Autumn and Wintertime Polycyclic Aromatic Hydrocarbons in PM$_{2.5}$ and PM$_{2.5-10}$ from Urumqi, China

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**ABSTRACT**

Concurrent sampling of PM$_{2.5}$ and PM$_{2.5-10}$ aerosols on a rooftop (15 m above ground) was conducted at a location in urban Urumqi (Xinjiang University 43°77‘N, 87°61‘E) during September 2010 to March 2011. These filters were analyzed for fifteen polycyclic aromatic hydrocarbons (PAHs). The $\Sigma$PAHs (sum of 15 PAHs) ranged from 0.11 to 1058.08 ng/m$^3$ in PM$_{2.5}$ and 0.01 to 90.89 ng/m$^3$ in PM$_{2.5-10}$, respectively. 90% of the $\Sigma$PAHs existed in PM$_{2.5}$. In the autumn the $\Sigma$PAHs ranged from an undetectable level to 10.93 ng/m$^3$ in PM$_{2.5}$ and 2.10 ng/m$^3$ in PM$_{2.5-10}$, and in the winter from an undetectable level to 54.11 ng/m$^3$ in PM$_{2.5}$ and 5.12 ng/m$^3$ in PM$_{2.5-10}$.

Benzo(a)pyrene-equivalent carcinogenic potency (BaPeq) was calculated to evaluate the cancer risk of carcinogenic PAHs to the public. The level of BaPeq in PM$_{2.5}$ was an average of 5.97 ng/m$^3$, significantly higher than the value recommended by the WTO (1 ng/m$^3$). This suggests that it is important to control regional combustion sources to reduce air pollution-related health risks in urban Urumqi.

**Keywords:** Fine particulate (PM$_{2.5}$); Coarse particulate (PM$_{2.5-10}$); PAHs Source apportionment; Urumqi.

**INTRODUCTION**

Polycyclic aromatic hydrocarbons (PAHs) are formed by incomplete combustion or pyrolysis of materials containing carbon and hydrogen. They have both anthropogenic and natural sources. The former includes combustion processes of fossil fuels and biomass, and the release of uncombusted petroleum products (Simcik et al., 1999). PAHs, such as benzo(a)pyrene, have been shown to be causative agents of lung, esophageal, gastric, colorectal, bladder, skin, prostate and cervical cancers in humans and animal models; and lung cancer is one of the leading causes of cancer-related death in many countries (Lodovici et al., 1998).

Many epidemiological studies have shown a strong relationship between the exposure to PM$_{10}$ (particulate matter with aerodynamic diameter smaller than 10 mm) and morbidity and mortality rates. Since partition between PM$_{2.5}$ (particles with aerodynamic diameter less than 2.5 µm, Fine fraction) and PM$_{2.5-10}$ (2.5 µm < aerodynamic diameter < 10 µm, Coarse fraction) is still unknown, it is important to obtain PAHs size distribution for the purpose of effective air pollution control and establishing air quality standards by assessing public exposure to PAHs and their associated health risks (Slezakova et al., 2009; Kong et al., 2010).

Urumqi, the capital of the Xinjiang Uyghur Autonomous Region of China, is in central Xinjiang, at the north foot of Tianshan Mountain and on the south edge of Jungger Basin. Urumqi is located almost in the center of Asia, north of the Taklamakan Desert, and south of the Guerbantonggute Desert. Urban Urumqi is bordered by the Tianshan Mountains in three directions, with summit up to 5000 m, and into the northern face of the city, the wind can carry soil dust into the urban area. Urumqi city is divided into six administrative areas. Tianshan District, Saybag district, Xinshi district, Shuimogou district, Midong district, and Toutunhe district (Chetwittayachan et al., 2002). During the past two decades, the air has been heavily polluted and Urumqi is alway found to be one of the most polluted cities in the world (Mamtimin and Meixner, 2007).

In this study we present the spatial and temporal variations of PAHs in PM$_{2.5}$ and PM$_{2.5-10}$ in urban Urumqi. The possible sources are also discussed based on the diagnostic ratios and the principal component analysis (PCA).

**DATA AND METHODS**

**Sampling Sites**
A total of 84 particle samples, half in PM$_{10-2.5}$ and PM$_{2.5}$, were collected at the rooftop of a 5-storey building (~15 m above ground) in the campus of Xinjiang University (XUT, 43°77’N, 87°61’E, Fig. 1) between 25 September 2010 and 5 March 2011. The XUT campus is situated between the Urumqi Friendship hospital and water park; and the building is approximately 500 m away from the main road (Sheng Li Road).

**Sampling Method**

A middle-volume sampler (NL20; Tokyo Dylec Corp JP) was used to collect PM$_{10-2.5}$ and PM$_{2.5}$ particles simultaneously on quartz fiber filters (Whatman, Mainstone, UK) at a flow rate of 20 m$^3$/min for 24-h. PM$_{10-2.5}$ samples were collected on filters with 47 mm outside diameter and 20 mm inside diameter and PM$_{2.5}$ samples on 47 mm diameter filters. Before field use, filters were baked in an oven for 4 h at 450°C, then wrapped in aluminum foil and zipped in Teflon bags. After sample collection, filters were again wrapped in aluminum foil, zipped in polytetrafluoroethylene bags, and stored in a refrigerator at 5°C until analysis.

**Sample Extraction**

Prior to 72 h Soxhlet extraction with redistilled (dichloride methane) DCM, a mixture of deuterated PAH standards (acenaphthene-d10, phenanthrene-d10, chrysene-d12, and eylene-d12) was added to each sample as surrogate compounds. The extracts were concentrated and solvent-exchanged to redistilled hexane, and then purified using a 1:2 alumina/silica column chromatography. The first fraction, containing aliphatic hydrocarbons, was eluted with 30 mL of hexane. The second fraction, containing PAHs, was collected by eluting 70mL of DCM/hexane (3:7 v/v). The latter was then concentrated to a final volume of 200 mL under a gentle stream of nitrogen. Eight microliters of 50 mg/L hexamethylbenzene (Aldrich Chemicals, Gillingham, Dorset, USA), was added to the samples as an internal standard before instrumental analysis.

**Instrumental Analysis and Parameters**

PAHs were analyzed by an Agilent 6890N gas chromatograph (GC) coupled with an Agilent 5973N mass selective detector in the selective ion monitoring mode. The GC column used was a 30 m HP-5 capillary column (0.25 mm id., 0.25 μm film thickness). The column temperature was initiated at 80°C (held for 2 min) and increased to 290°C at 4 °C/min (held for 30 min). Target compounds were identified based on their mass spectra and retention times.

PAHs were quantified by authentic standards with internal approach (Cao et al., 2005), including Naphthalene (Nap), acenaphthylene (Acey), fluorene (Fl), phenanthrene (Phe), anthracene(Ant), fluoranthene (Flu), pyrene (Pyr), benz[a]anthracene (BaA), chrysene (Chr), benz[e]fluoranthene (BbF), benzo[k]fluoranthene (BkF), benzo[a]pyrene (BaP), indeno [1,2,3-cd] pyrene (IcdP), benzo[g,h,i]perylene (BghiP), dibenz[a,h]anthracene (DahA).

**Quality Control/Quality Assurance**

Six laboratory blanks were extracted and analyzed in the same way as field samples. Target PAHs were very low and in most cases not detectable in the blanks. Recovery efficiencies were determined by evaluating surrogate standards in the samples. The mean recoveries were 30% for naphthalene-d8, 40% for acenaphthalene-d8, 37% for phenanthrene-d10, 89% for chrysene-d12, 65% for perylene-d12 and 87% for evoglucosan-13C6.

**RESULTS AND DISCUSSION**

**Concentrations of PM$_{2.5}$ and PM$_{2.5-10}$**

The concentrations of PM$_{2.5-10}$ and PM$_{2.5}$ mass were measured approximately twice a week during the period of September 2010 to March 2011. The daily concentrations of PM$_{2.5-10}$ and PM$_{2.5}$ reached 139.05 μg/m$^3$ and 263.77 μg/m$^3$ with the latter 7.5 times higher than the daily standard of 35 μg/m$^3$ for PM$_{2.5}$ proposed by the U.S EPA (showing...
As expected, the high concentrations of PM\textsubscript{2.5} (averagely 297.21 μg/m\textsuperscript{3}) and PM\textsubscript{2.5–10} (averagely 143.2 μg/m\textsuperscript{3}) were found in winter (November, December, January), which was most likely associated with high activities of fossil fuels burning for heating. Whereas the relatively low PM\textsubscript{2.5} and PM\textsubscript{2.5–10} level were observed in autumn (September and October) (196.89 μg/m\textsuperscript{3} and 130.76 μg/m\textsuperscript{3}, respectively), due to the absence of combustion sources. In Urumqi there is a half-year for house heating domestically and industrially from 15 October to 15 April of next year.

Table 1 presents the maximum, minimum, and mean concentrations of ΣPAHs in PM\textsubscript{2.5} and PM\textsubscript{2.5–10}. A sharp increase in PAHs concentration was found in early morning with the peak concentration observed between 7:00 and 8:00 a.m., and followed by a rapid reduction during the daytime and gradually increase again in the evening (Chetwittayachan et al., 2002). Enhanced biomass burning and less photo-degradation of PAHs further contributed to the higher level of PAHs in January (Gao et al., 2011).

### Seasonal Variations of PAHs in PM\textsubscript{2.5} and PM\textsubscript{2.5–10}

Table 2 presents the mean concentrations of individual PAH in PM\textsubscript{2.5} and PM\textsubscript{2.5–10} in autumn and winter. The total concentrations of PM\textsubscript{2.5} PAHs and PM\textsubscript{2.5–10} PAHs were in the range of 0.11–1058 ng/m\textsuperscript{3} and 0.01–90.89 ng/m\textsuperscript{3}. The mean concentrations of PAHs were the higher in autumn (10.93 ng/m\textsuperscript{3} in PM\textsubscript{2.5} and 2.1 ng/m\textsuperscript{3} in PM\textsubscript{2.5–10}), and the highest in winter (54.11 ng/m\textsuperscript{3} and 5.12 ng/m\textsuperscript{3} in PM\textsubscript{2.5} and PM\textsubscript{2.5–10}, respectively). Fig. 3 shows the mean PAH profiles (contribution of each PAH compound to ΣPAH). During no-heating period Nap, BaA and Chr were abundant in PM\textsubscript{2.5}, and Nap, Ant were dominant in PM\textsubscript{2.5–10}, while during heating period Flu, Pyr, BaA, BbF, BkF, BeP, BaP, IcdP, BghiP, DahA exhibited high levels in PM\textsubscript{2.5} and Acey, FL exhibited high concentrations in PM\textsubscript{2.5–10}. This phenomenon revealed the importance of vehicle emissions as PAH sources in no-heating period and coal combustion and vehicular emissions as PAH sources in heating period, because BkF, BbF, Chr and BaA were identified as markers of vehicle emissions and Pyr, FL, Ant and Chr were abundant in coal combustion emission (Khalili et al., 1995).

### Distributions of PAHs with Different Ring Numbers

These 15 PAHs can be classified into 3 groups: 2 + 3-ring (Nap, Acey, Fl, Phe and Ant), 4-ring (Flu, Pry, BaA, Chr) and 5 + 6-ring (BbF, BkF, BaP, IcdP, DahA and BghiP) PAHs. Atmospheric PAHs exist in both gaseous and particle phases. PAHs with 2–3 aromatic rings were predominant in gaseous phase, while compounds with 4 or more rings are primarily associated with particulate phase (Katsoyiannis et al., 2007). It can be observed that the PAHs with 2 + 3-, 4- and 5 + 6-rings are dominant in both fine and coarse particles (Fig. 4). High molecular weight (HMW) PAHs prefer partitioning in PM\textsubscript{2.5} as compared to low molecular weight (LMW) PAHs (Yunker et al., 2002). The 2 + 3-ring PAHs exhibited low concentrations in particle phase owing to their high volatility. The 4-rings PAHs were lower in autumn than winter Not only in PM\textsubscript{2.5} and PM\textsubscript{2.5–10}. Due to semi-volatility the 4-ring PAHs in the atmosphere exhibited a strong seasonal variation in Urumqi. The 5 + 6-rings PAHs were much richer in PM\textsubscript{2.5} than PM\textsubscript{2.5–10} in both seasons. The carcinogenic 5 + 6-rings species are predominantly associated with particles especially in the accumulation mode (0.5 μm < d < 1.0 μm) (Fang et al., 2006).

| Sampling Date          | Concentration (μg/m\textsuperscript{3}) |
|------------------------|------------------------------------------|
| 2010.9.28              |                                          |
| 2010.10.14             |                                          |
| 2010.10.31             |                                          |
| 2010.11.10             |                                          |
| 2010.11.23             |                                          |
| 2010.12.7              |                                          |
| 2010.12.13             |                                          |
| 2011.1.1               |                                          |
| 2011.1.19              |                                          |
| 2011.1.24              |                                          |
| 2011.1.29              |                                          |
| 2011.3.3               |                                          |

**Table 1.** Maximum, minimum, mean concentration and related PAHs collected during the sampling period.

|           | PM\textsubscript{2.5} | PM\textsubscript{2.5–10} | PM\textsubscript{2.5} ΣPAH | PM\textsubscript{2.5–10} ΣPAH |
|-----------|----------------------|--------------------------|---------------------------|-----------------------------|
| Minimum (μg/m\textsuperscript{3}) | 11.9     | 86.81                    | 0.01                      | 0.11                        |
| Maximum (μg/m\textsuperscript{3}) | 356.06   | 579.86                   | 90.89                     | 1058.08                     |
| Mean (μg/m\textsuperscript{3})   | 139.05   | 263.77                   | 4.12                      | 54.12                       |
| Sample number          | 42       | 42                       | 42                        | 42                          |
| Sampling period        | September 2010–March 2011 | September 2010–March 2011 | September 2010–March 2011 | September 2010–March 2011  |
Table 2. Average concentrations (ng/m³) of PM$_{2.5}$ and PM$_{2.5-10}$-bound PAHs in urban Urumqi in winter and autumn sampling.

|            | PM$_{2.5}$ (Winter) | PM$_{2.5-10}$ (Winter) | PM$_{2.5}$ (Autumn) | PM$_{2.5-10}$ (Autumn) |
|------------|----------------------|-------------------------|---------------------|------------------------|
| Nap        | 0.00                 | 0.00                    | 0.14                | 0.05                   |
| Acey       | 0.09                 | 0.10                    | 0.05                | 0.04                   |
| Fl         | 0.17                 | 0.22                    | 0.13                | 0.07                   |
| Phe        | 0.55                 | 0.22                    | 0.18                | 0.11                   |
| Ant        | 0.13                 | 0.07                    | 0.05                | 0.06                   |
| Flu        | 3.28                 | 0.81                    | 0.10                | 0.11                   |
| Pyr        | 1.30                 | 0.13                    | 0.07                | 0.06                   |
| BaA        | 3.15                 | 0.48                    | 2.76                | 0.13                   |
| Chr        | 1.97                 | 0.26                    | 1.38                | 0.11                   |
| BbF        | 3.47                 | 0.47                    | 0.47                | 0.28                   |
| BkF        | 3.42                 | 0.67                    | 0.79                | 0.15                   |
| BaP        | 2.21                 | 0.25                    | 0.53                | 0.09                   |
| IcdP       | 19.66                | 0.52                    | 3.36                | 0.45                   |
| BghiP      | 7.58                 | 0.03                    | 1.76                | 0.09                   |
| DahA       | 7.12                 | 0.89                    | 0.14                | 0.30                   |
| ΣPAHs      | 54.11                | 5.12                    | 11.90               | 2.10                   |

Fig. 3. Distribution of 16 PAHs at autumn and winter in PM$_{2.5}$ and PM$_{2.5-10}$.

Fig. 4. Relative concentrations of 2+3-, 4- and 5+6-ring groups in 16 PAHs at Autumn and winter in PM$_{2.5}$, PM$_{2.5-10}$.

Carcinogenic Potency of PAHs

BaP, known as the most carcinogenic PAH, is the most investigated PAH and often regarded as an indicator of carcinogenicity of total PAHs. To evaluate the carcinogenic potency of PAHs, benzo(a) pyrene-equivalent carcinogenic potency (BaP$_{eq}$) was
calculated using the cancer potency equivalency factors (PEF) proposed by Yassaa et al. (2001) as the following equation (Gao et al., 2011):

$$\text{BaPeq} = \text{BaA} \times 0.06 + \text{BF} \times 0.07 + \text{BaP} + \text{DahA} \times 0.6 + \text{IcdP} \times 0.08$$ (1)

The mean concentration of $$\text{BaPeq}$$ in PM$_{2.5}$ was 5.96 ng/m$^3$ and higher than WHO air quality guideline value of 1.0 ng/m$^3$ (Fig. 5). The exceedances were mostly taken place in winter, but only once in the no heating period. The highest level of $$\text{BaPeq}$$ was observed on January 21, 2011 with the value reaching 112.8 ng/m$^3$, this day temperature, dew point, humidity, visibility and wind speed is –19°C, –22°C, 77%, 1.2 and 1 m/s.

**Source Identification of PAHs**

The ratios of PAH isomers are frequently employed as diagnostic tools to identify the sources of PAHs in ambient air. PCA is an important method to identify the major sources of air pollutants (Shi et al., 2010). We used PAH ratios and PCA to further identify the sources of PAHs in Urumqi.

**Ratio of PAH Isomers**

Ratios of PAHs with similar molecular weights have been used for source identification (Tian et al., 2009). The results of diagnostic ratios IcdP/(IcdP + BghiP), FluA/[FluA + Pyr], BaP/BghiP, and BaA/[BaA + Chr]) are listed in Table 3.

The IcdP/(IcdP + BghiP) ratios of < 0.4, > 0.5 and 0.35–0.47 indicates vehicle emission, coal combustion and mixed sources, respectively (Gu et al., 2010). The ratios of IcdP/(IcdP + BghiP) in PM$_{2.5}$ and PM$_{2.5-10}$ were 0.72, 0.94 in winter and 0.66, 0.88 in autumn, suggesting that coal combustion was the dominant source of PAHs at this site. PAHs from petrogenic sources have FLU/(Flu + Pyr) ratios < 0.4, 0.4–0.5 is characteristic of liquid fossil fuel (automotive and crude oil) combustion and > 0.5 implies coal, grass or wood combustion (Yunker et al., 2002). In this study, the FluA/(FluA + Pyr) ratios were above 0.5, indicating a strong contribution of coal and fossil fuel combustion, except the PM$_{2.5}$ samples in winter. For BaA/(BaA + Chr), a ratio higher than 0.35 means pyrolytic sources, lower than 0.2 indicates petrogenic sources and 0.2–0.35 could be either petrogenic or pyrolytic source (Socol et al., 2000). The values were 0.61, 0.65 in winter and 0.67, 0.56 in autumn for PM$_{2.5}$ and PM$_{2.5-10}$, indicating the pyrolytic sources. A BaP/BghiP ratio higher than 0.6 implies grass/coal/wood combustion, while lower than 0.6 indicates fuel combustion (Katsoyiannis et al., 2007). In PM$_{2.5}$ and PM$_{2.5-10}$, the ratios of BaP/BghiP were 0.29 and 7.44 in winter, 0.3 and 0.95 in autumn, indicating that PAHs came from fossil fuel combustion in winter and grass/coal/wood combustion in autumn, respectively.

**Principal Component Analysis (PCA)**

Principal component analysis (PCA) is a widely used technique of multivariate linear data analysis (Wang et al., 2010). We apportioned the sources of PAHs in the PM$_{2.5}$ and PM$_{2.5-10}$ in fall and winter using SPSS software. The results are shown in Tables 4 and 5. Different combustion sources can produce different compounds, therefore the factor loading of each component can be used to determine the source of PAHs.

In PM$_{2.5}$ during winter, contribution rate of factor 1 was 84%. BaA, Flu, Pyr and Chr are markers of coal combustion (Duval and Friedlander 1981; Wang et al., 2010). BkR, BbF and BaP are markers of vehicle (gasoline and diesel) exhaust. So factor 1 represents the sources of coal combustion and

![Fig. 5. Concentrations of BaPeq (ng/m$^3$) in the PM$_{2.5}$ during the September 2010–March 2011 sampling.](image_url)
Table 3. The BaPeq concentrations of PAHs in fine fraction.

|                  | Winter (PM$_{2.5}$) | Winter (PM$_{2.5-10}$) | Autumn (PM$_{2.5}$) | Autumn (PM$_{2.5-10}$) |
|------------------|---------------------|------------------------|---------------------|------------------------|
| IcdP/(IcdP + BghiP) | 0.72                | 0.94                   | 0.66                | 0.83                   |
| Flu/(Flu + Pyr)  | 0.11                | 0.64                   | 0.65                | 0.51                   |
| BaA/(BaA + Chr)  | 0.61                | 0.65                   | 0.67                | 0.56                   |
| BaP/BghiP        | 0.29                | 0.74                   | 0.30                | 0.95                   |

Reference source emissions:
- < 0.4 vehicles emission
- > 0.5 coal combustion
- 0.35–0.47 mixed sources
- < 0.4 petrogenic source
- > 0.4–0.5 liquid fossil fuels
- > 0.5 coal, grass or wood combustion
- > 0.35 pyrolytic sources
- < 0.2 petrogenic
- > 0.6 Grass/coal/wood combustion
- < 0.6 Fuel combustion

Table 4. PCA analysis of PAHs in PM$_{2.5}$ and PM$_{2.5-10}$ at winter.

|                  | PM$_{2.5}$ |   | PM$_{2.5-10}$ |   |
|------------------|------------|--|--------------|--|
|                  | 1          | 2 | 3            |   |
| Acey             | 0.946      | 0.239 | 0.035       |   |
| Fl               | 0.151      | 0.931 | 0.327       |   |
| Phe              | 0.983      | 0.083 | 0.102       |   |
| Ant              | 0.98       | 0.068 | 0.107       |   |
| Flu              | 0.991      | 0.002 | 0.098       |   |
| Pyr              | 0.978      | 0.024 | 0.136       |   |
| BaA              | 0.988      | 0.015 | 0.055       |   |
| Chr              | 0.995      | 0.002 | 0.086       |   |
| BbF              | 0.945      | 0.115 | 0.12        |   |
| BkF              | 0.974      | 0.05  | 0.045       |   |
| BaP              | 0.913      | 0.083 | 0.147       |   |
| IcdP             | 0.992      | 0.009 | 0.093       |   |
| BghiP            | 0.985      | 0.012 | 0.009       |   |
| DahA             | 0.62       | 0.436 | 0.616       |   |

Contribution rate %
- 84.015
- 29.82

Table 5. PCA analysis of PAHs in PM$_{2.5}$ and PM$_{2.5-10}$ at autumn.

|                  | PM$_{2.5}$ |   | PM$_{2.5-10}$ |   |
|------------------|------------|--|--------------|--|
|                  | 1          | 2 | 3            |   |
| Acey             | 0.037      | 0.193 | 0.684       |   |
| Fl               | 0.395      | 0.32  | 0.335       |   |
| Phe              | 0.828      | 0.177 | 0.105       |   |
| Ant              | 0.92       | 0.003 | 0.029       |   |
| Flu              | 0.817      | 0.317 | 0.273       |   |
| Pyr              | 0.507      | 0.563 | 0.567       |   |
| BaA              | 0.584      | 0.042 | 0.634       |   |
| Chr              | 0.172      | 0.983 | 0.023       |   |
| BbF              | 0.157      | 0.984 | 0.034       |   |
| BkF              | 0.886      | 0.006 | 0.13        |   |
| BaP              | 0.816      | 0.049 | 0.231       |   |
| IcdP             | 0.654      | 0.018 | 0.535       |   |
| BghiP            | 0.138      | 0.988 | 0.011       |   |
| DahA             | 0.034      | 0.991 | 0.072       |   |

Contribution rate %
- 37.69
- 29.9

Vehicle (gasoline and diesel) exhaust. Factor 2 has the contribution rate of 8.2% with a high loading of Fl, which is a marker of vehicle exhaust. So factor 2 represents the emissions from coal-fired emissions.

In PM$_{2.5-10}$ during winter, factor 1 has contribution rate of 54.3%, factor 1 Flu, BaA, BbF, BkF, BaP, IcdP, BghiP, DahA a high correlation coefficient. BaA, Flu heated to high temperatures to produce a large amount of markers are
coal-fired emissions, BkF, BaP marker of gasoline emissions and diesel emissions, BbF, vehicle emission markers. Factors determine the markers for coal-fired emissions and emissions of gasoline, diesel emissions, vehicle emissions. Factor 2, the contribution rate of 29.8% is a high correlation coefficient, Acey, Fl, Phe, Ant. Which Fl, Phe, Ant coal combustion and vehicle emission markers. Therefore, factor 2 to determine markers for coal combustion and emissions of gasoline (Wang et al., 2010). Factor 3 of the contribution rate of 12.6%, a high correlation coefficient, Pyr and Chr, Pyr and Chr markers of the coal-fired emissions. So the factor of three coal-fired emissions. In general, winter PM$_{2.5}$ and PM$_{2.5-10}$ comes mainly from coal-fired emissions.

Table 5 shows that fall a total parse out the three factors, the fall of PM$_{2.5}$ in the contribution of factor 1 was 37.69%, factor 1 Phe, Ant, Flu, BkF, BaP, a high correlation coefficient. Which Phe, Ant vehicle emission markers and coal combustion, BkF, BaP gasoline emissions and diesel emissions markers. Flu coal combustion markers, so the factors a judge for gasoline emissions and coal combustion markers. Factor 2, the contribution rate of 29.9%, a high correlation coefficient is the Chr, BbF, BghiP. DahA, factor 1 in Chr, BbF, coal combustion and vehicle emission markers, so the factor 2 judged as coal combustion and vehicle emission sources.

Autumn PM$_{2.5-10}$ factor 1 contribution rate of 68.434%, factor 1 in Fl, Phe, Flu, Pyr, Chr, BbF, BkF, IcdP, BghiP, DahA a high correlation coefficient. Which Fl, BbF vehicle combustion markers, Flu, Pyr coal combustion markers, Phe, coal combustion and vehicle emission markers BkF gasoline emissions and diesel emissions markers. Therefore, the factor a judge for vehicle emissions, gasoline emissions, and diesel emission sources.

CONCLUSIONS

PAHs in PM$_{2.5}$ and PM$_{2.5-10}$ were measured in Urumqi city during autumn to winter to determine the compositions, temporal and spatial distribution and sources. The total PAHs concentrations in PM$_{2.5}$ and PM$_{2.5-10}$ were in the range of 0.11-1058.08 ng/m$^3$ and 0.01 to 90.89 ng/m$^3$, respectively. 90% of the PAHs were in PM$_{2.5}$ with 3-, 4- and 5-rings dominant in both fractions. The BaP$_{eq}$ was averagely 5.96 ng/m$^3$ and much higher than WHO air quality guideline value of 1.0 ng/m$^3$. Although, PM$_{2.5}$ had higher PAHs concentrations than PM$_{2.5-10}$, they had similar spatial distribution of total PAHs and BaP$_{eq}$ concentrations. Similarities of PAHs profiles between fine and coarse fraction were also compared by coefficient of divergence revealing that PAHs species concentrations and significant difference exists between fine and coarse fraction in Urumqi city.

PAH diagnostic ratios revealed that coal combustion and vehicle exhaust were the major sources of PAHs for both PM$_{2.5}$ and PM$_{2.5-10}$. Correlation analysis on the concentrations of individual PAHs, correlation coefficients $r^2 > 0.90$, results indicated that PAHs with comparative ring sizes ($r^2 > 0.90$) had similar sources. Other sources like gas burning and wood combustion were identified as common sources in Urumqi city. To obtain insight into sources of PAHs in urban Urumqi, a study is being conducted to determine gas- and particle-phases PAHs from different emission sources as well as in the ambient.

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