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Polycyclic Aromatic Hydrocarbons in the Water Bodies of Dong Lake and Tangxun Lake, China: Spatial Distribution, Potential Sources and Risk Assessment

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Abstract: Polycyclic aromatic hydrocarbons (PAHs) are a group of highly toxic organic pollutants. At present, there has only been limited research into PAH contamination in Tangxun Lake and Dong Lake, which are the first and second largest urban inland lakes in China, respectively. This study investigated the concentration, spatial distribution, sources, and ecological risks of PAHs in the water from Dong Lake and Tangxun Lake. The focus of this study is to use models to analyze the sources of PAHs, as well as their potential toxicity to humans, in the water bodies of Dong Lake and Tangxun Lake. This study performed liquid–liquid extraction to extract PAHs from lake water samples using dichloromethane and then used gas chromatography–mass spectrometry (GC-MS) to quantitatively analyze the PAHs in the samples. The total concentration of the $\sum_{16}$PAHs showed high variability among different sampling points, ranging from 12.92 to 989.09 ng/L, with an arithmetic mean of 121.97 ng/L. The composition of the $\sum_{16}$PAHs was mainly concentrated at a low molecular weight (>70%). The molecular distributions of PAH studies, combined with positive matrix factorization (PMF), indicate that oil and coal combustion are the main sources of PAHs in Dong Lake and Tangxun Lake. The model of PMF succeeded in identifying and quantifying five sources with similar contributions: the combustion of petroleum products, heavy oil burning, coal combustion, traffic emissions, and natural gas and oil combustion mixed. According to toxicity equivalency (TEQ) and lifelong cancer risk (ILCR) research, PAHs from traffic sources in the environment may be more toxic, and the potential carcinogenic risk of PAH pollution to humans in Tangxun Lake and Dong Lake water bodies is relatively inferior.

Keywords: polycyclic aromatic hydrocarbons; risk assessment; source identification; urban lake; water

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1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a kind of complex organic chemical, that include carbon and hydrogen, and contain at least two benzene rings in their condensed ring structure [1,2]. PAHs have become a focus worldwide due to their difficult biochemical degradation, bioaccumulation, ecotoxicity, and carcinogenic properties [3]. In view of their potential toxicity, the United States Environmental Protection Agency (US EPA) has designated 16 PAHs as priority pollutants [4]. Their sources are diverse, including traffic-related sources, incomplete fossil fuel combustion, and biomass combustion. Pyrolysis-related pollution is the main source [5]. In the environment, PAHs are widely dispersed, particularly in lakes, rivers, estuaries, and oceans [6].

In the surface water environment, especially in urban lakes, the presence of PAHs is usually related to the degree of urbanization [7]. In metropolitan regions, intensive human activities primarily produce and release a considerable amount of particulate and gaseous PAHs into the atmosphere via pyrolysis processes, including biomass combustion, fossil fuel combustion, refuse burning, and coke manufacture [8]. PAHs are subsequently concentrated in a variety of urban media, such as lakes, dust, soil, sediment, etc., as a result of atmospheric diffusion and deposition [9,10]. At the same time, urbanization has increased the number of hardened lands, and more rainfall runoff has brought PAHs into urban lakes via impervious surfaces, such as streets and roofs [9].

Urban lakes are natural discharge sites for urban rivers, drainage networks, and surface runoff, and they may collect a variety of pollutants [11]. At the same time, as an important component of the surface water environment, urban inner lakes play an important role in urban production and life [12]. Urban inner lakes are crucial for urban drainage and water storage during the dry and rainy seasons, for the control of the urban microclimate, for the provision of water, and for satisfying public recreational demands [13]. Urban inner lakes are the most visited urban ecological landscapes by the public [14].

Some studies have shown that, in highly urbanized areas, PAHs have a relatively high biological toxicity, which may pose certain hazards to human health in water bodies via ingestion and dermal contact [6,15]. Currently, PAHs have become one of the serious environmental issues in urban areas and pose a potential carcinogenic risk to urban residents [16]. Thus, it was necessary to investigate the concentration, distribution, and source of PAHs in urban lakes and evaluate their potential carcinogenic risks. This paper determined the concentration and spatial variation of PAHs in Tangxun Lake and Dong Lake. The purpose of this work was: (I) to examine and contrast the spatial distribution and pollution level of PAHs in Tangxun Lake and Dong Lake; (II) to determine the possible source of PAHs; and (III) to evaluate the potential carcinogenicity of PAHs in the two lakes through toxicity equivalent and lifelong cancer risk models.

2. Methods

2.1. Study Area and Sampling

2.1.1. Study Area

With a water area of 47.6 square kilometers, Tangxun Lake is the largest intra-city lake in Asia and is situated in the southeast of Wuhan, China. The majority of the land around it is used for construction, and the traffic on the roads is complicated. Factories and fishing sites are distributed around the lake [17]. Dong Lake is situated in Wuhan's eastern region. It covers an area of 31.75 square kilometers and has a volume of 81.5 million cubic meters. Dong Lake is an important water source and aquaculture base, and it is a famous ecological tourist attraction in Wuhan, receiving more than 20 million tourists every year.

2.1.2. Sampling

Eight water samples were gathered from both Tangxun Lake and Dong Lake, as shown in Figure 1. Samples of two liters of water were taken from each location at a depth of about 0.1 m, and they were placed without headspace in previously cleaned amber glass vessels. A portable multimeter was used to test dissolved oxygen (DO), conductivity, PH, and redox potential in all sampling locations (HACH HQ40d). Within 48 h of collection, all samples were brought to the lab, kept at 4 °C, and analyzed.

2.2. Chemical and Instrumental Analysis

In this study, 16 PAHs identified as priority pollutants by the US EPA were investigated in each sample, including benzo[b]fluoranthene (BbF), anthracene (Ant), fluoranthene (Fla), naphthalene (Nap), benzo[k]fluoranthene (BkF), pyrene (Pyr), benzo[a]pyrene (BaP), benzo[g,h,i]perylene (BghiP), dibenzo[a,h]anthracene (DahA), benzo[a]anthracene (BaA), acenaphthene (Ace), indeno [1,2,3-cd]pyrene (IcdP), chrysene (Chr), acenaphthylene (Acy), fluorene (Flu), and phenanthrene (Phe).

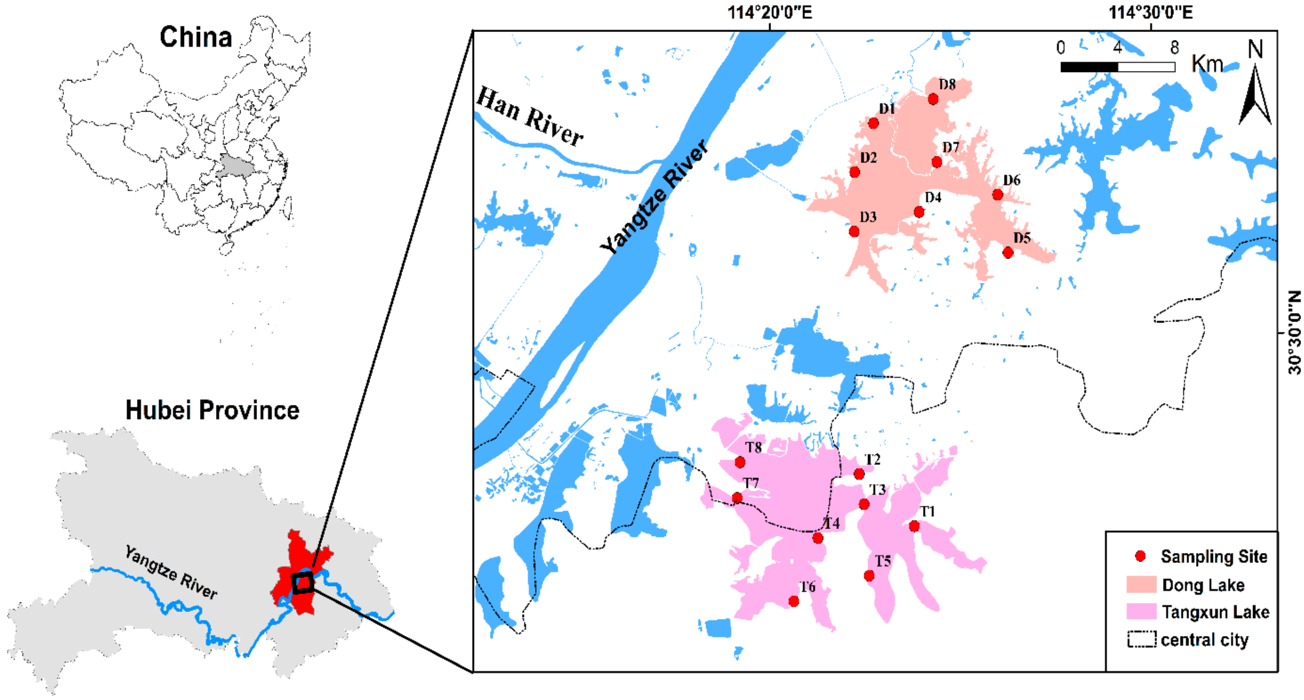

Figure 1. Map of the study area and sampling sites.

The water samples were first filtered using a pre-combustion glass fiber filter (0.45 µm, d = 47 mm) that was heated for four hours at 450 °C. A deuterium PAH replacement (2-fluorobiphenyl and p-triphenyl-d14) was combined with 1 L of filtered water before using 25 mL of dichloromethane to extract the material three times. Using anhydrous sodium sulfate, the extracts were dried and then concentrated to 2–3 mL using a rotary evaporator after changing the solvent to n-hexane. The n-hexane solution was cleaned using a 30 mL dichloromethane/hexane (v/v = 2/3) column and a 1:2 (v/v) alumina/silica gel column. Perylene-d12, chrysene-d12, and phenanthrene-d10 were used as internal standards for instrument analysis by concentrating the eluate to 0.2 mL using a gentle high-purity nitrogen flow.

An Agilent 6890 N/5975 MSD gas chromatograph–mass spectrometer (GC-MS) fitted with a DB-5 capillary column with a 30 m × 0.25 mm diameter and 0.25 um film thickness was utilized for sample analysis. In the chosen ion monitoring (SIM) mode, the MS utilized electron collision ionization with an energy of 70 eV. While using high-purity helium as the carrier gas, the flow rate was 1.2 mL/min. In split-free mode, 1 µL of concentrated sample was injected. The temperature of the GC injector was 280 °C Initially set to 80 °C for 2 min, the temperature of the oven was raised to 180 °C at a speed of 10 °C/min, and then maintained at 290 °C for 13 min at a speed of 4 °C/min.

Selected ions at a specific retention period were used to qualify the target molecule, and the internal standard method was used to quantify it. Daily injections into the GC-MS included solvent banks and a PAH standard solution. The solvent blank samples did not contain any target PAHs, and the PAH standard solution's variation was under 15%. The PAH standard stock solution was diluted with n-hexane solvent and mixed evenly to prepare the PAH standard solution. This standard stock solution of PAHs can be purchased from the market directly. In order to screen for distractions and cross-contamination in each group of ten samples, a procedural blank and a parallel sample were used. All values provided were adjusted using the combination of surrogate recoveries and blanks. The surrogate recoveries varied between 57.6% to 116%. For data analysis, data that were smaller than the detection lines were changed to half-detection lines.

3. Results and Discussion

3.1. Concentration and Spatial Distribution

In this study, the detection rates (DRs) in more than half of these target PAHs reached 85% or even 100%, and DahA, Chr, BaA, and NaP showed a low DR value, with the values reaching 12.5%, 25.0%, 31.25%, and 43.75%, respectively (Figure 2b). A much higher coefficient of variation (CV) of the $\sum_{16}$PAHs (value = 2.162) was observed, which reflected the significant difference in the spatial variation of the PAHs in this study (Figure 2a). In terms of all water samples, the concentrations of the $\sum_{16}$PAHs ranged from 12.92 to 989.09 ng/L, with an arithmetic mean (AM) of 121.97 ng/L. More specifically, the concentrations of the $\sum_{16}$PAHs in Dong Lake and Tangxun Lake were 13.05–989.09 ng/L and 12.92–442.53 ng/L, with AM values reaching up to 155.21 ng/L and 80.39 ng/L, respectively.

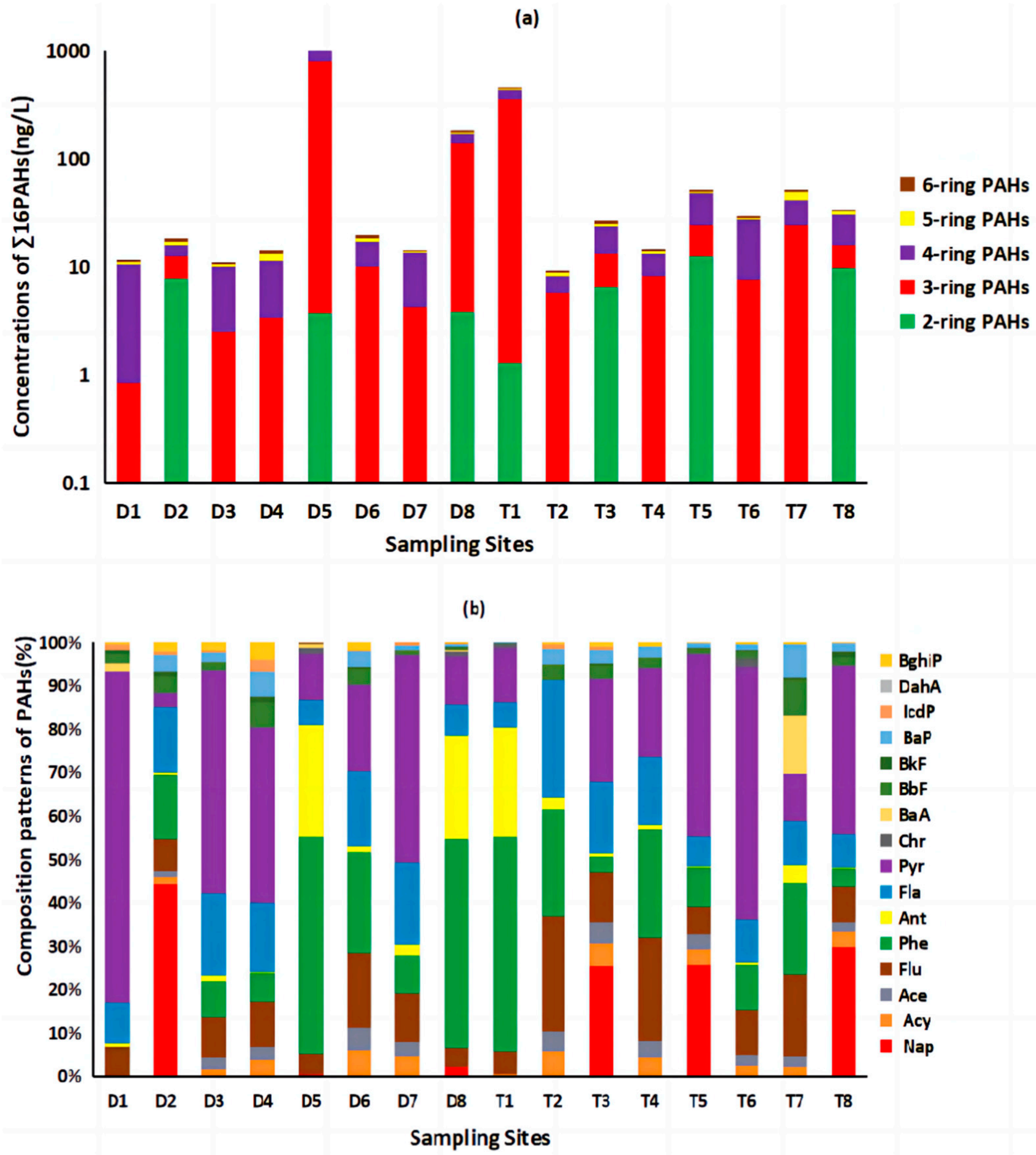

Figure 2. Composition patterns and concentrations of PAHs in Dong Lake and Tangxun Lake. (**a**) The total concentration of PAHs at each sampling point and the proportion of PAHs with different number of rings. (**b**) The proportion of 16 types of PAHs detected in each sampling point.

Globally, the $\sum_{16}$PAH values from Dong Lake and Tangxun Lake were much higher than those reported in the Seine River, Tiber River, New York Estuary, and the Wuhan section of the Yangtze [18–21]; slightly higher than the results recorded in the Yellow River Delta and Poyang Lake [3,22]; similar to those in Sanliqi Lake and Yinjia Lake [23]; and tens to hundreds of times less than those in the Daliao River Estuary and Minjiang River [4,24].

In terms of data structure, the concentrations of the $\sum_{16}$PAHs in most of the samples were dispersed at a low concentration zone, with over 80% of them exhibiting a low level (below the AM at 121.97 ng/L). Relatively high values of PAHs were discovered at several sites, such as D5, D8, and T1 (Figure 2a). Among these sites, the concentrations of Ant, Phe, Chr, Pyr, and BaA reached 10 to 100 times that of the others. In general, a large number of PAHs can be discharged by coal combustion and traffic pollution [25]. Dong Lake is close to Wuhan's industrial area, and numerous thermal power plants, such as Qingshan Thermal Power Co., are scattered around the area. The exhaust gases from the coal-fired boiler are likely to carry PAHs, which will settle in the lake area [16]. The site of T5 is close to the Third Ring Road and railway network. Higher pollution levels at T5 may be associated with the combined effects of transportation and coal-burning pollutants. The two lakes have a relatively low level of high-molecular-weight (HMW; 4–6 rings) PAHs and a high level of low-molecular-weight (LMW; 2–3 rings) PAHs (> 70%) (Figure 2a). LMW PAHs frequently make up a larger portion of the $\sum_{16}$PAHs in water due to their water solubility and higher vapor pressure [26].

3.2. Source Identification

Several individual PAH ratios have become widely used for distinguishing between pyrolytic and petrogenic sources, such as BaA/(BaA + Chr), Ant/(Ant + Phe), IcdP/(IcdP + BghiP), and Fla/(Fla + Pyr). As shown in Figure 3, these ratio pairs are dispersed on the whole; however, excluding points with a low contribution to the total PAHs, the ratio pairs of points D5, D8, and T1 with a high contribution are relatively clustered. This indicates that these points have a similar potential source. Specifically, all Ant/(Ant + Phe) ratios were dispersed in a range of 0 to 0.4, with half of the results falling into the pyrogenic area (>0.1), including D5, D8, and T1 [27]. Almost all of the Fla/(Fla + Pyr) ratios had a distribution less than 0.5, with the values between 0.4 and 0.5 indicating liquid fossil fuel combustion, such as diesel and crude oil, and some values were less than 0.4, reflecting petroleum sources [28]. The Icdp/(Icdp + BghiP) and BaA/(BaA + Chr) ratios indicate that the sources of the PAHs were a mixture of petroleum and petroleum combustion, and of biomass and coal combustion. These findings were consistent with the conclusion that oil and industrial emissions are the main sources of pollution in the Wuhan section of the Yangtze River [21].

The site of D8 is located in the northern part of Dong Lake, close to the old industrial area of Qingshan with high-energy-consuming enterprises, including the Wuhan Iron and Steel (Group) Company (WISCO). There are also some adjacent amusement parks and a railway station. These are things that can to some extent aggravate the loading of PAHs at D8. The sites of D5 and T1 are located in the southern part of Dong Lake and the eastern part of Tangxun Lake, respectively. Several coal-fired thermal power companies are located between these two points. Both production and transportation may cause PAH pollution [10]. It is worth mentioning that there is a golf course near T1, and the sewage generated by golf course lawn management may also enter the lake and cause pollution [29].

A positive matrix factorization (PMF) model was used to identify the major anthropogenic PAH pollution sources. The input to the PMF model consisted of a set of 16 samples from 17 different species. The species were categorized as strong, bad, or weak based on the percentage of samples falling below the detection limit (BDL) and the signal-to-noise ratio (S/N) [30]. In general, the model classified species with an S/N greater than 2 as robust species. Weak individuals were those with an S/N between 0.2 and 2, or with a percentage BDL greater than 50%. S/N values below 0.2 and BDL levels above 60% were considered to be of poor quality and eliminated from the PMF analysis [31]. This classified the NaP as an undesirable species, whereas the total PAHs were classified as a weak species, and the 15 remaining species were classified as strong species.

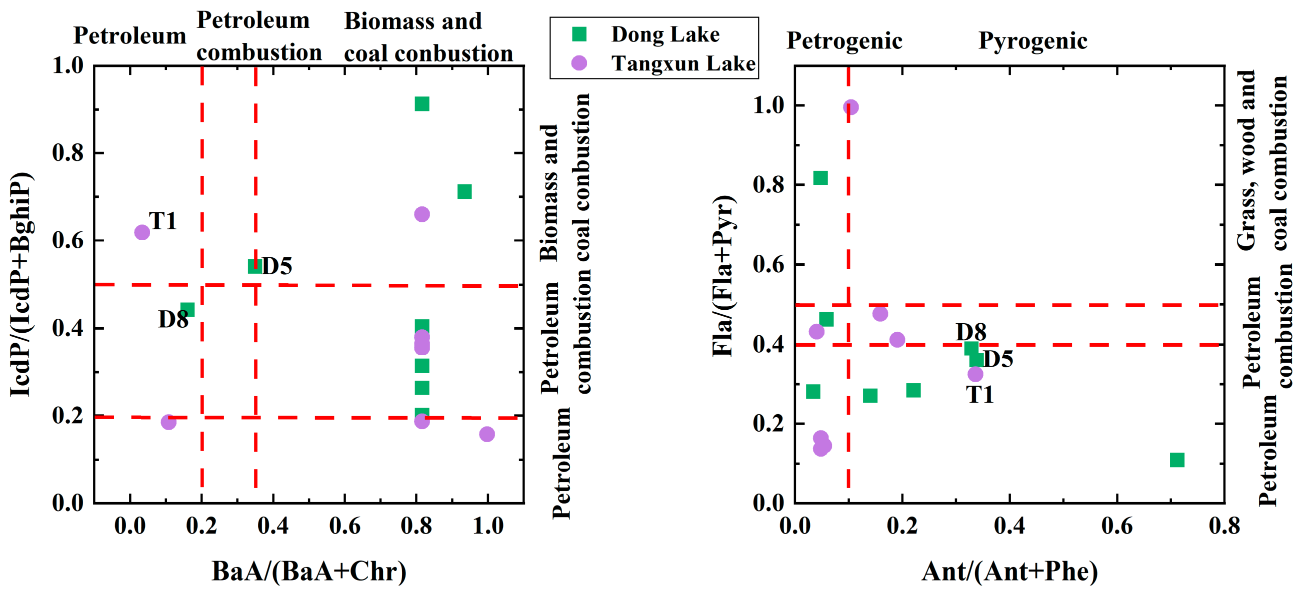

Figure 3. Scatter diagram of molecular index used to recognize the source of PAHs.

The PAHs were determined to be from five sources, and Figure 4 displays their profiles. Factor 1 was mainly characterized by Acy, Ace, BaP, BbF, and DahA. High levels of these PAHs were linked to emissions from petroleum combustion [32]. According to Li et al.'s research, Nap, Acy, and Flu are the main PAHs in coke oven emissions, and 2–3 rings of PAHs are the PAHs emitted from oil-fired power plants [33]. DahA is typical of traffic emissions and is related to diesel combustion emissions [31]. Factor 1 is, therefore, thought to be connected to the burning of petroleum products, with a contribution of 10.1%.

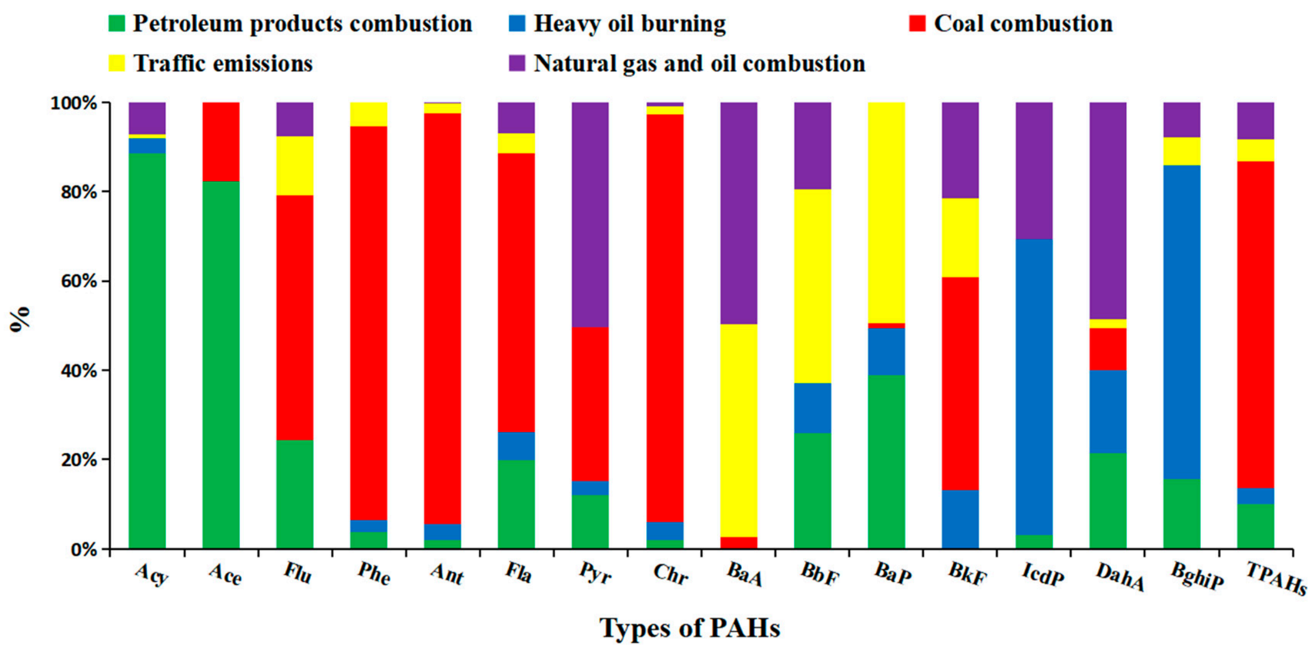

Figure 4. The individual contribution distribution map of each factor obtained through the PMF model.

As HMW PAHs, IcdP and BghiP were the dominant chemicals in factor 2 (Figure 4), and together they accounted for 3.4% of the total PAHs. Generally, HMW PAHs are considered to be released from the majority of vehicle emissions [34]. Callén et al. clarified that these HMW PAHs are linked to the burning of heavy oil [35]. The chemical production, steel manufacturing, and transportation activities of enterprises around the lake area may be related to the combustion of heavy oil. Thus, factor 2 may be related to heavy oil combustion.

Factor 3 is the highest source contributor, with a value of 73.3%. It was mainly impacted by Phe, Ant, Pyr, Chr, Flu, BkF, and Fla. The high levels of Fla, Pyr, Flu, and Phe have been confirmed to be closely related to the emissions from coal-fired power plants [31]. Coal-fired thermal power companies, such as the Qingshan Thermal Power Company and Wuhan Wumei Baijiang Gas Company, are located near the lake area. Qingshan Thermal Power Plant is the backbone power plant of the Central China Power Grid, which provides power support for large-scale heavy industrial production, such as the adjacent WISCO. Therefore, factor 3 may come from coal combustion, and the impact of these thermal power plants is well reflected in this factor.

Factor 4 contributed only about 5% of the total PAHs and is composed of BaA, BaP, BbF, and BkF. BaP and BaA are considered as the indicators of gasoline combustion [36], while BkF and BbF are indicators of diesel combustion [37]. Trains and some trucks with high capacities use diesel as energy [35]. Dong Lake is near Wuhan High-speed Railway Station, which is a busy railway and highway transportation network, and there are many cross-lake channels, such as Third Ring Road and Tangshan Lake Bridge. This factor can be deemed as a source of traffic emissions.

Factor 5 is mainly composed of Pyr, BaA, and DahA, with a contribution of 8.2%. DahA mainly exists in diesel particles from diesel combustion [38]. BaA is a sign of natural gas combustion [39], whereas Pyr and IcdP indicate gasoline engine combustion [37]. Thus, factor 5 is relatively complex, and is possibly from a mixed source of petroleum and natural gas combustion, such as diesel and gasoline.

Overall, whether it is due to the combustion of petroleum products, the power supply of coal-fired power plants, or traffic emissions, the accumulation of PAHs in the sampling lake area was caused by human life and industrial activities. This finding is the same as the conclusion that human activities were mostly responsible for the loading of PAHs into the atmospheric dust fall from Hubei Province's industrial corridor. Rapid industrialization and urbanization result in frequent human activities that discharge various pollutants into urban inner lakes. Currently, human activities have become the main source of PAHs in the environment [40].

3.3. Ecological and Human Risk of PAHs

PAHs have drawn greater attention because of their high toxicity, propensity for causing cancer, teratogenic and mutagenic effects, and endocrine disruption. They can inflict varying degrees of damage on the human body through a variety of direct and indirect routes, as well as through passive absorption into the food chain [26].

In this examination of lake water toxicity, the potential impact of PAHs was evaluated using BaP toxicity equivalency factors (TEFs) [1] Use Equation (1) to obtain the PAH toxic equivalency (TEQ) [15]:

$$TEQ = \sum TEF_i \times C_{PAHi} \quad (1)$$

where C_{PAHi} is the level of each identified PAHi, and TEF_i is the toxic equivalency factor of each PAH in relation to BaP. The TEQ in Dong Lake and Tangxun Lake were in the range of 0.24–5.31 ng TEQ/L and 0.44–4.93 ng TEQ/L, with a median of 1.44 ng TEQ/L and 1.39 ng TEQ/L, respectively. It can be seen that the distribution of the TEQ has significant spatial differences (Figure 5). This is similar to the situation in Sanliqi Lake; except for some points where the TEQ concentration is higher, all other points are less than 2.8 ng/L, which is lower than the limit value of the China Surface Water Environmental Quality Standard [23]. The first and second highest TEQ values of 5.31 and 4.93 ng TEQ/L were detected at sites D5 and T7, respectively. The $\sum_{16}$PAH concentration at D5 was the highest among all sampling points, and there is no doubt that it has a high TEQ value. But, unexpectedly, the levels of the Σ_{16}PAHs at T7 were low with a high TEQ value. As shown in Figure 5, the levels of BaP, BaA, BbF, and BkF at T7 are much higher than that of other sampling points, especially for BaP and BaA. Among the many PAHs, BaP is the most potentially carcinogenic [41]. BbF and BkF are categorized as Group 2B chemicals (possible carcinogens) and BaA and BaP as Group 2A chemicals (probable carcinogens) by the International Agency for Research on Cancer [42]. Although the concentration of the Σ_{16}PAHs at the site of T7 is low, the potential cancer risk is high. In addition, BaP, BaA, BbF, and BkF mainly exist in the combustion products of diesel and gasoline, and they are typical sources of transportation. Accordingly, the releasing of PAHs by traffic may cause greater harm to the human body, which is in accordance with the findings reported by Chłopek et al. [43]. This outcome is also in line with the earlier study of Lee et al., where high levels of the presence of cancer-causing PAHs close to traffic sources were found to play a significant role in Taiwan's high risk of lung cancer [44]. Traffic is an unavoidable and very important link in urban life, so we should pay higher attention to the sources of traffic in the process of preventing and controlling PAHs.

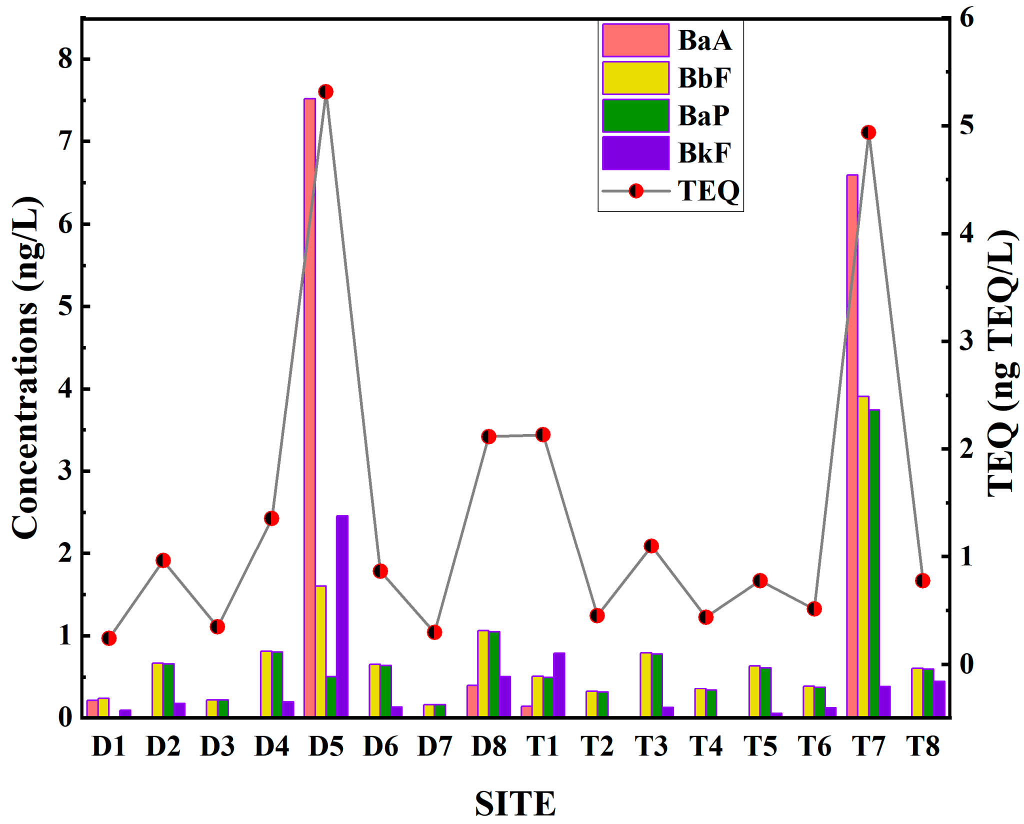

Figure 5. The TEQ level in relation to BaA, BbF, BaP, and BkF.

In terms of human risk, PAHs pose a potential threat to health through direct ingestion and skin contact [10]. A life-long carcinogenic risk (ILCR) model was used to assess the potential risk of PAHs to human health [16] as follows (Equations (2) and (3)):

$$ILCRs_{Ingestion} = \frac{TEQ_{BaP} \times CSF_{Ingestion} \times IR_{Ingestion} \times EF \times ED}{BW \times AT} \quad (2)$$

$$ILCRs_{Dermal} = \frac{TEQ_{BaP} \times CSF_{Dermal} \times K_P \times ET \times SA \times CF \times ABS \times EF \times ED}{BW \times AT} \quad (3)$$

where $ILCRs_{Ingestion}$ and $ILCRs_{Dermal}$ represent the ILCRs of PAHs exposed to water by ingestion and dermal contact, respectively; $CSF_{Ingestion}$ is the carcinogenic slope factor (kg·d·mg^{-1}); BW is the average body weight (kg); AT is the mean time of being carcinogenic; EF is the annual exposure frequency (d·year^{-1}); ED is the exposure duration (years); $IR_{Ingestion}$ is the ingestion rate (L·d^{-1}); CF is the conversion fraction; and ET is the exposure time (h d^{-1}). Based on the capacity of BaP to cause cancer, the $CSF_{Ingestion}$ and CSF_{Dermal} of BaP were found as being 7.3 and 25 kg·d·mg^{-1}, respectively [16]. Other factors used in the model were decided upon based on the US EPA's Risk Assessment Guidance and other publications connected to it, as stated in Table 1.

The $ILCRs_{Ingestion}$ was between 10^{-9} and 10^{-7} at all of the sampling points, while the $ILCRs_{Dermal}$ ranged from 10^{-10} to 10^{-9} (Table 2). In most regulatory standards, an ILCR between 10^{-6} and 10^{-4} suggests a potential risk, with an ILCR of 10^{-6} or less designating virtual safety. The ILCRs of all sampling points were less than 10^{-6}, which belong to the low carcinogenic risk level [42]. In fact, there are many farmed fish in both Dong Lake and Tangxun Lake, and these fish may be contaminated with PAHs because of the nearby production and living conditions. Consuming these fish may raise the risk of developing cancer, and [45] reported that fish from urban water intakes may be affected by pyrogenic PAHs, which is consistent with the conclusion of our findings. Ingesting these contaminated fish may indeed increase the risk of cancer [46]. The studied areas are famous tourist attractions for adults and children to enjoy leisure and entertainment. Children can easily ingest PAH pollutants due to their hand-to-mouth activities [47]. Adults are prone to come in contact with pollutants through dermal contact with water in lakes, such as through swimming, fishing, and boating. Since the adult skin area is larger, there may be a higher potential risk for cancer through dermal contact [25]. Therefore, despite the low potential cancer risk associated with lakes bodies, we cannot disregard this information.

In all, there is indeed a certain potential cancer risk due to the PAH pollution in these water bodies, especially near the sampling points D5 and D7. Thus, the PAH pollution in Wuhan's urban lakes still needs more attention.

Table 1. Lifetime carcinogenic risk assessment parameters.

Parameter	Meaning	Numerical Value
$IR_{Ingestion}$	Ingestion rate	2.0 L·d^{-1}
EF	Annual exposure days	350 d·year^{-1}
ED	Exposure time	70 years
BW	Average body weight	70 kg
AT	Mean time of carcinogenic effect	ED × EF d
SA	Dermal surface exposure	2800 cm^2
Kp	Dermal permeability constant	0.001
ABS	Dermal absorption fraction	0.001
ET	Exposure time	0.6 h·d^{-1}
CF	Conversion fraction	1L (1000 cm^3)$^{-1}$
$CSF_{Ingestion}$	Carcinogenic slope coefficient of ingestion	7.3 kg·d·mg^{-1}
CSF_{Dermal}	Carcinogenic slope coefficient of dermal contact	25 kg·d·mg^{-1}

Table 2. The values of ILCRs in Dong Lake and Tangxun Lake.

	Site	$ILCR_{Ingestion}$	$ILCR_{Dermal\ contact}$	$ILCR_{PAHs}$
Dong Lake	D1	6.90×10^{-9}	1.44×10^{-10}	7.01×10^{-9}
	D2	2.70×10^{-8}	5.77×10^{-10}	2.76×10^{-8}
	D3	9.90×10^{-9}	2.09×10^{-10}	1.01×10^{-8}

Table 2. *Cont.*

	Site	$ILCR_{Ingestion}$	$ILCR_{Dermal\ contact}$	$ILCR_{PAHs}$
Dong Lake	D4	3.90×10^{-8}	8.13×10^{-10}	3.95×10^{-8}
	D5	1.50×10^{-7}	3.19×10^{-9}	1.55×10^{-7}
	D6	2.50×10^{-8}	5.18×10^{-10}	2.52×10^{-8}
	D7	8.50×10^{-9}	1.78×10^{-10}	8.64×10^{-9}
	D8	6.00×10^{-8}	1.27×10^{-9}	6.17×10^{-8}
Tangxun Lake	T1	6.08×10^{-8}	1.28×10^{-9}	6.21×10^{-8}
	T2	1.29×10^{-8}	2.71×10^{-10}	1.32×10^{-8}
	T3	3.13×10^{-8}	6.58×10^{-10}	3.20×10^{-8}
	T4	1.25×10^{-8}	2.63×10^{-10}	1.28×10^{-8}
	T5	2.21×10^{-8}	4.65×10^{-10}	2.26×10^{-8}
	T6	1.46×10^{-8}	3.07×10^{-10}	1.49×10^{-8}
	T7	1.41×10^{-7}	2.96×10^{-9}	1.44×10^{-7}
	T8	2.22×10^{-8}	4.65×10^{-10}	2.26×10^{-8}

4. Conclusions

This study systematically investigated the concentration, distribution, and source of PAHs in urban lakes and evaluated their potential carcinogenic risks. The concentration of the $\sum_{16}$PAHs showed high variability among different sampling points, ranging from 12.92 to 989.09 ng/L with a geometric mean of 121.97 ng/L. In terms of data structure, the concentrations of the $\sum_{16}$PAHs in most of the samples were dispersed at the low concentration zone, with over 80% of them exhibiting a low level (below the AM at 121.97 ng/L). The proportion of single polycyclic aromatic hydrocarbon homologues indicates that the source of polycyclic aromatic hydrocarbons is a mixture of petroleum combustion, biomass combustion, and coal combustion products. The PMF model was successfully applied to identify and quantify five sources with similar contributions, including the combustion of petroleum products, heavy oil combustion, coal combustion, traffic emissions, and mixtures of natural gas and oil combustion. Toxicity equivalency factor studies have shown that the release of polycyclic aromatic hydrocarbons via transportation may lead to a greater potential cancer risk. According to the ILCR model evaluation, the ILCR values for all sampling points were less than 10–6, indicating that the PAH concentration in the lake area is at a low carcinogenic risk level. Although the potential cancer risk of Dong Lake and Tangxun Lake is relatively low, we still cannot ignore it. This study also has certain limitations, especially regarding the relatively small sample size and the neglect of the impact of seasonal changes. This may lead to some uncertainty in the research results. However, the application of the PMF model, toxicity equivalency factor, and ILCR model still provides us with reliable research results in the source apportionment of PAHs and the assessment of the potential carcinogenic risk of PAHs in Dong Lake and Tangxun Lake. The source of PAHs in the lake area has been preliminarily identified, and it has been assessed that the risk of cancer in the lake area is relatively low. This provides a certain reliable basis for formulating PAH control measures in Dong Lake and Tangxun Lake.

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