Polycyclic aromatic hydrocarbons (PAHs) in precipitation samples collected at Mount Taishan were determined by HPLC, to evaluate their concentrations and variations. Individual precipitation events were sampled for 2 years from Sep. 2005 to Aug. 2007. Low concentrations of PAHs were found at the site. Phenanthrene was the most abundant compound with a volume-weighted mean concentration of 33.31 ng/L. The next most abundant compound was fluoranthene, with a concentration of 16.61 ng/L. Other individual PAHs occurred at concentrations lower than 10 ng/L. The volume-weighted mean concentration of the total PAHs in winter precipitation was much higher than in summer, showing a seasonal variation. Most of the individual PAHs compounds have strong correlations with rainfall amount. Pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene and benzo(a)pyrene all had strong correlations with Na⁺ and Cl⁻. Diagnostic ratio analysis and factor analysis indicated that the sources of PAHs are mainly from fossil fuel combustion, especially coal.

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Keywords: Precipitation, PAHs, Seasonal variation, Mount Taishan

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous pollutants in the environment and are primarily of anthropogenic origin. Although some natural sources (volcanoes and forest fires) could contribute to the PAHs burden, residential heating, coke production, incineration and combustion of fossil fuels are by far the major sources of PAHs. Because of their carcinogenic and mutagenic potential, PAHs have been extensively studied in various environmental and biological compartments. Once PAHs enter the atmosphere, they are redistributed between gas and particle phases, low molecular weight (LMW) PAHs tend to be more concentrated in the vapor-phase while the ones with higher molecular weight (HMW) are often associated with particulates. Before deposition in terrestrial and aquatic systems through wet and dry deposition, PAHs can be transported over long distances. Thus, PAHs have been found in many remote rural areas, which are far from anthropogenic sources.

In recent years, a number of studies on PAHs have been conducted in various cities around the world. These studies have identified and quantified several PAHs compounds in samples collected from ambient air. Rapid industrialization and economic development in China may contribute to contamination by various pollutants, including PAHs. However, few studies have described the PAHs concentrations and seasonal variations of wet deposition in China, especially at high mountain sites far away from ground level pollution sources. The objective of this research was to analyze the concentrations and seasonal variations of PAHs in precipitation at Mount Taishan (a.s.l. 1545 m), a famous tourist site. The concentrations of PAHs in the precipitation were examined in relation to meteorological parameters and soluble ions in the precipitation. Finally, the sources of the
PAHs were identified by means of diagnostic ratios and by multifactor statistical analysis.

2. Materials and methods

2.1. Site description

Fifty precipitation samples were collected at Mount Taishan from September 2005 to August 2007. Mount Taishan is a famous tourist site in China, located in the North China Plain in the middle of Northeastern China, 230 km away from the Pacific Ocean (Fig. 1). The area is one of the most rapidly developing areas in China and many coal-fired power plants are present in the plain. Our monitoring site is at a meteorological station (E117°06′, N36°16′), which was set up in 1932 at the summit of Mount Taishan (1534 m a.s.l.). Because of its importance as a tourist site, Mount Taishan is protected from industrial pollution. The annual average temperature of this site is 7 °C, and its average rainfall is 1132 mm.

2.2. Sampling

Sampling of rain and snow were performed by an APS-3 automatic sampler (made by Xianlan Company in Changsha, China), with a cross-sectional area of 1500 cm². The sampler contains a humidity sensor, which automatically controls the collection of wet and dry deposition samples. During the wet deposition events, the lid on the wet collector moves away and precipitation sample is collected in a Teflon container through a stainless steel funnel. The precipitation samples were stored in a refrigerator at 4 °C until analysis. The analysis was carried out within 24 h after the rain/snow events.

2.3. Extraction and analysis

Preconcentration of the PAHs was performed by solid-phase extraction on an octadecyl–silicon cartridge (Kiss et al., 1996). Separation and quantification of the compounds was done by liquid chromatography. All liquid chromatographic analyses were carried out on a Shimadzu HPLC 2010A. The apparatus consisted of two LC-20AT pumps; an SPD-M20A detector; an RF-10AXL fluorescence detector; an SCL-10AVP system controller; an SIL-10AF auto-sampler; a CTO-10AS VP column oven; and a SUPELCOSILTM LC-PAH column (15 cm × 4.6 mm, 5 µm). All analysis was kept at a constant flow of 1.0 mL/min. The solvents used for the mobile phase were water and acetonitrile. The solvent gradient program was shown in Fig. 2; the detector program of fluorescence detector was shown in Table 1. 13 non-alkylated PAHs were analysed, which include fluorene (Flu), phenanthrene (PhA), anthracene (AnT), fluoranthene (FluA), pyrene (Pyr), benzo(a)anthracene (BaA), chrysene (Chr), benzo(b)fluoranthene (BbF), benzo(k)fluoranthene (BkF), benzo(a)pyrene (BaP), indenol[1,2,3-c,d]pyrene (Ind), dibenzo(a,h)anthracene (DbA) and benzo(g,h,i)perylene (BP). Recoveries of the analytes by the utilized technique were from 70% to 89%.

Fig. 1. Location of our site at the summit of Mountain Taishan (marked with a yellow frame).

Fig. 2. Solvent gradient program for PAHs separation.
Meteorological data of the sampling site were obtained from automatic weather system reports published by the local meteorological station (for years 2005 to 2007). The ions in the wet deposition samples were analyzed by Dionex IC-2500 (Wang et al., 2008).

3. Results and discussion

3.1. Precipitation deposition of PAHs

Fifty precipitation samples were analyzed from September 2005 to August 2007. Volume-weighted mean concentrations of PAHs and the range of concentrations in the precipitation samples are summarized in Table 2. BP and Ind have lower concentrations than the detection limit, are not listed. In our research, PAHs deposition is dominated by the LMW compounds Fig. 3, namely PhA, Flu and FluA, however, the major compounds detected are different from those in previous studies (Olivella, 2006; Fernandez et al., 2003). The mean concentration of PAHs in the samples ranged from 1.76 (BaA) to 33.31 (PhA) ng/L, and the volume-weighted mean concentration of total PAHs was 81.16 ng/L. PhA was the most abundant compound with a volume-weighted mean concentration of 33.31 ng/L. The next most abundant compound was Flu, with a concentration of 16.61 ng/L. Other PAHs compounds occurred at concentrations lower than 10 ng/L. Six potential carcinogenic PAHs (BaA, BbF, BkF, BaP, Ind, and DbA), as proposed by the International Agency for Research on Cancer (IARC) (1984), were not present at high concentrations, accounting for only 13.1% of the total PAHs. BbF was the most abundant compound among the potential carcinogenic PAHs, with a concentration of 2.62 ng/L. Ind was not detected.

For comparison, deposition of PAHs in precipitation reported in several countries is listed in Table 2. Although the conditions of these studies are different, they provide an overall picture of PAHs in precipitation in different countries. The mean PAHs concentrations in this study were comparable with the mean concentrations reported in Germany (De Rossi et al., 2003). However, PAHs concentrations in the precipitation of a rural site in Hungary (Kiss et al., 2001) and in Gdansk, Poland (Polkowska et al., 2000) were much higher than those found in our study. The concentrations of higher molecular weight PAHs (4–5 rings) in this study were much lower than those seen at the other sites, and the potentially carcinogenic PAHs also had lower concentrations. However, PAHs levels are expected to be significantly affected by the sampling location and its proximity to emission sources.

In this study, the lower molecular weight PAHs were predominant in the precipitation samples. Coal combustion, the dominant energy source in China, represents a large source of lower molecular weight PAHs (Simcik et al., 1999). As previously reported, the solubilities of low molecular weight PAHs are higher than the higher molecular weight compounds (Lee and Lee, 2004; Sahu et al., 2004). However, lower molecular weight PAHs are easier to accumulate at an elevated site, which may partly explain our observations.

3.2. Seasonal variation of PAHs concentration

Seasonal variability of PAHs concentration has been analysed in many research. In Fernandez et al.’s (2003) study, higher PAHs concentrations in bulk deposition were observed in warmer months at remote areas of Europe. However, more studies found that PAHs concentrations in

<table>
<thead>
<tr>
<th>Location</th>
<th>Sampling period</th>
<th>Flu</th>
<th>PhA</th>
<th>AnT</th>
<th>FluA</th>
<th>Pyr</th>
<th>BaA</th>
<th>Chr</th>
<th>BbF</th>
<th>BkF</th>
<th>BaP</th>
<th>DbA</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mount Taishan</td>
<td>2005.9–2007.8 (wet only deposition)</td>
<td>Max 65.36</td>
<td>102.86</td>
<td>15.53</td>
<td>46.39</td>
<td>34.60</td>
<td>31.55</td>
<td>20.83</td>
<td>16.06</td>
<td>30.54</td>
<td>31.26</td>
<td>10.80</td>
<td>50</td>
</tr>
<tr>
<td>Lake Balaton, Hungary</td>
<td>1995.1–1996.3 (wet only deposition)</td>
<td>Mean 16.61</td>
<td>33.31</td>
<td>3.64</td>
<td>7.80</td>
<td>6.07</td>
<td>1.76</td>
<td>3.11</td>
<td>2.62</td>
<td>1.97</td>
<td>2.26</td>
<td>0.85</td>
<td>20</td>
</tr>
<tr>
<td>Trier, Germany (Site located on a hill in a rural area)</td>
<td>1999–2000 (bulk deposition)</td>
<td>Max 16</td>
<td>44</td>
<td>ND</td>
<td>56</td>
<td>37</td>
<td>17</td>
<td>29</td>
<td>47</td>
<td>20</td>
<td>ND</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Gdansk, Poland</td>
<td>1996–1997 (wet only deposition)</td>
<td>Max 354</td>
<td>3396</td>
<td>310</td>
<td>8200</td>
<td>4000</td>
<td>10000</td>
<td>8000</td>
<td>12800</td>
<td>2500</td>
<td>573</td>
<td>814</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Min 15</td>
<td>5</td>
<td>5</td>
<td>11</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>11</td>
<td>0.52</td>
<td>0.34</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Mean 225</td>
<td>182</td>
<td>679</td>
<td>408</td>
<td>326</td>
<td>478</td>
<td>452</td>
<td>18</td>
<td>76</td>
<td>73</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
colder days were always higher. The concentration of PAHs measured in this study was highest in winter (from December to February), with a mean concentration of 94.24 ng/L, lowest in summer (from June to August), with a mean concentration of 72.90 ng/L, showing an evident seasonal variation (Fig. 4). This is consistent with the normal seasonal trend of PAHs deposition both in dissolved and particle-bound forms (Moon et al., 2006; Kiss et al., 2001; Pekey et al., 2007). A number of factors contribute to the seasonal variation. In the cold winter, large amounts of PAHs are emitted from residential heating. Some studies have reported that domestic heating is a source of PAHs in the atmosphere worldwide (Wild and Jones, 1995; Manoli et al., 2000). Typically, total consumption of fossil fuels (coal and petroleum) in the winter is much higher than in summer. In addition to the high emissions, the typical meteorological conditions in winter (lower intensity of sunshine, lower inversion height, lower OH radical concentration and less efficient photochemical decomposition) favor the accumulation of PAHs in the atmosphere (Kiss et al., 2001). However, snow has a high specific surface area and can scavenge PAHs in the atmosphere more efficiently than rain. In summer, there is a lower intensity of source emissions and prevailing atmospheric conditions may favor PAHs dispersion and decomposition, resulting in relatively low PAHs levels.

Though the mean concentration consists with typical seasonal variation, we should notice that summer has a higher PAHs concentration in the LMW group than in autumn. It can be explained by the reason below: At lower temperature, a larger faction of the atmospheric PAHs will associate with air particles (Fernandez et al., 2003); this will increase the HMW PAHs proportion to the total concentration and reduce the LMW group burden.

### 3.3. Relationships of PAHs concentrations with meteorological parameters and ions in precipitation

Correlation coefficients for the relationships of PAHs concentrations with meteorological parameters and ions in precipitation are listed in Table 3. Meteorological data, such as rainfall deposition, temperature and wind speed, were collected along with the precipitation samples, and the soluble ions in the precipitation were also analyzed. Among the meteorological parameters, though temperature has been reported to be highly correlated with PAHs deposition flux in some bulk deposition studies (Motelay-Massei et al., 2003), in this research we did not find an evident correlation between PAHs concentrations and temperature. However, most of the individual PAHs compounds have significant negative correlations with rainfall amount. That is because most of the PAHs could be scavenged during the initial stage of precipitation, so PAHs concentrations decrease with increasing cumulative rainfall. In Stein et al.’s (2006) study, they found that between 30% and 60% of the total PAHs load was discharged in the first 20% storm volume. Higher PAHs fluxes of wet deposition are always associated with higher precipitation (Fig. 5). In August, the highest PAHs fluxes belong to the highest rain amount, and winter days, in which precipitation are smaller, have much lower PAHs fluxes. No significant correlation was observed between PAHs concentrations and other meteorological parameters.

Analysis of correlations between individual PAHs concentrations and soluble ions showed that concentrations of individual PAHs including Pyr, BaA, BbF, BkF and BaP have significant positive correlations with Na+ and Cl− in precipitation, suggesting that these individual PAHs have been transported by ocean air currents. However, these compounds are not the dominate group in this study, they only account for 18.1% of the total concentration. The most two abundant compounds, Flu and PhA, did not show evident correlation with Na+ and Cl−, so the ocean source may not

#### Table 3

<table>
<thead>
<tr>
<th>Dep amount (mm)</th>
<th>Temp (°C)</th>
<th>Speed (m/s)</th>
<th>pH</th>
<th>NH4+</th>
<th>K+</th>
<th>Na+</th>
<th>Ca2+</th>
<th>Cl−</th>
<th>NO3−</th>
<th>SO42−</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flu –0.437*</td>
<td>–0.101</td>
<td>–0.220</td>
<td>–0.118</td>
<td>0.058</td>
<td>–0.101</td>
<td>0.014</td>
<td>0.080</td>
<td>0.089</td>
<td>0.114</td>
<td>0.063</td>
</tr>
<tr>
<td>PhA –0.528**</td>
<td>–0.237</td>
<td>–0.278</td>
<td>0.109</td>
<td>0.095</td>
<td>–0.122</td>
<td>0.291</td>
<td>0.078</td>
<td>0.256</td>
<td>0.115</td>
<td>0.041</td>
</tr>
<tr>
<td>AnT –0.333</td>
<td>–0.144</td>
<td>–0.209</td>
<td>–0.015</td>
<td>0.014</td>
<td>–0.116</td>
<td>0.135</td>
<td>–0.099</td>
<td>0.075</td>
<td>0.056</td>
<td>0.079</td>
</tr>
<tr>
<td>FluA –0.602**</td>
<td>–0.059</td>
<td>–0.301</td>
<td>0.162</td>
<td>–0.102</td>
<td>–0.042</td>
<td>0.420*</td>
<td>0.057</td>
<td>0.283</td>
<td>–0.099</td>
<td>0.186</td>
</tr>
<tr>
<td>Pyr –0.626**</td>
<td>–0.003</td>
<td>–0.343</td>
<td>0.270</td>
<td>0.080</td>
<td>0.196</td>
<td>0.586**</td>
<td>0.324</td>
<td>0.534*</td>
<td>0.238</td>
<td>0.026</td>
</tr>
<tr>
<td>BaA 0.016</td>
<td>0.069</td>
<td>0.154</td>
<td>0.479</td>
<td>–0.046</td>
<td>0.210</td>
<td>0.638**</td>
<td>0.294</td>
<td>0.467*</td>
<td>–0.040</td>
<td>–0.132</td>
</tr>
<tr>
<td>Chr –0.438*</td>
<td>0.000</td>
<td>–0.177</td>
<td>0.354</td>
<td>–0.064</td>
<td>0.103</td>
<td>0.397</td>
<td>0.207</td>
<td>0.189</td>
<td>–0.025</td>
<td>–0.168</td>
</tr>
<tr>
<td>BbF –0.418*</td>
<td>0.088</td>
<td>–0.054</td>
<td>0.506*</td>
<td>0.084</td>
<td>0.216</td>
<td>0.616**</td>
<td>0.310</td>
<td>0.454*</td>
<td>0.116</td>
<td>0.088</td>
</tr>
<tr>
<td>BkF –0.309</td>
<td>0.095</td>
<td>–0.058</td>
<td>0.392</td>
<td>0.181</td>
<td>0.113</td>
<td>0.568**</td>
<td>0.170</td>
<td>0.502*</td>
<td>0.136</td>
<td>–0.012</td>
</tr>
<tr>
<td>BaP –0.359</td>
<td>0.094</td>
<td>–0.033</td>
<td>0.517*</td>
<td>0.088</td>
<td>0.220</td>
<td>0.666**</td>
<td>0.291</td>
<td>0.511*</td>
<td>0.103</td>
<td>–0.085</td>
</tr>
<tr>
<td>Dba –0.194</td>
<td>0.175</td>
<td>0.096</td>
<td>0.106</td>
<td>–0.091</td>
<td>0.171</td>
<td>0.408</td>
<td>0.020</td>
<td>0.275</td>
<td>–0.102</td>
<td>–0.099</td>
</tr>
</tbody>
</table>

* 0.01 < p < 0.05; ** 0.001 < p < 0.01; *** p < 0.001.
affect PAHs concentration evidently. This proposal needs to be analyzed further. In this research, good positive correlations were also found between the pH of precipitation and PAHs including BaA, BbF and BaP, suggesting that these three carcinogenic PAHs tend to solute more effectively at a higher pH condition. Other ions in the rain did not affect PAHs concentrations significantly.

3.4. Back trajectory analysis

In previous studies, precipitation came when wind blowing from the most polluted area always presents higher PAH concentrations (Olivella, 2006). Back trajectory analysis was conducted here to classify the precipitation influenced by different source regions in China. 6-day backward trajectories using HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory; Draxler and Rolph, 2003) model with FNL meteorological datasets were computed here at 1500 m. To account for the uncertainty of the trajectory computation, 50 trajectory ensembles were calculated at each level with 0.1° offset about our site.

All of the rain events are classified into four major categories: N/NW — continental air masses from the north and northwest, the coldest area of China; SW/CC — air masses from the southern/south-western or central China; EC — air masses from South China Sea/Western Pacific and then transverse over eastern China to our site; EA — air masses from the Korean Peninsula and/or Japan; and L — samples with short and looped trajectories staying within a radius of 1000 km about our site. Samples have been omitted when their associated trajectory paths passed over two regions defined above.

The category N/NW is the dominate type, accounting for 22% of the total, followed by the categories SW/CC (20%), EC (18%), and L (16%). EA is the least type, accounting for 10% of the total. The air masses of the N/NW group originate from Siberia, northwest China or Mongolia where they are much colder than in other sites elsewhere in this study, these areas are considered to consume more fossil fuels. The precipitation of this group is featured by highest concentration of PAHs, the concentration reaches to 102.35 ng/L. The categories SW/CC and EC have lower concentration; reaching to 91.47 and 66.26 ng/L, respectively (Fig. 6). However, individual PAHs in the four categories have similar contributions to the total concentration. PhA accounts for nearly 40% of PAHs concentration, followed by Flu (nearly 20%), FluA (nearly 10%) and Pyr (nearly 6%), other compounds have proportions lower than 6% for the concentration. In L category’s group, PAHs concentration is 49.78 ng/L. PhA accounts for 54% of the concentration, the contribution of Flu drops to 12%, AnT and FluA are the following abundant compounds, accounting for 8% and 7% of the concentration. Other compounds have proportions lower than 6%. The EA category group has the concentration of 34.08 ng/L, lowest of the categories. PhA, Flu, FluA and Pyr are the major compounds, accounting for 28%, 20%, 15% and 14%, respectively. Other compounds have contributions lower than 4% for PAHs concentration.

PAHs concentrations in this study were influenced by the masses transported from different regions. Masses from the...
PAHs in the environment (Panther et al., 1999; Guo et al., 2003). Some marker PAHs have been used to identify sources of emissions. Diagnostic ratios of PAHs are effective in characterizing sources of emissions.

### 3.5. Diagnostic ratios of PAHs

Although several constraints exist, molecular ratios of some marker PAHs have been used to identify sources of PAHs in the environment (Panther et al., 1999; Guo et al., 2003). Ratios of specific individual PAHs are characteristic of different sources (Zhang et al., 2008; Venkatesan, 1988). The results of common diagnostic ratios used in this study (PhA/PhA+AnT, FluA/(FluA+Pyr), and BaA/(BaA+Chr)) are presented in Table 4.

Khalili et al. (1995) found that the ratio PhA/PhA+AnT was 0.65 for diesel emissions, 0.50 for gasoline and 0.76 for coal combustion. In this study, the ratio was 0.92 for the heating period (November to March) and 0.90 for the non-heating period (April to October), suggesting that coal combustion was the dominant source of PAHs at this site, and the higher ratio for the heating period indicates the increased contribution of coal combustion in winter. Another widely used indicator is FluA/(FluA+Pyr), where a ratio <0.4 implies the predominance of unburned petroleum; a ratio from 0.4 to 0.5 indicates the combustion of liquid fossil fuels and a ratio >0.5 suggests grass, wood, and coal combustion (Yunker et al., 2002). In Table 4, the FluA/(FluA+Pyr) ratios for the two periods were both above 0.5, indicating a strong contribution from coal and fossil fuel combustion. The heating period also shows more evident character of coal combustion. For the 4-ring PAH isomer indicator BaA/(BaA+Chr), a ratio higher than 0.35 signals pyrolytic sources, lower than 0.2 indicates petrogenic sources, and between 0.2 and 0.35 could be either petrogenic or pyrolytic sources (Soclo et al., 2000). The values for the two periods were 0.29 and 0.31, indicating that the PAH sources could be either of petrogenic or pyrolytic origin, however, the fact that the ratio approached 0.35 shows that incomplete combustion was the main source.

Overall, the above PAH compositional ratios basically indicate a dominance of coal combustion for PAHs in precipitation at the Mount Taishan site. The PAHs collected in the heating period were more characteristic of coal combustion sources than those in the non-heating period.

### 3.6. Factor analysis

Diagnostic ratios provide only qualitative information about pollutant sources. However, factor analysis was used to quantify PAH sources, thus to further characterize the emission sources of PAHs to the atmosphere, the 11 PAH compounds measured in this study were subjected to factor analysis with Varimax rotation by SPSS version 14 (SPSS Inc.). The factors, with correlation matrix eigenvalues > 1 for the deposition samples, are listed in Table 5.

Three factors accounted for 82.3% of the total variance of the data. Factor 1, which explained 47.8% of the variance, showed high loading for BaA, BkF and BaP. BA is the major component of emissions from coal combustion (Duval and Friedlander, 1981). BkF and BaP are indicators of diesel vehicle and gasoline emissions, respectively. In addition, factor 1 also had relevant high loading for FluA, Pyr and Chr. Khalili et al. (1995) identified these as markers of coal combustion. Thus, factor 1 may be related to sources from both coal combustion and liquid fuel burning. Factor 2, which explained 23.7% of the variance, had high loadings for FluA, Pyr and Chr. The presence of these compounds can be attributed to coal combustion and vehicular emissions. Factor 3, which explained 10.9% variance, showed high loading for DbA and moderate loading for BbF. BbF is an indicator of gasoline emissions, suggesting that gasoline-powered vehicular emissions were the main source. DbA could result from different sources. Therefore, factor 3 suggests influence from multiple sources.

The results obtained through factor analysis for our precipitation samples provided better insight into the PAHs sources than did the data from the diagnostic ratios. However,
there is considerable similarity among the PAHs profiles from different source categories.

4. Conclusion

The concentrations of PAHs in wet deposition samples were determined in order to examine the seasonal variations, sources and relationships with meteorological parameters and soluble ions at Mount Taishan. Concentrations of PAHs, ranged from 1.76 (BaA) to 33.31 (PhA) ng/L, and particularly carcinogenic PAHs (individual concentrations were lower than 2.62 ng/L) were quite low at this site. Typical seasonal trends of low PAHs concentrations in summer and high in winter were found in this study. In this research, we find low concentrations of PAHs on the elevated site, though China is consumed to emission large amount of PAHs. The particle or bulk deposition should be conducted further to analysis of the PAHs flux in the region.

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References