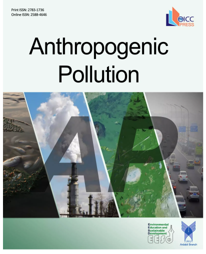

Volume 8, Issue 1, 082410 (1-7)

Anthropogenic Pollution (AP)

https://dx.doi.org/10.57647/j.jap.2024.0801.10

Polycyclic aromatic hydrocarbons in street dust of Babylon City, Iraq: Identification, quantification, and possible sources

Roa Mahdi Marmous[1], Atefeh Chamani[2]*

[1] *Environmental Science and Engineering Department, College of Agriculture and Natural Resources, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.*
[2] *Environmental Science and Engineering Department, Waste and Wastewater Research Center, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.*

***Corresponding author:** atefehchamani@yahoo.com

Original Research

Received:
20 November 2022
Revised:
20 February 2023
Accepted:
5 December 2023

Abstract:

Polycyclic aromatic hydrocarbon compounds (PAHs) are stable organic isomers known for their carcinogenic, mutagenic, and teratogenic effects, making monitoring and quantifying their presence in the environment critically important. This study aimed to identify, quantify, and determine the origin of PAH compounds in street dust samples collected from Babylon City, Iraq in 2023. A total of 39 street dust samples were collected from 13 selected locations with three replicates. The analytes were extracted using the Soxhlet method, followed by identification and quantification using gas chromatography with mass spectrometry (GC-MS). Ten PAH compounds were identified in the dust samples, with a mean concentration of 19.5 mg/kg. The total concentration ranged from 4.19 to 123 mg/kg. Low molecular weight isomers accounted for 86.2% of the total PAH content. The mean levels of phenanthrene (PHE), fluoranthene (FULA), and pyrene (PYR) isomers were below the maximum levels set by the Dutch Ministry of Health, while other isomers did not statistically differ from the permissible limit. Dust pollution with PAHs was very high at 7 locations (>50.00 mg/kg) and high at the remaining 6 locations. Strong positive correlations were observed among all isomers at a significance level of 99%, and multivariate data analysis indicated pyrogenic sources as the origin of PAHs in the dust samples. Results suggest that gasoline combustion and mixed combustion are the primary sources of PAH dust pollution in the study area. Therefore, regular monitoring of PAH levels is recommended to mitigate associated risks in Babylon City, Iraq.

Keywords: Organic pollutants; Street dust; Polycyclic aromatic hydrocarbons; Gas chromatography; Iraq

1. Introduction

Dust comprises fine inhalable solid particles or larger non-breathable particles. When these particles are small, they can penetrate deeply into the respiratory tract, posing a significant threat to human health (Wippich et al., 2020; Mostofie et al., 2014)). Among the pollutants found in dust, polycyclic aromatic hydrocarbons (PAHs) stand out due to their carcinogenic, mutagenic, and teratogenic properties. PAHs consist of 16 dimethylphenanthrene isomers (Li et al., 2014), including naphthalene (NAPH), acenaphthylene (ACY), acenaphthene (ACE), fluorine (FLU), phenanthrene (PHE), anthracene (ANT), fluoranthene (FULA), pyrene (PYR), benzo(alpha)anthracene (BaA), chrysene (CHR), benzo(beta)fluoranthene (BbF), benzo(k)fluoranthene (BkF), benzo(alpha)pyrene (BaP), dibenz(a,h)anthracene (DahA), benzo(g,h,i)perylene (BghiP), and indeno(1,2,3-cd)pyrene (IcdP). These compounds are classified as priority pollutants by the United States Environmental Protection Agency (EPA) due to their environmental and health impacts (Liao et al., 2012).

The variation in molecular weight among PAH isomers plays a crucial role in their behavior and persistence. The initial ten PAH isomers are categorized as low molecular weight, while the subsequent six are considered high molecular weight (Vila et al., 2020). PAHs can stem from both natural and anthropogenic sources. Natural sources like forest fires and volcanic activities contribute to PAH emissions, as do human activities such as biomass burning (pyrogenic sources) and the combustion or discharge of petroleum-based products like kerosene, gasoline, diesel, and asphalt (petrogenic sources) (Sakizadeh, 2020). Once released into the environment, PAHs form strong chemical bonds—covalent, hydrogen, or van der Waals—with organic materials in soil, sediment, or dust. This leads to their persistence in these environmental matrices over extended periods.

While numerous studies worldwide have examined PAH presence and concentrations in street dust (Grmasha et al., 2022; Li et al., 2022), only one such study was conducted in Iraq (Asia et al., 2022). Given the gravity of this issue and the dearth of local data, our research endeavors to identify and quantify PAH compounds in street dust samples from Babylon, Iraq, in 2023. This study aims to fill a critical knowledge gap, providing insights into the environmental burden of PAHs in the region where their impact remains relatively unexplored even with the presence of various emitting sources. Understanding the prevalence of these pollutants would be vital for devising effective strategies to mitigate their risks and safeguard public health.

2. Material and methods

2.1 Study area and dust sampling procedure

Babylon Province is located 100 km south of Baghdad, the capital of Iraq (Figure 1), and is considered one of the oldest cities globally (Ashraf et al., 2022). The province has a population of approximately 2.15 million people and covers a total area of 5315 km^2. Babil Province is home to several significant cities, including Al-Mahawil, Al-Masiyab, Halla, Al-Qasim, and Al-Hashimia. The climate of the studied area is characterized by an annual mean wind speed of 7.2 km/h and an annual mean precipitation of 102 mm (Chabuk et al., 2020). These climatic factors play a crucial role in environmental processes, including the dispersion and deposition of pollutants such as dust and other particulate matter.

This descriptive cross-sectional study, conducted in August 2023 under dry weather conditions, focused on collecting dust samples from 13 distinct locations three replicates (a total of 39 dust samples) situated within Babylon's commercial, high-traffic, and industrial hubs. These locations were selected based on their high potential for pollution due to intense human activities, vehicle emissions, and industrial processes, thereby capturing a comprehensive overview of potential pollution sources. The strategic selection was designed to ensure that the data collected would provide a reliable assessment of PAH distribution across different urban environments. Using a polyethylene brush, dust samples weighing 100 g each were collected from a designated four-square-meter area of the sidewalk, selected for its impervious surface. To prevent cross-contamination, a separate brush was used for sampling at each location. Subsequently, the samples from each location were combined to create composite samples, each weighing 50 g. To maintain the integrity of fine particles, the samples were carefully transferred into clean, air-tight, zippered polyethylene bags and promptly transported to the laboratory for further analysis. Upon arrival at the laboratory, the samples underwent freeze-drying and were stored at -15 °C until they were analyzed using machine techniques.

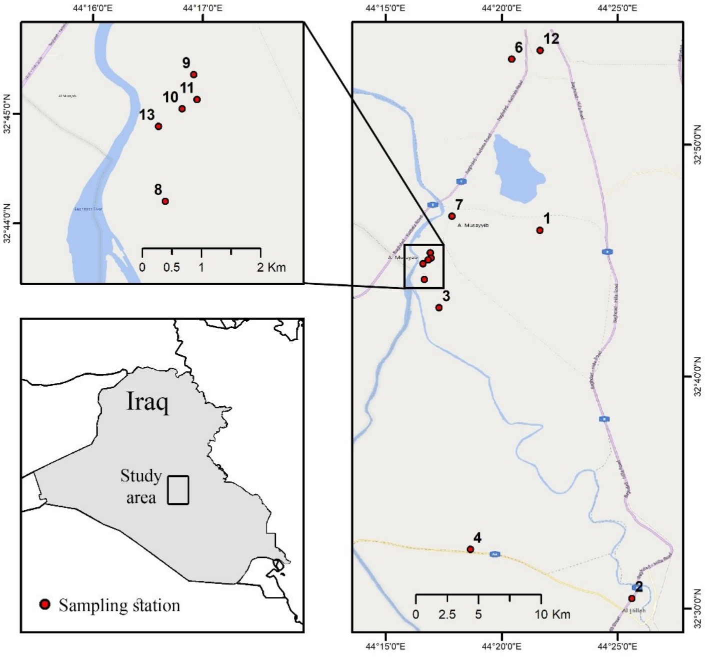

Figure 1. Distribution of dust sampling locations across Babylon, Iraq.

2.2 Preparation of dust samples and PAH analysis

High-purity chemicals and reagents were procured from Merck, Germany, and Sigma-Aldrich, Spain. All containers used in the experiment underwent rigorous cleaning, involving triple washing with double-distilled water followed by organic solvents—methanol, acetone, and n-hexane. Subsequently, they were sterilized at 70 °C for 4 hours (Melnyk et al., 2015). The extraction, separation, and clean-up of PAH compounds from dust samples were conducted using an Agilent model 7890 gas chromatography-mass spectrometer (GC-MS) manufactured in America. This process involved two chromatographic stages employing column chromatography. Notably, the GC-MS device featured a fused silica capillary column (DB-5 30m × 0.25mm × 0.25μm) coupled with an Agilent model 5973 mass spectrometer operating in Selective Ion Monitoring (SIM) mode for effective separation. Rather than measuring the total mass-to-charge ratio (m/z) across a broad spectrum, this method focused solely on determining the m/z value with the highest frequency (Dalvand et al., 2022).

To extract PAH analytes from the dust samples, 100 mg of each sample was accurately weighed using a laboratory digital scale with a precision of 0.0001 g and transferred into a 12 mL glass centrifuge tube. A specific concentration of internal standards was added, and the mixture was allowed to equilibrate overnight at room temperature (25 °C). Subsequently, each sample underwent ultrasonication three times, each lasting 30 minutes, with 4 mL of hexane/acetone (4:1 volume ratio). After ultrasonication, centrifugation was performed at 2000 rpm for 10 minutes to complete the extraction process. The resulting extracts were then concentrated to 1 mL using a gentle flow of nitrogen for instrumental analysis (Chen et al., 2013). Helium gas with a purity of 99.99% and a flow rate of 1 mL per minute was employed as the carrier gas for the analysis. This procedure ensured the effective extraction and concentration of PAH compounds from the dust samples for subsequent analysis using GC-MS.

2.3 Quality assessment and PAH source identification

The reliability of measurements was assessed using Standard Reference Material (SRM) 2585, Procedural Blank samples (one for every 10 dust samples), and sodium sulfate (as Dust Replica) containing specified amounts from standard solutions. To minimize potential errors during instrumental analysis, a control sample was injected into the instrument alongside other samples. Additionally, the detection limit of the instrument was determined using the signal-to-noise method (Chen et al., 2013) to establish the detection and quantification limits of PAH compounds.

The results showed that the average recovery rates of the identified isomers were as follows: NAPH ranged from 96% to 101%, ACY from 94% to 100%, PHE, FULA, FLU, and ANT from 93% to 101%, PYR, CHR, BkF from 94% to 101%, and BbF varied from 95% to 101%. To investigate potential sources of dust particle contamination with PAH compounds, the method of molecular diagnostic ratios (MDRs) between pairs of PAH isomers was employed, as detailed in Table 1. Accordingly, ”petrogenic” refers to compounds derived from petroleum sources, while ”pyrogenic” indicates those originating from combustion processes (Zarkesh Rabieimesbah et al., 2024).

2.4 Statistical analysis

Various statistical analyses were employed in this study. The one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test was utilized to categorize the sampling locations based on their PAH content. Additionally, the one-sample t-test was applied to compare the mean PAH values in the samples against the Maximum Permissible Concentration (MPC). Furthermore, the Pearson correlation coefficient (PCC) test was conducted to assess the correlation among the PAH compound values.

3. Results

Results of PAH measurement at the sampling locations are presented in Table 2. The maximum level of 29.5 mg/kg was observed for FLU at S2. The lowest value was 0.12, related to BkF at station 1. On average, the measured levels ranged between 0.53 and 4.59 mg/kg. The standard deviation of the measurements was notably high for all PAHs and averaged 3.21 which is significantly higher than the mean of 1.95 mg/ kg. The one-way ANOVA analysis of PAH compounds indicated that there were no statistically significant differences ($p < 0.050$) in the mean concentration of NAPH in dust samples between certain pairs of locations, specifically between locations 5 and 6, 3 and 8, and 7 and 13. In contrast, statistically significant differences ($p < 0.050$) were observed among other sampling locations. Similarly, no statistically significant differences ($p < 0.050$) were found between locations 3, 4, 5, 6, 7, 8, and 13 in terms of the mean concentration of ACY in dust samples. This trend is likely to extend to other identified isomers.

The results of the one-sample t-test, comparing the mean

Table 1. Characteristics of molecular diagnostic ratios of PAHs (Zarkesh Rabieimesbah et al., 2024).

Molecular marker	PAH origin	
	Petrogenic	Pyrogenic
(PHE+ ANT) / ANT	> 0.10	< 0.10
(PYR + FULA) / FULA	> 0.40	< 0.40
PYR / FULA	> 1.0	< 1.0
(PYR + FLU) / FLU	> 0.50	< 0.50
ANT / PHE	< 10.0	> 10.0

Table 2. Descriptive statistics of PAHs in street dust samples from Babylon City (mg/kg dry weight).

sampling location	**PAH**									
	NAPH	**ACY**	**FLU**	**PHE**	**ANT**	**FULA**	**PYR**	**CHR**	**BbF**	**BkF**
1	6.79b	3.00b	6.72b	1.24c	2.00b	2.61b	0.777b	3.41b	3.10b	1.28b
2	27.1a	13.6a	29.5a	7.96a	3.45a	8.93a	2.56a	11.8a	11.0a	7.17a
3	0.965j	0.424e	0.988i	0.207g	0.239d	0.321g	0.206d	0.397f	0.267g	0.176g
4	1.59g	0.634e	1.58f	0.622d	0.292d	0.450f	0.281cd	0.694ef	0.429efg	0.427f
5	1.39h	0.668e	1.52fg	0.335ef	0.292d	0.589e	0.291cd	0.690ef	0.494efg	0.386f
6	1.38h	0.620e	1.22ghi	0.397e	0.232d	0.550ef	0.173d	0.547ef	0.388fg	0.191g
7	1.21i	0.762e	1.53fg	0.568d	0.201d	0.489ef	0.177d	0.640ef	0.483efg	0.212g
8	0.978j	0.472e	1.10hi	0.270fg	0.149d	0.445f	0.172d	0.340f	0.385fg	0.118g
9	2.26f	1.28d	2.53e	0.634d	0.280d	1.03d	0.273cd	1.02de	0.905def	0.635e
10	3.66c	1.76c	3.93c	1.27bc	0.361cd	1.01d	0.343c	1.43cd	0.967de	0.409f
11	2.91e	1.93c	3.55d	0.692d	0.553c	1.39c	0.717b	1.67c	1.62c	1.06c
12	3.31d	1.93c	4.08c	1.37b	0.586c	1.48c	0.662b	1.87c	1.12d	0.810d
13	1.14i	0.538e	1.41fgh	0.394e	0.150d	0.571e	0.231cd	0.587ef	0.556efg	0.367f
min	0.97	0.42	0.99	0.21	0.15	0.32	0.17	0.34	0.27	0.12
max	27.1	13.6	29.5	7.96	3.45	8.93	2.56	11.8	11	7.17
mean	4.21	2.12	4.59	1.23	0.676	1.53	0.528	1.93	1.67	1.02
stdev	7.07	3.54	7.67	2.06	0.966	2.31	0.647	3.08	2.91	1.88

* Values represent the mean concentration of three replicates.

** Different letters (e.g., a, b, c, etc.) denote statistically significant differences ($p < 0.05$) between sampling sites regarding the mean PAH values, as determined by the results of the one-way analysis of variance (Duncan's post hoc test).

concentration of PAH isomers in dust samples with the permissible limit set by the Ministry of Health of the Netherlands, are presented in Table 3, indicating that the mean values of PHE, FULA, and PYR isomers in surface dust samples remained significantly lower ($p < 0.050$) than their permissible limits. Conversely, the mean values of other isomers did not exhibit statistically significant differences compared to the permissible limits ($p < 0.050$).

The correlation coefficients among the PAHs consistently demonstrated positive values, all exceeding 0.98, and were statistically significant as delineated in Table 4. The outcomes of the MDRs analysis, specifically concerning the ratios (PHE+ANT)/ANT, (PYR+FULA)/FULA, PYR/FULA, (PYR+FLU)/FLU, and ANT/PHE were 0.367, 0.712, 0.0, 2.61, 0.873, and 1.96, respectively. These results strongly suggest a pyrogenic origin for all identified PAHs. Moreover, the molecular weight distribution analysis (Figure 2) revealed prevalent low molecular weights across all sampling stations. Specifically, over 83.3% of the molecular weights recorded across the stations fell within the low weight range. Notably, station 10 exhibited a particularly high concentration, with over 90% of its molecular weight distribution falling into the low category. In contrast, station 11 demonstrated the highest proportion of high molecular weights at 16.7%.

4. Discussion

This study revealed significant variation in the concentrations of the 10 PAH detected in dust samples, ranging from 4.19 to 123 mg/kg. Notably, the majority of PAHs identified

Table 3. Results of mean comparison of PAHs in street dust samples with their Maximum Permissible Concentration (MPC).

PAH	**MPC (mg/kg dry weight)**	**t stat**	**Sig level**	**Mean comparison**	**95% confidence interval**	
					Upper limit	**Lower limit**
NAPH	0.69	1.79	0.098	3.52	7.79	-0.75
ACY	0.17	1.99	0.069	1.95	4.09	-0.18
FLU	1.60	1.41	0.185	2.99	7.62	-1.64
PHE	3.60	-4.15	0.001	-2.37	-1.13	-3.62
ANT	0.34	1.25	0.234	0.34	0.92	-0.25
FULA	4.80	-5.10	0.000	-3.27	-1.88	-4.67
PYR	80.1	-7.09	0.000	-1.27	-0.88	-1.66
CHR	1.60	0.386	0.706	0.33	2.19	-1.53
BbF	0.79	1.09	0.296	0.88	2.64	-0.88
BkF	0.79	0.438	0.669	0.23	1.37	-0.91

Table 4. Descriptive statistics of PAHs in street dust samples from Babylon City (mg/kg dry weight).

Isomer	NAPH	ACY	FLU	PHE	ANT	FULA	PYR	CHR	BbF	BkF
NAPH	1	**	**	**	**	**	**	**	**	**
ACY	0.998	1	**	**	**	**	**	**	**	**
FLU	0.999	0.999	1	**	**	**	**	**	**	**
PHE	0.991	0.993	0.994	1	**	**	**	**	**	**
ANT	0.948	0.937	0.94	0.905	1	**	**	**	**	**
FULA	0.997	0.997	0.997	0.984	0.958	1	**	**	**	**
PYR	0.981	0.986	0.984	0.972	0.944	0.989	1	**	**	**
CHR	0.998	0.997	0.998	0.986	0.96	0.986	0.989	1	**	**
BbF	0.996	0.996	0.996	0.981	0.959	0.998	0.986	0.998	1	**
BkF	0.993	0.996	0.995	0.988	0.925	0.986	0.986	0.992	0.993	1

** Correlation at a significance level of 1%.

in the samples consisted of isomers containing two (NAPH), three (ACY, FLU, PHE, and ANT), and four (FULA, PYR, and CHR) benzene rings in their molecular structures, constituting 21.6%, 44.2%, and 20.4% of the total compound amount, respectively. Isomers with five benzene rings (BbF and BkF) contributed 13.8% to the overall identified compounds. Furthermore, an assessment of PAH isomer distribution in dust samples based on molecular weight revealed that the predominant proportion of PAH isomers across sampling locations comprised isomers with low molecular weight. The descending order of PAH species distribution in the samples was as follows: 2-3-ring (65.8%) > four-ring (20.4%) > five-ring (13.8%). In a related study, Asia et al. (2022) assessed health risks associated with exposure to PAH-contaminated street dust in Babylon City and found a similar predominance of light isomers (86.7%) over heavy isomers (13.3%) in the city. Similarly, studies by Agarwal et al. (2009), and Zhao et al. (2014) also identified low molecular weight isomers as predominant compounds in their soil samples. This distribution pattern is noteworthy considering the higher environmental volatility and lower stability of lighter PAH compounds compared to heavier ones because isomers with low molecular weight exhibit greater mobility in the atmosphere and can be transported over long distances via atmospheric processes. It is important to highlight that compounds such as FULA, PYR, CHR, BbF, and BkF, identified as carcinogenic by the International Agency for Research on Cancer (IARC), have reported permissible limits ranging from 0.350 to 0.500 mg/kg in urban areas. The mean concentrations of these isomers in Babylon City dust samples (mg/kg) were 1.53, 0.528, 1.93, 1.67, and 1.02, respectively, suggesting contamination of dust samples due to anthropogenic activities. The one-sample t-test comparing the mean PAH values in dust samples with maximum permissible limits revealed that the mean values of PHE, FULA, and PYR isomers in the samples were all below the allowable limits. According to the quality standard established by Baumard et al. (1998) categorizing soils into four pollution levels based on PAH concentrations, dust pollution with PAHs at locations 3 and 8 fell into the ”high pollution” category (5.00-50.00 mg/kg), while other locations were classified as ”very high pollution” (>50.00 mg/kg). Despite the reliability and widespread use of the MDRs method for identifying potential sources of PAHs, molecular markers lack sufficient certainty and may indicate a combination of pyrogenic and petrogenic sources contributing to environmental matrix pollution. While compounds with low molecular weight accounted for 86.2% of the detected PAHs, the MDR analysis indicated that the origin of dust sample contamination with PAHs across all sampling locations was pyrogenic, attributed to the release of high molecular weight compounds into the environment. Li et al. (2014) acknowledged that molecular marker values exceeding 0.10 for (PHE+ANT)/ANT indicate combustion processes as the primary source of PAH pollution. The mean value of 0.367 observed across all sampling locations

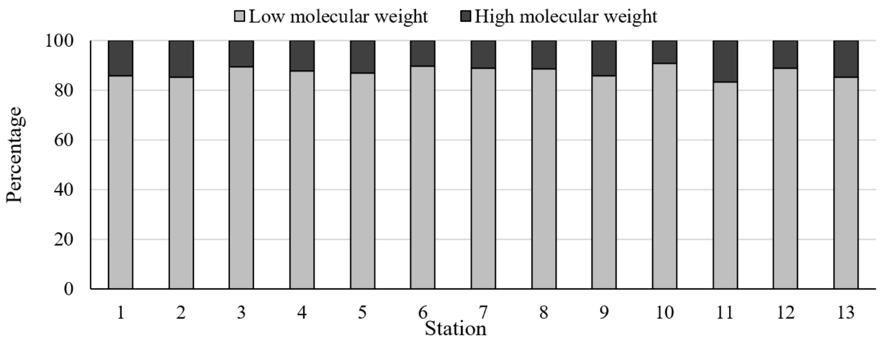

Figure 2. Distribution of PAH isomers in street dust samples based on molecular weight.

suggests that combustion is a significant source of PAH dust pollution. Furthermore, although PHE and ANT isomers are light compounds, their sensitivity to biological decomposition and oxidation processes may contribute to dust pollution by these isomers. Hence, this indicator may not be entirely reliable for determining the PAH compound source, as noted in other studies. Zhang et al. (2021) also recognized that molecular marker values exceeding 0.40 for (PYR+FLU)/FLU point to combustion processes as the primary source of PAH pollution. With a mean value of 0.873 across all sampling locations, combustion is implicated as a significant source of PAH dust pollution. The combined values of these indicators suggest that gasoline combustion and mixed combustion are the primary sources of PAH dust pollution in the study area. Long-term atmospheric deposition is a key source of soil pollution with PAH compounds, with vehicle traffic, domestic heating, and local industries being identified as primary contributors to PAH soil pollution. The notably high mean PAH isomer content observed at sampling location 2 (123 mg/kg) can be attributed to its proximity to chemical industries and residential areas, where incomplete combustion and pyrolysis of fossil fuels due to heavy traffic and slow-moving diesel and gasoline vehicles, along with residential heating, are prevalent factors. Heywood et al. (2006) reported similar findings, emphasizing the impact of emission sources on the accumulation and content of PAH compounds in soil, thereby explaining the elevated PAH levels in dust samples. Conversely, the pyrogenic origin of PAH compounds at other sampling locations, particularly in the agricultural area of Al-Masiyab, may be linked to the combustion of organic materials leading to PAH release into the air and subsequent sedimentation into the soil. Overall, however, correlation results suggest a common origin for the isomers, indicating that both low and high-molecular-weight isomers likely share the same source.

5. Conclusion

This study was undertaken to identify and quantify PAHs in street dust from Babylon, Iraq, with the goal of determining their content and origin. The analysis identified 10 PAH isomers in the samples, with a mean concentration of 19.5 mg/kg. Notably, the mean levels of PHE, FULA, and PYR isomers were found to be below the maximum limit set by the Dutch Ministry of Health, while other isomers did not significantly differ from the permissible limits. PAH compounds with low molecular weight constituted 86.2% of the total isomer content. Furthermore, dust pollution with PAHs was classified as ”high pollution” in two sampling locations, and ”very high pollution” in other locations. The results from the MDRs analysis indicated that the contamination of dust samples with PAHs across all sampling locations was pyrogenic in origin, attributed to the release of high molecular weight compounds into the environment. Given the potential health risks associated with PAH compounds for living organisms, it is recommended to conduct regular monitoring of PAHs in environmental matrices such as water, soil, and sediment to safeguard environmental and public health. However, the analysis was limited to a specific number of PAH isomers, potentially overlooking the presence and impact of other relevant PAH compounds. The study's geographical scope was also restricted to specific sampling locations within Babylon City, which may not be representative of broader regional or global trends. Moreover, the study primarily relied on surface dust samples, potentially missing deeper soil contaminants that might contribute to long-term environmental and health risks.

Funding
This research was funded by Islamic Azad University, Isfahan (Khorasgan) Branch, Isfahan, Iran.

Authors Contributions
All authors have contributed equally to prepare the paper.

Availability of Data and Materials
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Agarwal T., Khillare P., Shridhar V., Ray S. (2009) Pattern, sources and toxic potential of PAHs in the agricultural soils of Delhi, India. *Journal of hazardous materials* 163:2–3.

Ashraf I., Khanum A., Akhtar S. (2022) An Analytical Study of the Mesopotamian Civilization. *Perennial Journal of History* 3 (1): 237–247.

Asia A.S., Hasan H.M., Roaa B.S. (2022) Health risk evaluation of toxic polycyclic aromatic hydrocarbons (PAHs) in the street dust of Basra, Iraq. *Bulletin of Pharmaceutical Sciences. Assiut* 45 (1): 469–479.

Baumard P., Budzinski H., Michon Q., Garrigues P., Burgeot T., Bellocq J. (1998) Origin and bioavailability of PAHs in the Mediterranean Sea from mussel and sediment records. *Estuarine, Coastal and Shelf Science,* no. 1, 47.

Chabuk A., Al-Maliki A., Al-Ansari N., Laue J. (2020) Evaluation of the groundwater quality for irrigation: Case study of Hilla district, Babylon Province, Iraq. In: IOP Conference Series: Materials Science and Engineering. *IOP Publishing,* 022056.

Chen M., Huang P., Chen L. (2013) Polycyclic aromatic hydrocarbons in soils from Urumqi, China: distribution, source contributions, and potential health risks. *Environmental monitoring and assessment* 185:5639–5651.

Dalvand N., Sobhanardakani S., Sadr M.K., Cheraghi M., Lorestani B. (2022) Analysis of polycyclic aromatic hydrocarbons (PAHs) in household dusts of the city of Khorramabad, Iran.

Grmasha R.A., Al-sareji O.J., Salman J.M., Hashim K.S. (2022) Polycyclic aromatic hydrocarbons (PAHs) in urban street dust within three land-uses of Babylon governorate, Iraq: Distribution, sources, and health risk assessment. *Journal of King Saud University-Engineering Sciences* 34 (4): 231–239.

Heywood E., Wright J., Wienburg C.L., Black H.I., Long S.M., Osborn D., Spurgeon D.J. (2006) Factors influencing the national distribution of polycyclic aromatic hydrocarbons and polychlorinated biphenyls in British soils. *Environmental Science & Technology* 40 (24): 7629–7635.

Li H., Zeng X., Zhang D., Chen P., Yu Z., Sheng G., Fu J. (2014) Occurrence and carcinogenic potential of airborne polycyclic aromatic hydrocarbons in some large-scale enclosed/semi-enclosed vehicle parking areas. *Journal of hazardous materials* 274:279–286.

Li H.H., Yang Z.B., Xu X.X., Zhu X.M., Xian J.R., Yang Y.X., Cheng Z. (2022) Polycyclic aromatic hydrocarbons in street dust from different functional areas in Chengdu, China: seasonal variation and health risk assessment. *Environmental geochemistry and health,* 1–13.

Liao C., Lv J., Fu J., Zhao Z., Liu F., Xue Q., Jiang G. (2012) Occurrence and profiles of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) in soils from a typical e-waste recycling area in Southeast China. *International journal of environmental health research* 22 (4): 317–330.

Melnyk A., Dettlaff A., Kuklińska K., Namieśnik J., Wolska L. (2015) Concentration and sources of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) in surface soil near a municipal solid waste (MSW) landfill. *Science of the Total Environment* 530:18–27.

Mostofie N., Fataie, HezhabrPour Gh., Kheikhah M.M. (2014) Assessment centers and distribution centers dust (case study: NorthWest, Iran). *International Journal of Farming and Allied Sciences* 3 (2): 235–243.

Sakizadeh M. (2020) Spatial distribution and source identification together with environmental health risk assessment of PAHs along the coastal zones of the USA. *Environmental Geochemistry and Health* 42 (10): 3333–3350.

Vila J., Tian Z., Wang H., Bodnar W., Aitken M.D. (2020) Isomer-selective biodegradation of high-molecular-weight azaarenes in PAH-contaminated environmental samples. 707:135503.

Wippich C., Rissler J., Koppisch D., Breuer D. (2020) Estimating respirable dust exposure from inhalable dust exposure. *Annals of Work Exposures and Health* 64 (4): 430–444.

Zarkesh Rabieimesbah A., Sobhanardakani S., Cheraghi M., Lorestani B. (2024) Concentrations, source identification and potential ecological and human health risks assessment of Polycyclic Aromatic Hydrocarbons (PAHs) in agricultural soils of Hamedan County, West of Iran. *Soil and Sediment Contamination: An International Journal* 33 (4): 482–506.

Zhang Q., Meng J., Su G., Liu Z., Shi B., Wang T. (2021) Source apportionment and risk assessment for polycyclic aromatic hydrocarbons in soils at a typical coking plant. *Ecotoxicology and Environmental Safety* 222:112509.

Zhao L., Hou H., Shangguan Y., Cheng B., Xu Y., Zhao R., Zhang Y., Hua X., Huo X., Zhao X. (2014) Occurrence, sources, and potential human health risks of polycyclic aromatic hydrocarbons in agricultural soils of the coal production area surrounding Xinzhou, China. *Ecotoxicology and Environmental Safety* 108:120–128.