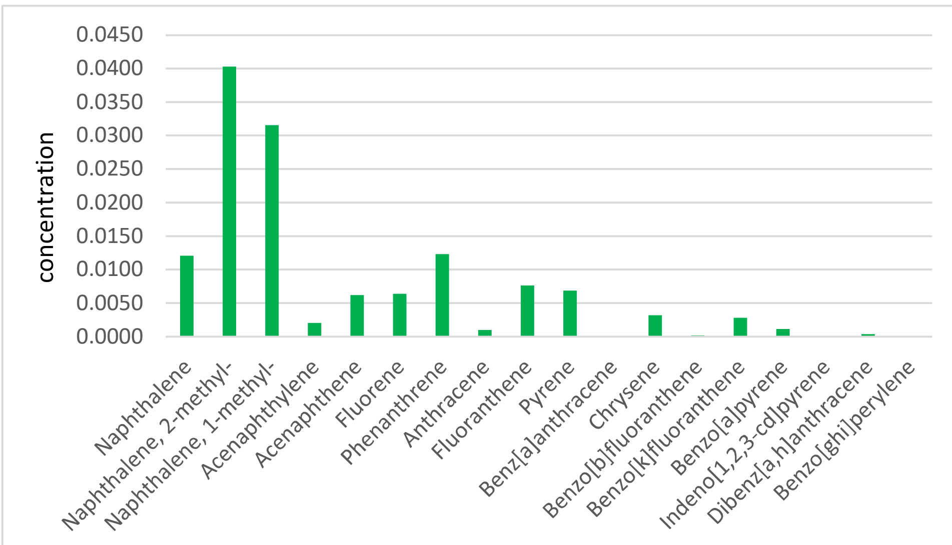


Fig (5) Concentration of Aromatic Compounds in the station 3

Table (3) Concentration of PAH compound (ng/g) in barley (*Hordeum vulgare*)

Compounds	St1	St2	St3
Naphthalene	0.0083	0.0044	0.0057
Naphthalene, 2-methyl-	0.0222	0.0363	0.0490
Naphthalene, 1-methyl-	0.0268	0.0314	0.0399
Acenaphthylene	0.0017	0.0024	0.0070
Acenaphthene	0.0063	0.0015	0.0047
Fluorene	0.0084	0.0063	0.0121
Phenanthrene	0.0134	0.0116	0.0118

Compounds	St1	St2	St3
Anthracene	0.0005	0.0003	0.0007
Fluoranthene	0.0024	0.0030	0.0014
Pyrene	0.0028	0.0030	0.0019
Benz[a]anthracene	0.0003	0.0007	0.0000
Chrysene	0.0006	0.0011	0.0000
Benzo[b]fluoranthene	0.0006	0.0017	0.0003
Benzo[k]fluoranthene	0.0044	0.0018	0.0040
Benzo[a]pyrene	0.0012	0.0007	0.0006
Indeno[1,2,3-cd]pyrene	0.0000	0.0001	0.0001
Dibenz[a,h]anthracene	0.0005	0.0003	0.0002
Benzo[ghi]perylene	0.0008	0.0004	0.0006
Total	0.1012	0.1070	0.1400

Table (4) Concentration of Indices PAH compound (ng/g) in in barley (*Hordeum vulgare*)

LPAHs	0.0876	0.0942	0.1309
HPAHs	0.0136	0.0128	0.0091
L/H	6.4412	7.35938	14.3846
Phenanthrene/Anthracene	26.8	38.6667	16.8571
Fluoranthene/Pyrene	0.8571	1	0.73684
Indeno[1,2,3-cd] pyrene/Benzo[ghi]perylene	0	0.25	0.16667
Benz[a]anthracene/Chrysene	0.5	0.6364	0

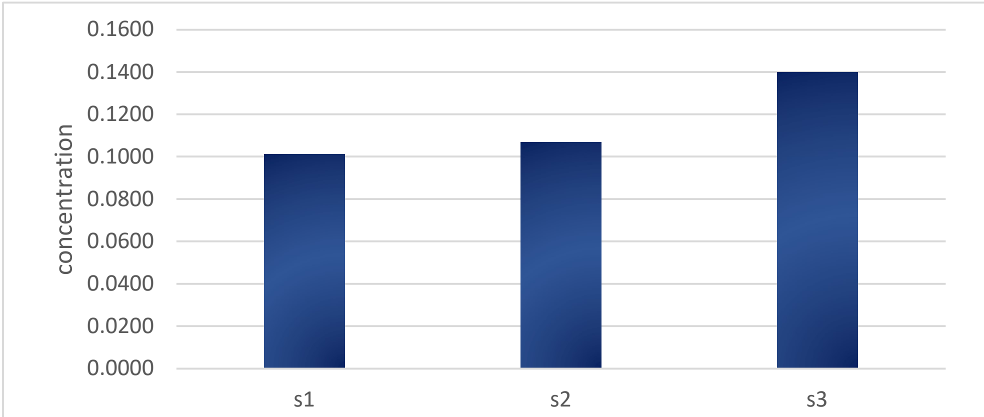


Fig (6) Total Concentration of Aromatic Compounds in Barley

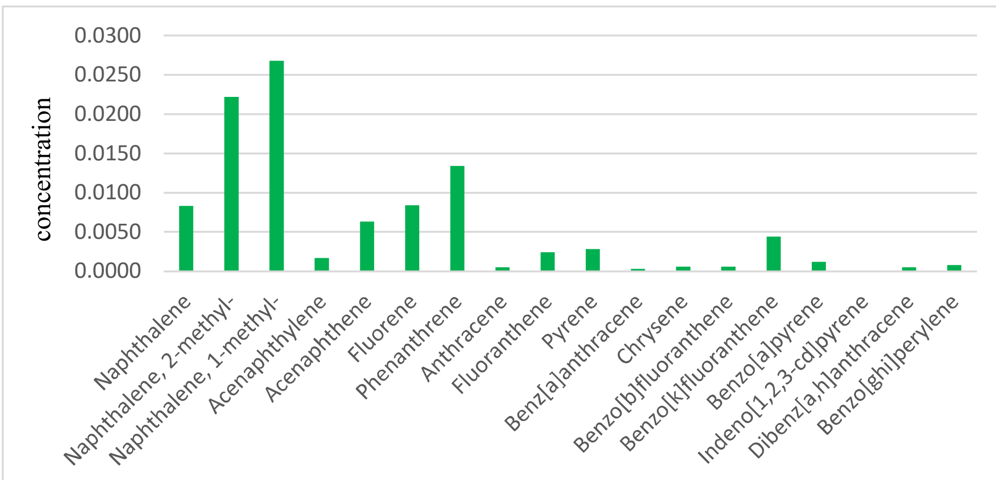


Fig (7) Concentration of Aromatic Compounds in the station 1

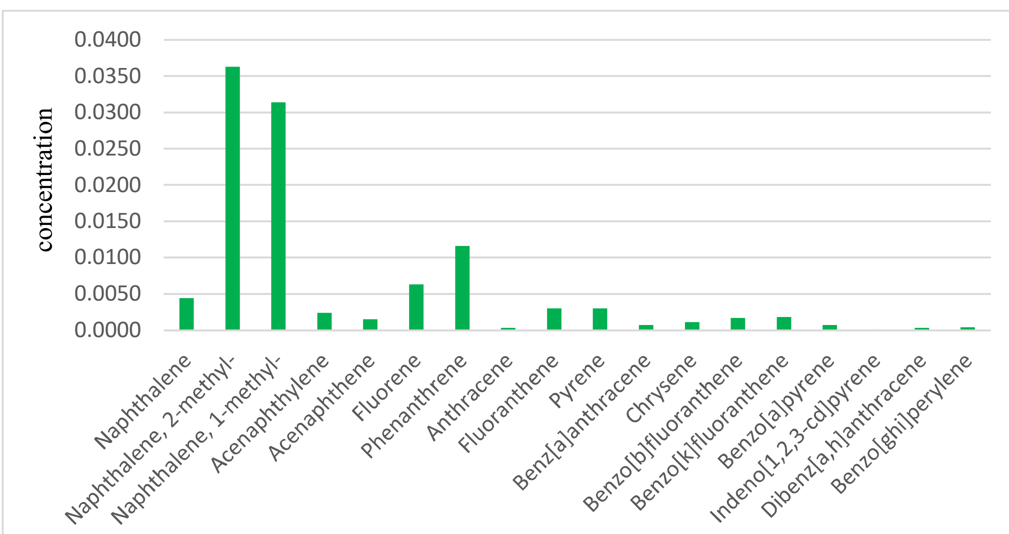


Fig (8) Concentration of Aromatic Compounds in the station 2

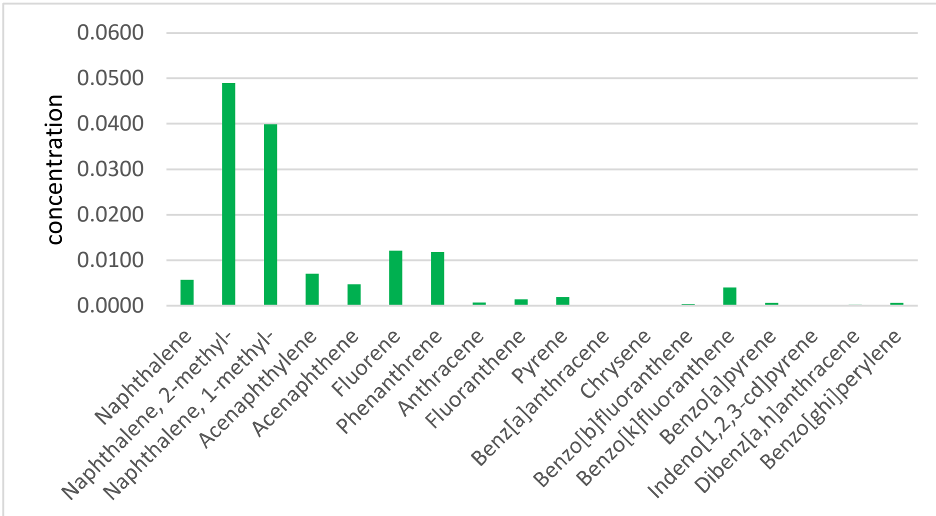


Fig (9) Concentration of Aromatic Compounds in the station 3

Table (5) Comparison of PAHs Concentrations in Wheat (*Triticum aestivum*) and Barley (*Hordeum vulgare*) from Different Regions of the World

Country/Region	Plant Type	ΣPAHs Concentration (µg/kg dry weight)	Number of PAHs Measured	Reference
Egypt (Delta)	Wheat	12.6	16	Hassan *et al*., 2020
China (Shaanxi)	Barley	25.3	16	Zhang *et al*., 2016
Iraq (Al-Basrah)	Barley	0.101-0.140	16	Current Study
Iran (Khuzestan)	Barley	21.7	12	Amirahmadi *et al*., 2013
Turkey (Adana)	Wheat	10.2	10	Demir *et al*., 2018
India (Punjab)	Barley	15.9	16	Sharma and Kalra, 2014
Poland (lodz)	Wheat	7.8	8	Wojnowski *et al*., 2017
Algeria (Setif)	Barley	11.3	10	Boudalia *et al*., 2021
Iraq (Al-Basrah)	Wheat	0.073-0.134	16	Current Study

Conclusion

PAHs in Basrah's wheat and barley derive predominantly from combustion (pyrogenic) and petroleum (petrogenic) sources, with refineries and power plants as major—but not sole—contributors. While current levels pose minimal risk, sustained industrial activity necessitates ongoing monitoring. Future studies should quantify direct deposition versus root uptake.

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توزيع ومصادر الهيدروكربونات العطرية متعددة الحلقات في محصولي القمح *Triticum aestivum* والشعير *Hordeum vulgare* المزروعين في شمال محافظة البصرة، العراق

فاطمة احسان كاظم الزبيدي , وداد مزبان طاهر الأسدي , فراس مصطفى الخطيب
قسم البيئة، كلية العلوم، جامعة البصرة، العراق

الخلاصة

تعد الهيدروكربونات العطرية متعددة الحلقات (PAHs) ملوثات بيئية ثابتة ذات خصائص مسرطنة ومطفرة، وغالباً ما تدخل السلسلة الغذائية من خلال التربة والمحاصيل الملوثة. تم في هذه الدراسة فحص توزيع ومصادر الهيدروكربونات العطرية متعددة الحلقات في محصولي القمح والشعير المزروع في ثلاث محطات في قضاء القرنة شمال محافظة البصرة وهم المحطة الاولى نهر العز، المحطة الثانية الترابة والمحطة الثالثة أم الشويج، اظهرت النتائج تواجد تراكيز مختلفة من الهيدروكربونات العطرية متعددة الحلقات الكلية في محصولي القمح والشعير في جميع محطات الدراسة وكالتالي: المحطة الاولى 0.0738 و 0.1012 والمحطة الثانية 0.0220 و 0.1070 والمحطة الثالثة 0.1341 و 0.1400 على التوالي، وعند مقارنة مستويات التلوث والمصادر بالبيانات العالمية، فإن المحطة الثالثة سجلت أعلى مستوى من التلوث، وتم العثور على أوجه تشابه كبيرة بين محتوى الهيدروكربونات العطرية متعددة الحلقات في المحصولين وأنماط التشتت عند تحليل عينات من القمح والشعير من ثلاث محطات بحثاً عن الهيدروكربونات العطرية متعددة الحلقات (PAHs) كان بنزو[أ] بيرين والهيدروكربونات العطرية متعددة الحلقات الخطرة الأخرى موجودة بكميات متفاوتة. مع وجود اختلافات في مستويات التركيز والتوزيعات الخاصة بالمركبات، تظهر البيانات أن تلوث الهيدروكربونات العطرية متعددة الحلقات موجود في كلا المحصولين.

الكلمات المفتاحية: القمح، الشعير، الهيدروكربونات العطرية متعددة الحلقات، كروماتوغرافيا الغاز-مطياف الكتلة.