

Characterization and sources of PAHs in an urban river system in Beijing, China

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Received: 26 January 2008 / Accepted: 7 July 2008 / Published online: 22 July 2008
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Abstract Water samples from 20 locations on rivers in the Tongzhou District of Beijing were collected four times from July 2005 to March 2006. In addition, sediment samples were collected in July 2005. All samples were analyzed for 16 US Environmental Protection Agency (EPA) priority pollutants polycyclic aromatic hydrocarbons (PAHs). The concentration, distribution, seasonal variation, and sources of the 16 PAH compounds identified in the water samples, suspended particles, and surface sediments were then evaluated. The concentrations of PAHs in the water and suspended particle and surface sediment samples ranged from 87.3 to 1,890 ng l⁻¹, 1,330 to 27,700 ng g⁻¹, and 156 to 8,650 ng g⁻¹, respectively. These results demonstrated that rivers in the Tongzhou District of Beijing had a high level of PAH pollution, especially in the suspended particles. The highest and lowest concentrations of PAHs in the water samples were observed in summer and spring. However, the seasonal variations in the concentration of PAHs in the suspended particles were more complicated. The dominant compounds in the water, suspended particle, and surface sediment samples were two-, three- and four-ring PAH compounds, respectively. Ratio analysis illustrated that

fuel-burning was the primary source of PAHs in the study area. Gasoline, diesel, coal, and coke oven sources were identified and the contributions of the different fuel-burning sources were then calculated using factor analysis and multiple linear regression. These analyses revealed that coal combustion, gasoline combustion plus coke oven emission, and diesel combustion accounted for 38.8%, 38.5%, and 22.7% of the PAHs in suspended particles, respectively.

Keywords PAHs · Water sample · Suspended particle · Sediment · Distribution · Source apportionment

Introduction

Polycyclic aromatic hydrocarbons (PAHs) with two or more rings are a group of compounds of great environmental concern due to their immunotoxicity, genotoxicity, carcinogenicity, and reproductive toxicity (Zhang et al. 2004). Accordingly, 16 PAH compounds have been listed by the United States EPA as priority pollutants (Keith and Telliard 1979). PAHs are primarily formed as incomplete combustion products of coal, gasoline, diesel, natural gas, garbage, or other organic substances such as tobacco (Nadal et al. 2004). Apart from being produced by incomplete combustion, another common anthropogenic source of PAHs is the accidental spillage of fossil fuels such as crude and refined oil (Harrison et al. 1996).

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PAHs are generally highly lipophilic; therefore, their solubility in water is usually low. PAHs reach the aquatic environment primarily via dry and wet deposition and surface runoff; however, industrial wastes can also contain PAHs (Chen et al. 2004). Sediments are usually considered to be the main sinks for PAHs in the aquatic environment (Mackay et al. 1992).

The source, occurrence, transport, and fate of PAHs in natural environments have been studied extensively (Charlesworth et al. 2002; Yunker et al. 2002; Zakaria et al. 2002; Dahle et al. 2003; Rebecca et al. 2003; Savinov et al. 2003; Cachot et al. 2006). Although similar studies have been conducted throughout China (Mai et al. 2003; Zhou and Maskouei 2003), until now there has been little information regarding the pollution of surface water and sediments in urban areas of China by PAHs.

Tongzhou District is located in the southeastern portion of Beijing, adjacent to the Chaoyang District, Daxing District, and Shunyi District of Beijing, and Langfang City, Sanhe County, Hebei Province. Tongzhou has undergone rapid economic development, urbanization, and industrialization in the last two decades and is now one of the most important residential and industrial centers in Beijing. There are 13 rivers in Tongzhou District with a total length of 245 km. In this study, the Tonghui/Beiyun River, the Chaobai River, the Feng River, and the Liangshui/Fenggangjian River were surveyed for the presence of polycyclic aromatic hydrocarbons. The concentrations, distribution, seasonal variation, and sources of the 16 EPA priority PAH compounds in water, suspended particles, and surface sediments are then discussed.

Materials and methods

Sampling

A total of 20 sampling sites were selected on rivers in the Tongzhou District of Beijing. These included nine on the Tonghui/Beiyun River (sampling sites 1–9), five on the Chaobai River (sampling sites 10–14), two on the Feng River (sampling sites 15–16), and four on the Liangshui/Fenggangjian River (sampling sites 17–20) (Fig. 1 and Table 1). Water samples were collected four times from 2005 to 2006 (July 2005, October 2005, December 2005, and March 2006).

A global positioning system (GPS) was used to locate the sampling positions. Water samples were collected into precleaned glass bottles. In addition, surface sediment samples were collected in July 2005 using a stainless-steel grab sampler. All samples were immediately frozen and then transported to the laboratory where they were stored at -18°C until analysis.

Water samples were collected in precleaned 10-l glass carboys and then filtered through 142-mm-diameter 0.7- μm -pore-size precombusted (450°C for 4 h) and pre-tared glass-fiber filters (GFF) housed in a stainless-steel filter holder (Yang et al. 2004). After filtration, the water samples (filtrate) and the GFFs were stored until further analysis. An additional 500 ml of unfiltered water was passed through precombusted and pre-tared 25-mm-diameter (0.7 μm pore size) GFFs to determine the concentration of total suspended solids (TSS).

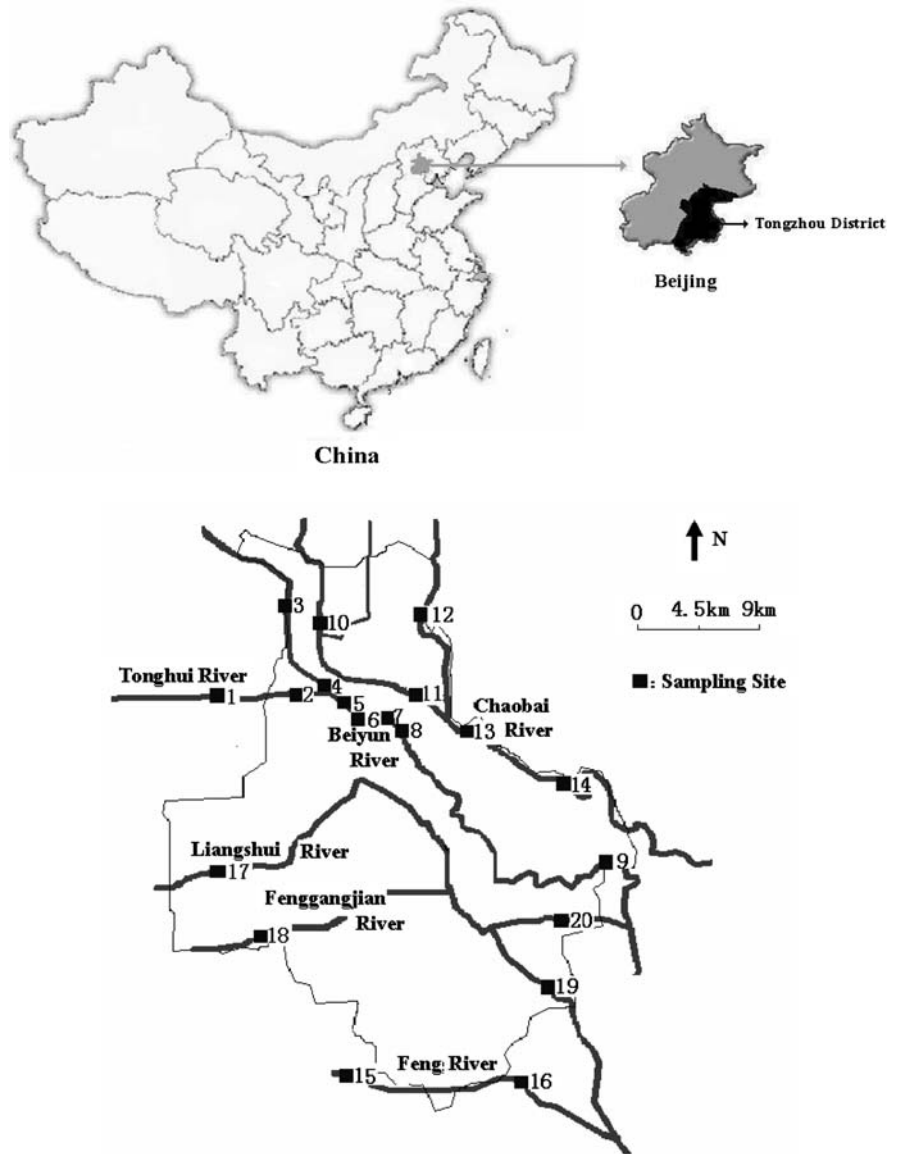
Sample extraction

The water samples were extracted using a solid-phase extraction (SPE) system (Supelco) following previously described procedures (Zhou et al. 1996, 2000). Briefly, the SPE cartridges were conditioned with 6 ml methanol followed by 6 ml deionized water. The water samples were then passed through the cartridges at a flow rate of 5–20 ml/min under vacuum. Following extraction, the cartridges were spiked with a mixture of five surrogate standards (naphthalene-d8, acenaphthene-d10, phenanthrene-d10, pyrene-d12, chrysene-d12, and perylene-d12), and then eluted with 10 ml of methylene chloride. After removing the water from the extracts using ashed Na_2SO_4 , the volume of the extracts was reduced by nitrogen blow-down.

Suspended particle samples were freeze-dried and extracted using a Soxhlet apparatus with sodium sulfate (Mai et al. 2003). Each sample was then spiked with the same mixture of five surrogate standards described above, after which they were extracted with 100 ml methylene chloride for 8 h. Next, activated copper was added to desulfurize the samples.

Sediment samples were air-dried and then extracted using a Soxhlet apparatus with sodium sulfate. Each sample (5 g) was then spiked with the same mixture of five surrogate standards described above, after which activated copper was added. The samples were then extracted with 100 ml methylene chloride for 72 h. Next, the extract was preconcentrated to 1 ml using a

Fig. 1 Map of sampling sites



rotary evaporator, after which the solvent was exchanged with hexane. The hexane extract was then fractionated and purified using an alumina/silica gel column. The column was then eluted with 70 ml methylene chloride/hexane (vol/vol = 3:7) to obtain the PAH. The combined collected solvent was then subjected to rotary evaporation again.

Sample analysis

The concentrations of PAHs in the extracts were determined using an Agilent 6890 GC equipped with a 5973N mass-selective detector (MSD) under the

selected ion monitoring mode (SIM) (Zhang et al. 2004). A HP-5 silica fused capillary column (30 m × 250 μm inner diameter × 0.25 μm film thickness) was used with helium being provided as the carrier gas at a constant flow rate of 1 ml/min. The temperature was programmed to ramp from 60°C to 280°C at a rate of 5°C/min, after which it was held at 280°C for 20 min. Quantification of the PAHs was then performed using the internal standard method. The detection limit was 0.85 ppb. The instrument stability and response were evaluated using internal standards (2-fluorobiphenyl and P-terpheny-d14). Deuterated spiked compounds were used. The spiked compounds

Table 1 Description of sampling sites

Sampling sites	Description
1. Port of Tonghui River	Residential area
2. Outflow of Tonghui River	Industrial and residential area
3. Yinge Village	Agriculture area
4. Dongguan Street	Industrial and residential area
5. Yudaihe Street	Industrial area and main road
6. Upriver of paper mill	Industrial area
7. Upriver of Orient Chemical Plant	Industrial area
8. Downriver of Orient Chemical Plant	Industrial area
9. Outflow of Beiyun River	Agriculture area
10. Xiaozhong River	Agriculture area
11. Lucheng Town	Residential area
12. Bai temple	Agriculture area
13. Chaobai River	Agriculture area
14. Xingge Village	Residential area
15. Port of Feng River	Agriculture area
16. Houshang bridge	Residential area and main road
17. Port of Liangshui River	Industrial area
18. Fenggangjian River bridge	Residential area
19. Outflow of Ganggou River	Agriculture area
20. Houjianping	Residential area

in the samples were identified and quantified with good precision. The samples were then analyzed for the following 16 EPA PAHs: naphthalene (N), acenaphthylene (Acy), acenaphthene (Ace), fluorene (Flu), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fl), pyrene (Py), benz[*a*]anthracene (BaA), chrysene (C), benzo[*b*]fluoranthene (BbFl), benzo[*k*]fluoranthene (BkFl), benzo[*a*]pyrene (BaPy), indeno[1,2,3-*cd*]pyrene (IPy), dibenz[*a,h*]anthracene (DBA), and benzo[*g,h,i*]perylene (BghiPer). SumPAHs (\sum PAH) is defined as the sum of the above compounds.

Quality assurance and quality control

All data were subjected to strict quality control procedures including analysis of method blanks and sample duplicates. All data were blank corrected. In addition, superpure water was used as a blank during the analysis of all sample types. Furthermore, 30% of

Table 2 Recoveries of the five compounds used to spike the samples

Compounds	Water (%)	Suspended particles (%)	Sediment (%)
Naphthalene-d8	76.2	52.8	58.5
Acenaphthene-d10	97.3	71	68.7
Phenanthrene-d10	103	73.8	79.2
Chrysene-d12	78.2	97.4	88.9
Perylene-d12	66.2	91.2	88.7

the samples were selected at random and analyzed to determine the recoveries, which were found to range from 66.2% to 103% for water samples, from 52.8% to 97.4% for suspended particle samples, and from 58.5% to 88.9% for sediment samples (Table 2).

Results and discussion

Concentration and seasonal variation

Statistical analysis indicated that all the log PAHs values followed normal distributions. The sumPAHs values in the water samples varied from 87.3 to 1,890 ng l⁻¹ (Table 3), with the highest concentration of total PAHs being observed in July, and the lowest concentration being observed in March. In addition, the maximum PAH level in the water samples was observed in July (geometric mean 546 ng l⁻¹) and the minimum PAH level was observed in March (geometric mean 256 ng l⁻¹). These findings indicate that the rivers in Tongzhou contained higher levels of PAHs in the summer and autumn than during the winter and spring. During the study period, there was much more rain in summer and autumn than during the other seasons. The higher amount of rainfall likely resulted in a high volume of surface runoff that contained PAHs from atmospheric deposition entering the rivers (Zhu et al. 2004; Liu et al. 2006). In addition, the solubility of PAHs is higher in the summer and autumn due to the higher temperatures.

The sumPAHs values in the suspended particles varied from 1,330 to 27,700 ng g⁻¹, but the seasonal variations in the concentrations of PAHs in the suspended particles were complicated. The maximum PAH levels in the suspended particles were observed in

Table 3 SumPAHs in water (ng l⁻¹) and suspended particles (ng g⁻¹) during different seasons and sumPAHs in sediment (ng g⁻¹)

Sampling site	Water (ng l ⁻¹)				Suspended particles (ng g ⁻¹)				Sediment (ng g ⁻¹)
	Jul	Oct	Dec	Mar	Jul	Oct	Dec	Mar	
1	538	503	226	316	9,770	5,460	5,780	6,120	4,390
2	750	478	267	417	7,570	1,700	6,260	5,550	7,970
3	303	349	293	187	2,060	5,730	14,000	3,800	253
4	808	503	346	470	7,710	4,420	17,000	18,800	8,650
5	419	701	667	237	11,300	2,010	5,160	2,930	171
6	957	742	606	345	8,510	6,010	10,500	4,580	5,180
7	645	475	977	697	6,430	4,170	6,920	7,670	4,500
8	326	522	685	705	12,600	2,280	7,860	19,300	6,120
9	650	575	870	416	10,400	9,750	3,820	3,510	4,810
10	186	666	162	230	2,790	2,990	19,500	2,290	541
11	249	497	462	347	2,230	5,580	6,800	3,050	1,430
12	260	252	–	373	2,220	2,300	–	2,110	156
13	223	361	481	188	2,940	5,360	5,970	4,010	217
14	564	240	414	175	5,880	3,470	7,780	7,750	829
15	708	469	619	133	4,360	9,500	7,710	6,810	2,630
16	853	799	–	267	3,160	2,360	–	6,120	914
17	1,660	1,210	205	87	27,700	8,380	20,600	7,730	3,890
18	1,290	1,560	732	128	9,880	6,370	27,300	8,220	3,900
19	1,890	344	1,100	116	13,100	1,330	2,390	4,420	1,850
20	275	120	925	174	4,660	1,380	5,080	3,890	1,410
Geometric mean	546	491	483	256	6,110	3,810	8,250	5,340	1,640
Standard deviation	474	332	272	176	5,927	2,609	6,485	4,716	2,646

December (geometric mean 8,250 ng g⁻¹), whereas the minimum values were observed in October (geometric mean 3,810 ng g⁻¹). The concentrations of the suspended particles varied from 0.0074 to 0.0693 g l⁻¹ in July, from 0.0018 to 1.13 g l⁻¹ in October, from 0.0053 to 0.0884 g l⁻¹ in December, and from 0.008 to 0.17 g l⁻¹ in March. The variations in the concentrations of PAHs observed in the suspended particles collected during different seasons may have been caused by the input sources, the persistence of sorbed substances against degradation, and the contents of the suspended particles. The trend of seasonal variations in the contents of the suspended particles was different from that of the sumPAHs in the suspended particles. However, the contents of the suspended particles and the concentrations of the PAHs, especially the low-molecular-weight PAHs, were significantly correlated.

The sumPAHs values in the sediment varied from 156 to 8,650 ng g⁻¹ and had a geometric mean of 1,630 ng g⁻¹.

Spearman correlation analysis was conducted on the PAHs in the water, suspended particles, and sediment. The results revealed that the total concentrations of the sumPAHs in water and the suspended particles were correlated (*P* < 0.05). In addition, the sumPAHs in water and in the sediment were also correlated (*P* < 0.05).

Spatial variations

Figure 2 shows the spatial variation in the PAHs found in rivers in the Tongzhou District. Significant differences in the concentrations of PAHs were found among sites. Specifically, the concentration of PAHs in the Tonghui/Beiyun River and the Liangshui/

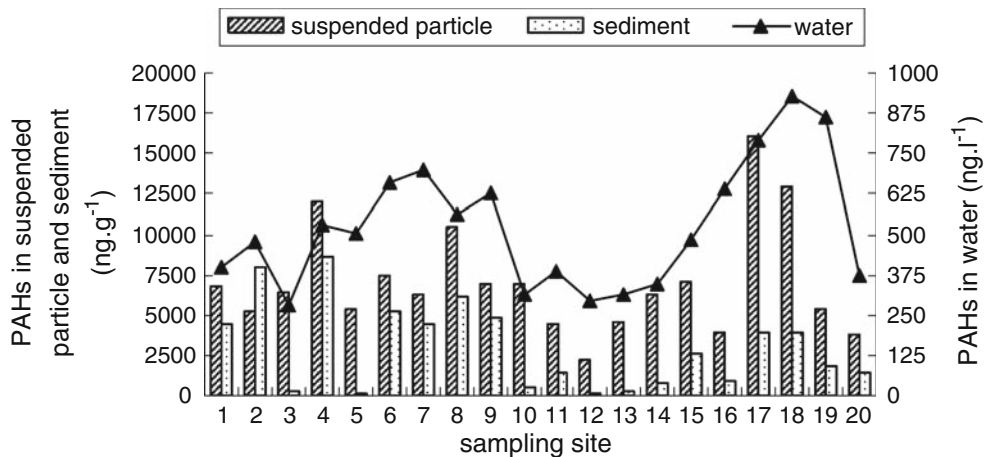


Fig. 2 Concentrations of sumPAHs in water, suspended particle, and sediment samples

Fenggangjian River were high, whereas they were low in the Chaobai River and the Feng River. Similar spatial trends were observed in the individual PAHs observed in the water, suspended particle, and sediment samples.

There are more industries and residential areas located along the Tonghui and Beiyun Rivers than along other rivers in the Tongzhou District. In addition, the Liangshui/Fenggangjian River was polluted upstream of the Tongzhou District. However, the Chaobai River and Feng Rivers are not heavily impacted by industrial or residential sources of pollution.

Dominant PAH compounds and their correlations

The percentages of PAH compounds (as determined by ring size) in the water, suspended particle, and sediment samples are presented in Table 4. The samples were dominated by two-ring PAHs (50.4–66.6%); however, they also contained a high proportion of three-ring PAHs (27.1–36.9%). In addition, the proportions of

two/three-ring PAHs in the water samples were higher in summer and autumn than during other seasons. Three-ring PAHs dominated the suspended particle samples (35.8–52.8%), although those samples also contained high proportions of two-ring PAHs (19.9–32.5%). The sediment samples were dominated by PAH compounds with four rings (34.8%) and five/six rings (32.8%). The presence of a high proportion of high-molecular-weight PAHs in sediments is similar to the results of previous studies (Chen et al. 2004; Zhou and Maskaoui 2003).

There are three possible reasons for the different patterns of PAH contamination that were observed between sample types: low-molecular-weight PAHs dissolve more easily than higher-weight PAHs; high-molecular-weight PAHs tend to be sorbed into sediment and be resistant to degradation (Zhu et al. 2004); low-molecular-weight PAHs can enter the water from the air through air-water exchange.

The relationships between the concentrations of sumPAHs and the concentrations of the dominant PAH compounds in each sample matrix are shown in

Table 4 Percentages of PAH compounds in water, suspended particle, and sediment samples

	Water				Suspended particles				Sediment
	Jul	Oct	Dec	Mar	Jul	Oct	Dec	Mar	
2 rings	50.4	54.6	62.0	66.6	27.7	32.5	28.7	19.9	13.0
3 rings	36.9	32.9	27.4	27.1	40.7	38.5	35.8	52.8	19.4
4 rings	10.2	11.5	7.72	5.93	20.2	19.7	21.2	20.2	34.5
5–6 rings	2.51	1.08	2.87	0.43	11.4	9.28	14.4	7.09	32.8

Note: 2 rings (N, Ace, Acy, Flu); 3 rings (Phe, Ant, Fl); 4 rings (Py, BaA, C, BbFl, BkFl); 5–6 rings (BaPy, DBA, IPy, BghiPer)

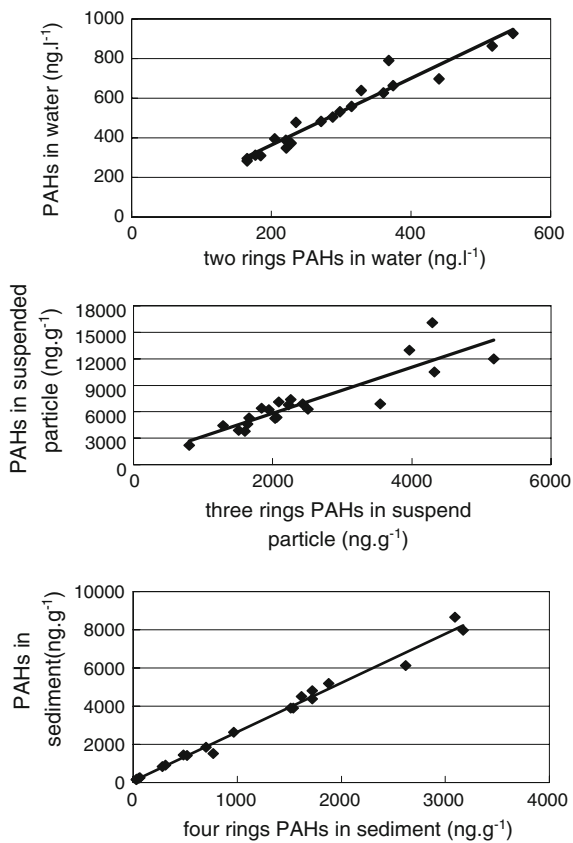


Fig. 3 Relationships between concentrations of sumPAHs and the dominant PAH compounds

Fig. 3. The results of unitary linear regression analysis indicated that the concentrations of the sumPAHs and the dominant PAH compounds were significantly correlated in the water, suspended particle, and sediment samples.

Statistical and multivariate analysis of data

The ratios of specific particulate phase PAHs can be used to trace the pollution sources (Matt et al. 1999). Commonly used ratios include benz[a]anthracene to chrysene (BaA/C), indeno[1,2,3-*cd*]pyrene to benzo [*g,h,i*]perylene (IPy/BghiPer), fluoranthene to fluo-ranthene plus pyrene (Fl/(Fl + Py)), phenanthrene to anthracene (Phe/Ant), and benzo [*a*]pyrene to benzo [*g,h,i*]perylene (BaPy/BghiPer). The ranges and geometric mean values for the ratios of these compounds in the suspended particle and sediment samples evaluated in this study are presented in Table 5 along

with values from other studies (Matt et al. 1999; Doong and Lin 2004; Fang et al. 2004).

The geometric mean BaA/C ratio was 0.37 and 0.74 for the suspended particle and sediment samples, respectively. These values are similar to the values measured for gasoline and coke oven emissions. The geometric mean of the BbFl/BkFl ratio fell within the ranges of the values for coal and firewood combustion. In addition, the geometric mean of the IPy/BghiPer and Fl/(Fl + Py) ratios for suspended particle and sediment samples were similar and indicated that they were from diesel and coal combustion sources. The geometric mean of the Phe/Ant ratio was 4.50 and 4.78 for suspended particle and sediment samples, respectively, which indicates that the PAHs in these samples were primarily produced by gasoline combustion. Additionally, the geometric mean of the BaPy/BghiPer ratio in the sediment samples revealed the contribution of diesel, and the geometric mean of the BaPy/BghiPer ratio in the suspended particle samples suggested that some of the PAHs were produced by coal combustion. Taken together, these findings indicate that the PAHs in rivers in the Tongzhou District came from a variety of sources.

The seasonal fluctuations in the ratios of specific particulate phase PAHs in the suspended particle samples were also evaluated. The results revealed that the ratio of Fl/Py in these samples was greater than one for all four seasons. This finding indicates that there was no significant difference in the sources of the PAHs found in the suspended particles.

Surface runoff and air precipitation during different seasons are important sources of PAHs in the study area. For example, previously conducted studies have found that surface runoff could be an important input pathway for PAHs in the urban river system in Beijing (Zhang et al. 2007). In addition, precipitation from the air in the Beijing area is the major contributor of PAHs to urban dust; therefore, these PAHs enter the river system through urban runoff (Zhang et al. 2008).

Ratio analysis allowed the sources of the PAHs to be qualitatively identified. However, we also attempted to describe the sources of the PAHs quantitatively (Seung and Young 2005; Manoli et al. 2000). To accomplish this, we conducted factor analysis with varimax rotation for all PAH concentrations observed in the rivers of the Tongzhou District, except N. The rotated

Table 5 Summary of diagnostic indicators

	BaA/C	BbFl/BkFl	IPy/BghiPer	Fl/(Fl + Py)	Phe/Ant	BaPy/BghiPer
Other studies:						
Gasoline	0.28–1.20	–	–	–	3.4–8	0.3–0.4
Diesel	0.17–0.36	–	1	0.65 ± 0.05	7.6–8.8	0.46–0.81
Coal	1.0–1.2	3.70 ± 0.17	1.09 ± 0.03	0.74	3	0.9–6.6
Coke oven	0.7	–	–	–	0.79	5.1
Firewood	0.93	0.92 ± 0.16	0.28 ± 0.05	–	–	–
Street dust	–	–	–	–	8	–
This study:						
Suspended particles (geometric mean)	0.16–1.15 0.37	0.88–4.19 1.69	0.98–2.26 1.32	0.43–0.76 0.53	1.98–14.42 4.50	0.66–2.99 1.20
Sediment (geometric mean)	0.37–1.10 0.74	0.51–3.11 1.49	0.82–1.63 1.20	0.50–0.59 0.54	2.67–11.41 4.78	0.39–1.43 0.81

Sources: Matt et al. (1999); Fang et al. (2004)

Table 6 Rotated component eigenvalues and squared loadings

Component	Suspended particles		
	Eigenvalues	% of variance	Cumulative %
1	6.04	40.2	40.2
2	4.74	31.6	71.8
3	2.15	14.3	86.1

component eigenvalues and compound matrix of the PAHs in the suspended particle samples are presented in Tables 6 and 7. The first three factors were found to account for more than 85% of the variability.

Diagnostic PAH compounds from different sources were selected based on the results of previous studies (Harrison et al. 1996; Matt et al. 1999; Simo et al. 1997; Fang et al. 2006). Phe, Ant, Fl, BbFl, BkFl, and Py were used to quantify PAH compounds that originated from coal combustion. Additionally, IPy, BaA, and Acy were considered to reflect PAHs that originated from diesel, natural gas, and gasoline combustion, respectively. Finally, Ace and Flu were used as the diagnostic PAH compounds to quantify coke oven emission.

The results of factor analysis revealed that factors 1, 2, and 3 accounted for 40.2%, 31.6%, and 14.3% of the variability in the suspended particle samples, respectively. Factor 1 was highly loaded with BbFl, BkFl, and BaPy, which are often found in high concentrations in emissions from coal combustion. Therefore, factor 1 was assumed to represent the

Table 7 Rotated component matrix

	Suspended particles		
	F1	F2	F3
Acy	0.441	0.854	−9.07E-02
Ace	0.390	0.828	1.74E-02
Flu	0.291	0.888	−3.89E-02
Phe	0.173	0.794	0.500
Ant	3.54E-02	2.96E-02	−1.34E-02
Fl	0.586	0.676	0.302
Py	0.649	0.634	0.264
BaA	0.777	0.488	0.318
C	0.742	0.539	0.303
BbFl	0.902	0.396	8.35E-02
BkFl	0.914	0.344	0.167
BaPy	0.929	0.209	0.187
DBA	0.189	−7.31E-02	0.937
Ipy	0.569	0.311	0.731
BghiPer	0.885	0.305	0.229

contribution of coal combustion. Factor 2 was highly loaded with Acy, Ace, and Flu. The presence of Acy and Flu suggest the contribution of coke oven emissions, while Acy is predominant in gasoline combustion signals. Therefore, factor 2 was assumed to represent the contribution of coke oven and gasoline combustion. The third factor was dominated by DBA and IPy, which reflect the contribution of diesel combustion.

The multiple regression model is:

$$Y = \sum A_i X_i, \tag{1}$$

where Y is the normalized concentration of the sumPAHs (except N), A_i is the modeled regression coefficient, and X_i is the score of the factors.

$$Y = \frac{(\sum \text{PAH} - \overline{\sum \text{PAH}})}{\sigma_{\sum \text{PAH}}}, \tag{2}$$

where $\sum \text{PAH}$ is the concentration of sumPAHs (except N), $\overline{\sum \text{PAH}}$ is the mean value of $\sum \text{PAH}$ s, $\sigma_{\sum \text{PAH}}$ is the standard deviation of $\sum \text{PAH}$ s.

The equations describing the relationship between $\sum \text{PAH}$ (except N) and the factors in the suspended particle samples were $\sum \text{PAH} = 0.859F1 + 0.438F2 + 0.218F3$; $\sum \text{PAH} = 0.638F1 + 0.634F2 + 0.373F3$.

The contributions of the different sources were calculated using the following function:

$$i = \frac{A_i}{\sum A_i} \times 100\%. \tag{3}$$

Using this equation revealed that coal combustion, gasoline combustion plus coke oven emission, and diesel combustion accounted for 38.8%, 38.5%, and 22.7% of the PAHs present in the suspended particle samples, respectively.

Conclusions

PAHs in water and suspended particle and sediment samples collected from 20 locations on rivers in the Tongzhou District of Beijing were evaluated. The results revealed that the levels of PAHs in these rivers were relatively high. The highest levels of PAHs were found in the Tonghui/Beiyun River and the Liangshui/Fenggangjian River, which are close to the Downtown Tongzhou area and the Yizhuang Industrial Park, respectively. This indicates that anthropogenic activity has a strong effect on the level of PAHs in rivers in the area. The dominant PAH compounds in the water and suspended particle and sediment samples were two- to four-ring PAHs, respectively. Additionally, unitary linear regression analysis indicated that the dominant PAH compounds were significantly correlated with the $\sum \text{PAH}$ s. Furthermore, ratio analysis revealed that

PAHs in the rivers of the Tongzhou District were primarily of pyrogenic origin, most likely due to high inputs from the combustion of gasoline, diesel, coal, and coke oven emissions. Finally, factor and multiple linear regression analysis was used to quantify the contributions of different fuel-burning sources to the PAH levels observed in the suspended particle samples. The results of these analyses revealed that coal combustion was the primary source of PAHs in suspended particle samples, but that coke oven emissions and diesel combustion were also important sources.

Acknowledgements This study was supported by the National Natural Science Foundation of China (40525003), Key MOE Research Project 306019, and the National Basic Research Program of China (2003 CB415004).

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