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Contamination and health risk assessment of PAHs in farmland soils of the Yinma River Basin, China

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ABSTRACT

The concentration, composition, sources and incremental lifetime cancer risk of farmland soil polycyclic aromatic hydrocarbons (PAHs) of the Yinma River Basin were analyzed. In 2016, the total concentration of 16 PAHs ranged from 491.65 to 1007.73 ng/g in May, from 427.31 to 781.38 ng/g in August and from 580.40 to 999.40 ng/g in November, respectively. Levels of seven potentially carcinogenic PAHs generally accounted for 33–36.7% of total 16 PAHs in three seasons, and the PAHs contained two to six rings, mainly Fla, Pyr, and Chr. The correlation analysis suggested that the soil organic matter (SOM) was no correlation with PAHs except for August, and there were no significant relationship between the pH and total PAHs. Isomer ratios indicated that the soil PAHs in the farmland of the Yinma River Basin was determined to be the combustion of coal, biomass, and petroleum. The toxic equivalent (BaP_{eq}) concentrations ranged from 15.2 to 133 ng BaP_{eq} g^{-1} in three seasons. The 95th percentiles of incremental lifetime cancer risk (ILCR) due to human exposure to farmland soil PAHs of the Yinma River Basin was (1.36×10^{-6}) in May, (1.00×10^{-6}) in August, and (1.18×10^{-6}) in November for children, (1.10×10^{-6}) in May, (8.15×10^{-7}) in August, and (9.58×10^{-7}) in November for adolescence and (1.61×10^{-6}) in May, (4.22×10^{-6}) in August and (1.40×10^{-6}) in November for adulthood. The result indicated a moderate carcinogenic risk and the risk of exposure to farmland soil PAHs was pervasive for residents. This investigation might provide useful information on human exposure to PAHs in soil of the Yinma River Basin, and is valuable for policy makers and scientists.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) have generated considerable interest in recent years due to their persistent nature, bioaccumulation and high toxicity (teratogenic, carcinogenic, and mutagenic) (Marrugo-Negrete et al., 2017; Hu et al., 2017; Chai et al., 2017; Cao et al., 2016). Numerous studies have revealed that in recent years, increasing incidences of lung cancer, bronchitis, asthma, and heart diseases are connected with exposure to PAHs (Cai et al., 2017; Ranjbar Jafarabadi et al., 2017; Kamal et al., 2016). PAHs are likewise regarded as endocrine disrupting compounds by reason that their ability to bind endogenous receptors (Rajpara et al., 2017). PAHs can be released into the environment through natural (volcanic eruptions and forest fires) and anthropogenic (incomplete combustion of fossil fuels such as diesel oil, gasoline, coal, and pyrolysis of organic matter) activities (Franco et al., 2017; Jiang et al., 2016). Because of their lipophilic and hydrophobic characteristics, PAHs have been found all over the world in settled dust, sediment, soil, air, and food samples, and so on. PAHs in the water environment is easy to be absorbed by solids, then they finally enter into sediment and soil by rainfall and atmospheric precipitation (Ali et al., 2017; Włóka et al., 2017).

16 PAHs have been listed as priority pollutants by the United States Environmental Protection Agency (USEPA). These 16 PAHs include the 7 carcinogenic PAHs BaA (benz[a]anthracene) (4-ring), Chr (chrysene) (4-ring), BbF (benzo[b]fluoranthene) (5-ring), BkF (benzo[k]fluoranthene) (5-ring), BaP (benzo[a]pyrene) (5-ring), DahA (dibenz[a,h]anthracene) (5-ring), IcdP (indeno[1,2,3-cd]pyrene) (6-ring), and 8 non-carcinogenic PAHs Nap (naphthalene) (2-ring), Acy (acenaphthylene) (3-ring), Ace (acenaphthene) (3-ring), Flo (fluorene) (3-ring), Phe (phenanthrene) (3-ring), Ant (anthracene) (3-ring), Fla (fluoranthene) (4-ring), Pyr (pyrene) (4-ring), and BghiP (benzo[g,h,i]perylene) (6-ring) (Cao et al., 2017; Zhao et al., 2014a, 2014b). These organic compounds are found in all environments especially at locations containing concentrated human activities (Ololade et al., 2017). PAHs reach the pedosphere mainly by dry and wet deposition and surface runoff, but additionally from industrial and household waste that

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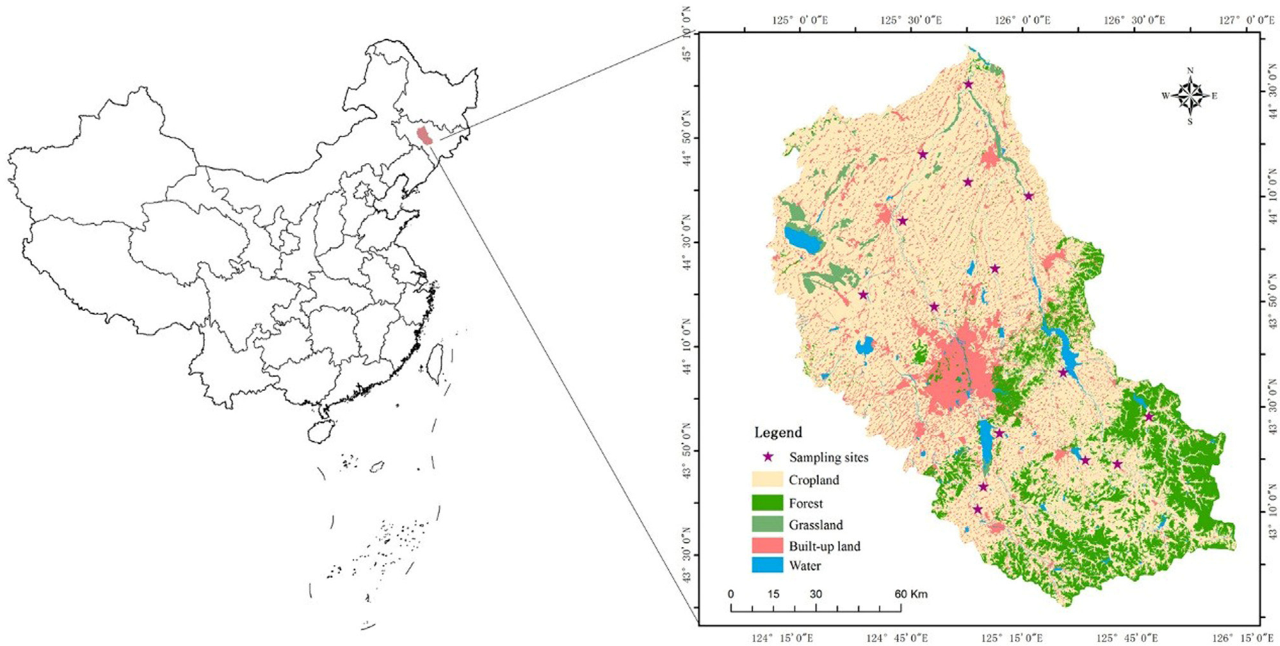

Fig. 1. Sampling sites of soils in the Yinma River Basin.

contains PAHs, which are strongly absorbed by the organic fraction of soils. Therefore, soil is usually considered the main sink for PAHs, which are persistent in the environment (Chen et al., 2004; Sun et al., 2012). PAHs absorbed by particles are emitted into ambient air through primary sources and are deposited via dry and wet deposition. Once deposited, PAHs with higher molecular weight tend to be absorbed in soil for a longer period of time (Yang et al., 2017; Wang et al., 2015). Direct exposures to PAHs can occur mainly through three pathways: inhalation, dermal absorption, and oral ingestion (Zhang et al., 2017). Also, PAHs in soil can be dispersed by surface soil emissions and dust production, which is another important route of exposure to PAHs (Mai et al., 2003). Among those, ingestion of PAHs from soil is the primary route (Lu et al., 2009; Ramesh et al., 2016).

The soil system is considered the most important environmental medium which reflected the spatial distribution and level of POPs (Cetin, 2016; Bortey-Sam et al., 2014). Farmland soils have been contaminated by high concentrations of PAHs all over the world (Wang et al., 2017a, 2017b). PAHs in farmland are more likely to be absorbed by crops and food chain is the major pathway for human exposure to PAHs, then causing a risk to human health (Jia et al., 2017).

Yinma River Basin, which located in the middle of Jilin Province in China, is the second tributary of the Songhua River. The basin provides water for 8 million residents. Through surface runoff and rainfall, pollutants in surrounding soil may pollute the surface drinking water source. In order to ensure water sources and crop safety, it is important to understand the accumulation status, affecting factors, and health risk of PAHs in farmland soil of the Yinma River Basin.

Accordingly, the aims of this study are (i) to investigate the concentration and composition of PAHs in farmland soils of the Yinma River Basin (ii) to identify the possible sources of PAHs (iii) to assess incremental lifetime cancer risk of PAHs in farmland soils to residents.

2. Materials and methods

2.1. Chemicals

The standard mixture containing 16 priority PAHs (100 < mu > g/ L in dichloromethane for each) was purchased from the National Standard Material Center (Beijing, China). All reagents (n-hexane, dichloromethane (DCM), acetone etc.) (chromatographic grade), used for sample processing and analysis, were provided by Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Copper power and moderate neutral alumina (analytical reagent) were procured from Sinopharm Chemical Reagent Co., Ltd. (SCRC).

2.2. Study area description

Yinma River Basin (43°0′N–45°0′N, 124°30′E –126°0′E) is located in the middle of Jilin Province, China. This area belongs to the northern temperate continental monsoon climate. The climate of the basin is marked by a long cold winter and a warm rainy summer. Yinma River Basin located in the core area of northeast black soil belt. It is the principal grain producing regions such as corn and rice producing area and is the primary commodity grain production in China. Yinma River Basin takes over a lot of industrial discharges, vehicular emissions, oil-related activities and agricultural runoffs. These anthropogenic activities possibly issue in pollution of PAHs in the environment connected with water (Zhang et al., 2017).

2.3. Sampling

A total of 45 soil samples was conducted in 3 different seasons, May 8th, August 27th, and November 3th, 2016, respectively. Stainless steel shovels were used to collect the soil samples from a depth of 0–10 cm. The position of sampling sites was recorded using a hand-held global positioning system (GPS). Five samples were gathered over an area of 100 m^2, mixed to form a composite sample (Suman et al., 2016). The locations of the research area are given in Fig. 1. Quintuplicate soil samples were collected from an area of 10 m × 10 m at each sampling sites (Jia et al., 2017). All samples were stored in plastic automatic sealing bags and delivered to laboratory. In the laboratory, the soil samples were air-dried under room temperature, to remove the twigs and stones. Soil samples were sieved through a 2 mm sieve, then stored in the dark at 4 °C until analysis (Jiao et al., 2017; Qing et al., 2015).

2.4. Determination of PAH content

For the PAHs extraction of each sample, 5 g of air dried soil were mixed with 5 g of anhydrous sodium sulfate and 5 g of copper power, and then extracted with dichloromethane (DCM)/acetone (1/1, v/v)