JOURNAL OF ENVIRONMENTAL SCIENCES XX (2016) XXX–XXX

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/jes

JES JOURNAL OF ENVIRONMENTAL SCIENCES www.jesc.ac.cn

Pollution characteristics, sources and lung cancer risk of atmospheric polycyclic aromatic hydrocarbons in a new urban district of Nanjing, China

Tao Wang[1,2], Zhonghuan Xia[1,2,3,4,*], Minmin Wu[1,2], Qianqian Zhang[1,2], Shiqi Sun[1,2], Jing Yin[1,2], Yanchi Zhou[1,2], Hao Yang[2]

1. *Jiangsu Provincial Key Laboratory of Materials Cycling and Pollution Control, School of Environment, Nanjing Normal University, Nanjing 210023, China. E-mail: 1186987261@qq.com*
2. *Key Laboratory of Virtual Geographic Environment (Nanjing Normal University), Ministry of Education, Nanjing 210023, China*
3. *Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing 210023, China*
4. *State Key Laboratory Cultivation Base of Geographical Environment Evolution (Jiangsu Province), Nanjing 210023, China*

ARTICLE INFO

Article history:
Received 1 March 2016
Revised 12 June 2016
Accepted 15 June 2016
Available online xxxx

Keywords:
PAHs
BaP_{eq}
Ring distribution
Source identification
ILCR

ABSTRACT

This paper focused on the pollution characteristics, sources and lung cancer risk of atmospheric polycyclic aromatic hydrocarbons (PAHs) in a new urban district of Nanjing, China. Gaseous and aerosol $PM_{2.5}$ (particulate matter with aerodynamic diameter smaller than 2.5 μm) samples were collected in spring of 2015. Sixteen PAHs were extracted and analyzed after sampling. Firstly, arithmetic mean concentrations of PAHs and BaP_{eq} (benzo[a]pyrene equivalent) were calculated. The mean concentrations of PAHs were 29.26 ± 14.13, 18.14 ± 5.37 and 48.47 ± 16.03 ng/m^3 in gas phase, particle phase and both phases, respectively. The mean concentrations of BaP_{eq} were 0.87 ± 0.51, 2.71 ± 2.17 and 4.06 ± 2.31 ng/m^3 in gas phase, particle phase and both phases, respectively. Secondly, diagnostic ratios and principal component analysis were adopted to identify the sources of PAHs and the outcomes were the same: traffic exhaust was the predominant source followed by fuel combustion and industrial process. Finally, incremental lung cancer risk (ILCR) induced by whole year inhalation exposure to PAHs for population groups of different age and gender were estimated based on a Monte Carlo simulation. ILCR values caused by particle phase PAHs were greater than those caused by gas phase PAHs. ILCR values for adults were greater than those for other age groups. ILCR values caused by total (gas + particle) PAHs for diverse groups were all greater than the significant level (10^{-6}), indicating high potential lung cancer risk. Sensitivity analysis results showed that cancer slope factor for BaP inhalation exposure and BaP_{eq} concentration had greater impact than body weight and inhalation rate on the ILCR.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are compounds whose structure consists of two or more fused benzene rings in linear, angular or cluster arrangements (Bortey-Sam et al., 2015). There is an increasing concern about the occurrence of PAHs in the atmospheric environment as they are ubiquitous and some of them are strongly carcinogenic (Ravindra et al.,

* *Corresponding author*. E-mail: zhhxia@njnu.edu.cn (Zhonghuan Xia).

http://dx.doi.org/10.1016/j.jes.2016.06.025
1001-0742/

2008). The United States Environmental Protection Agency (USEPA) fixed 16 parent PAHs as priority pollutants and these 16 compounds (16 USEPA priority PAHs) were always main research objects in many reports.

PAHs can be released from both anthropogenic and natural emission sources (Pongpiachan et al., 2015). Many methods have been adopted in the process of PAH source identification. Among these, relative ring abundance (Kong et al., 2015), diagnostic ratios (Chen et al., 2015), principal component analysis (Garrido et al., 2014) and positive matrix factorization (Khan et al., 2015; Y. Wu et al., 2014) are widely used and extremely useful. Results from relevant reports provide important knowledge for effective pollution control measures (Callén et al., 2014). In most regions, main sources of atmospheric PAHs appeared to be traffic exhaust and fossil fuel combustion (Hanedar et al., 2014). Constitution of PAHs in gas phase differs from that in particle phase, indicating different sources (Liu et al., 2014). However, most studies aimed at identifying the sources of particle phase PAHs, but paid little attention to the sources of PAHs in diverse atmospheric phases.

In particular, benzo(a)pyrene (BaP) has been identified as being highly carcinogenic (IARC, 2015). Hence BaP equivalent (BaP_{eq}) concentration was always calculated to evaluate PAH pollution level. Based on this, daily inhalation exposure level (E) and incremental lung cancer risk (ILCR) for human beings caused by atmospheric PAHs can be estimated to assess human health risk. However, studies on ILCR caused by PAHs in diverse phases and for population groups of different age and gender are scarce.

Nanjing, the capital of Jiangsu Province, China, is an industrialized city. With rapid social and economic development, Nanjing has been heavily polluted by air pollutants. Source apportionment showed that vehicle exhaust was the greatest contributor to particle phase PAHs in all seasons (He et al., 2014). Kong et al. (2015) pointed out that, the ILCR values in Nanjing during Chinese New Year were estimated to be 6.8×10^{-6} and 3.3×10^{-5} for children and adults, respectively, being both greater than the high potential cancer risk level (10^{-6}) proposed by USEPA (1992, 2005). The number of new urban districts has been increasing in recent years in China due to the rapid urban construction, with Nanjing being a typical example. Particular geographical locations may lead to various pollution characteristics of atmospheric PAHs. However, few reports concerned the sources and lung cancer risk of atmospheric PAHs in diverse phases in Nanjing. Meanwhile, few studies focused on atmospheric PAHs in a new urban district of China.

The objectives of this study were to investigate (1) the pollution level and ring distribution of atmospheric PAHs in spring in Nanjing, (2) the main sources of atmospheric PAHs in diverse phases, and (3) the ILCR caused by atmospheric PAHs in diverse phases for population groups of different age and gender in Nanjing.

1. Materials and methods

1.1. Sampling site

The study was performed on the rooftop (20 m above the ground level to avoid airflow obstruction) of a teaching building (32°07′N, 118°54′E) in Nanjing Normal University in spring of the year 2015. The sampling site is located in one of the new urban districts of Nanjing, Jiangsu Province, China (Fig. 1). Around the sampling site are teaching buildings, dwellings and vegetation. A traffic artery is located about 250 m southeast to the site. About 2 km south to the site is a commercial district and about 10 km north to the site (on the other side of Yangtze River) is an industrial district. Therefore, sampling site might receive urban air pollution from nearby streets and industrial process. During sampling, the maximum air temperature was 26.4°C, whereas the minimum value was 18.1°C. The wind through sampling site was mostly southerly or southeasterly in direction, with wind scale in the range of 1 to 4. The weather situation during sampling was mostly sunny or cloudy, without wet deposition.

1.2. Sample collection

Active air samplers (PUF-$PM_{2.5}$-300, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China; operating at a constant flow rate of 0.3 m^3/min) with polyurethane foam (PUF; Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, China) disks and glass fiber filters (GFFs; Nanjing Poly Kang Reagent Company, Nanjing, China) were used to collect gaseous and aerosol $PM_{2.5}$ samples, respectively. Detailed calibration method and uptake rates of the samplers were confirmed by consulting the Chinese National Standard (HJ 93-2013). The spring of Nanjing was short, ranging from March 24th to May 30th. Collection procedure was performed from April 1st to May 20th, with one gaseous sample and one aerosol $PM_{2.5}$ sample collected in each week. For each sampling, 24 hr was included from 8:00 to 8:00 in the next day. Totally seven gaseous samples and seven aerosol $PM_{2.5}$ samples were collected. Among these, six pairs of samples that contained both gas phase and particle phase PAHs collected during the same period can be used as total (gas + particle phase) atmospheric samples. PUF disks were stored at −18°C after each sampling. GFFs were equilibrated in a desiccator (25°C, 40% relative humidity) for 24 hr and weighted before and after each sampling, in accordance with the Chinese National Standard (HJ 656-2013).

1.3. Extraction and analytical procedure

PUF disks were Soxhlet extracted with 180 mL/1:1 n-hexane:acetone at 52°C for 8 hr. GFFs were subjected to microwave extraction (MARS2Xpress, CEM, USA) with 25 mL 1:1 n-hexane:acetone, being heated to 100°C at a rate of 10°C/min and then held for 10 min (Xia et al., 2013). The extracts of GFFs were press filtered prior to concentration, whereas that of PUF disks were concentrated directly, using a vacuum rotary evaporator (R-201, Qiyu, China) at 37°C. After concentration, extracts of gas phase PAHs and particle phase PAHs were transferred to the alumina silica gel column for purification, respectively. The alumina silica gel column consisted of 20 g silica gel and 20 g alumina, and was eluted with 20 ml n-hexane followed by 50 ml 1:1 n-hexane:dichloromethane at a rate of 2 mL/min. The eluted mixture from the column during cleanup was first concentrated to near dryness in the vacuum rotary evaporator (R-201, Qiyu, China) using a 37°C water bath.

Please cite this article as: Wang, T., et al., Pollution characteristics, sources and lung cancer risk of atmospheric polycyclic aromatic hydrocarbons in a new urban district of Nanjing, China, J. Environ. Sci. (2016), http://dx.doi.org/10.1016/j.jes.2016.06.025