Environmental Pollution 161 (2012) 36–42

Contents lists available at SciVerse ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Vegetative cover and PAHs accumulation in soils of urban green space

Chi Peng, Zhiyun Ouyang, Meie Wang, Weiping Chen*, Wentao Jiao

State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-environmental Sciences, Chinese Academy of Sciences, Beijing 100085, PR China

ARTICLE INFO

Article history:
Received 4 July 2011
Received in revised form
19 September 2011
Accepted 27 September 2011

Keywords:
Polycyclic aromatic hydrocarbons
Urban soil
Land use
Vegetation
Soil organic matter
Beijing

ABSTRACT

We investigated how urban land uses influence soil accumulation of polycyclic aromatic hydrocarbons (PAHs) in the urban green spaces composed of different vegetative cover. How did soil properties, urbanization history, and population density affect the outcomes were also considered. Soils examined were obtained at 97 green spaces inside the Beijing metropolis. PAH contents of the soils were influenced most significantly by their proximity to point source of industries such as the coal combustion installations. Beyond the influence circle of industrial emissions, land use classifications had no significant effect on the extent of PAH accumulation in soils. Instead, the nature of vegetative covers affected PAH contents of the soils. Tree–shrub–herb and woodland settings trapped more airborne PAH and soils under these vegetative patterns accumulated more PAHs than those of the grassland. Urbanization history, population density and soil properties had no apparent impact on PAHs accumulations in soils of urban green space.

1. Introduction

Green spaces are vital elements of modern cities. They enhance the quality of urban residents' life by refreshing them from mental fatigue, reducing their stress levels, and providing them open space for physical and recreational activities (Grahn and Stigsdotter, 2010; Schipperijn et al., 2010). About 70% dwellers of Beijing utilize the open green spaces at least once a week (Lo and Jim, 2010). Besides the aesthetic enhancements, urban green spaces also have ecological and environmental benefits. They produce food, harbor biodiversity, alter urban microclimate, generate oxygen, break up strong winds, reduce noise, and improve air quality (Escobedo and Nowak, 2009; Kong et al., 2010; Rafiee et al., 2009; Shan et al., 2007; Yang et al., 2005). Meanwhile, urban areas are geographical regions of intense resource inputs, energy consumptions and waste emissions. In urban settings, harmful contaminants may be inadvertently released into the atmosphere and then deposited in the soil that has a large capacity for retaining persistent organic pollutants such as polycyclic aromatic hydrocarbons (PAHs) (Cai et al., 2007; Wong et al., 2004).

PAHs are ubiquitous environment contaminants produced by incomplete combustion of organic substances (Agarwal, 2009; Aichner et al., 2007; Mantis et al., 2005) and some are human carcinogens prevalent in the modern cities (Szabová et al., 2008). PAHs accumulated in urban soils may have a direct impact on public health as they are readily transferable into human body via ingestion, inhalation, and dermal contact (Jiang et al., 2009). Furthermore, they may exhibit toxic effects toward plants and soil biota (Andreoni et al., 2004). The United States Environmental Protection Agency (USEPA) identified 16 priority PAHs as targets of regulatory attention that have become focuses of environmental investigations worldwide (Hao et al., 2007; Nam et al., 2008; Wang et al., 2007; Wong et al., 2004).

Once released, the distribution and fate of PAHs in the environment are affected by factors including ambient temperature, intensity and direction of prevailing wind, precipitation pattern, vegetation, and physicochemical properties and microbial activities of soils (Diamond and Hodge, 2007; Heywood et al., 2006). PAH concentrations are substantially lower in the less populated rural than the densely populated urban areas (Jensen et al., 2007). Soils of higher PAH concentrations are found in the proximity of emission sources that are susceptible to high rates of airborne depositions (Nam et al., 2008). Therefore, the urban land uses that determine locations of emission sources, patterns of transport and deposition, and characteristics of receptors are crucial factors influencing PAHs accumulation in the soils. Moreover, PAHs are adsorbed by soil organic matter (SOM) and volatilization, degradation and leaching of adsorbed PAHs are inhibited (Yu et al., 2006). The chemical properties of PAH congeners would eventually determine the extent of its fate in the soils (Nam et al., 2008; Wang et al., 2007; Zhang et al., 2006a). In all, 90% of the PAHs in the terrestrial environment accumulate in the soils (He et al., 2009).

* Corresponding author.
E-mail addresses: chenweip@yahoo.com.cn, wpchen@rcees.ac.cn (W. Chen).

0269-7491/$ – see front matter
doi:10.1016/j.envpol.2011.09.027

Forests are effective of scavenging airborne lipophilic organic compounds and depositing them in the soils (Staci and Simonich, 1994). Trees remove gaseous air pollution via leaf stomata uptake and absorption at the cuticles (Wania and McLachlan, 2001). Meanwhile the foliar canopy will intercept airborne particulate pollutants (Nowak et al., 2006). The intercepted PAHs are directly deposited on the ground, washed off the trees by rains, and dropped along with falling leaves and twigs. The stagnant atmosphere underneath the tree canopy likely will slow down the volatilization of PAHs from soils (Cousins et al., 1999). Furthermore, once volatilized from the soil in which the vegetation is growing, PAHs may subsequently be reabsorbed by plants and start the cycling over (Collins and Finnegan, 2010). Urban tree stands may therefore play a significant role in deciding the environmental fate of PAHs, decreasing their airborne half-life and transferring the chemical from the atmosphere to the soils (McLachlan and Horstmann, 1998). The deposition fluxes of PAHs are much greater in forests than adjacent grasslands (Hassanin et al., 2003; Meijer et al., 2002).

The vegetated open spaces in urban settings were expected to modulate PAH accumulations in surface soils (Tam and Wong, 2008). Plants might take up soil borne PAHs thus reducing their contents of the soils (Gao and Zhu, 2004; Lin et al., 2007; Watts et al., 2006). More importantly, plants might attenuate the PAH contaminated soils by providing a conducive environment for growth and metabolism of soil microorganisms through releases of nutrients and enzymes and transport of oxygen to the rhizosphere (Macek et al., 2000). Although PAH could undergo photochemical degradation and chemical oxidation, microbial degradation was by far the most significant process of PAH elimination in the soil (Haritash and Kaushik, 2009).

We hypothesized that the deposition and accumulation of PAHs in soils are affected interactively by the way urban land was used, nature of vegetative covers constituted the open spaces, and characteristics of soil in reacting with PAHs. This study identified the PAHs accumulation in the primary land use categories of urban environment, described how the vegetation patterns influencing PAH contents of soils, and delineated effects of soil properties, urbanization history and population density on PAHs accumulation in urban green spaces of Beijing.

2. Material and methods

2.1. Study area

Beijing is the largest yet typical metropolis of northern China with rapid urban development, dense population, heavy pedestrian and automobile traffic, rapid industrialization, and in the winter large-scale coal-fired heating installations throughout the City. The 650 km^2 city proper is anchored by the Forbidden City at the center and surrounded by five concentric squares of developments and circular traffic throughways (i.e. the ring roads). The city is interspersed with green and open spaces characterized by woods, parks, greenbelts, school grounds, roadside trees, and grassy open fields covering 44.4% of the surface areas. The population has exceeded 16 million and growing. The intense human activities and supporting services bringing in food, water, and energy may strongly influence the ecological integrity of the metropolitan area. The PAHs are found in Beijing's air and soils (Jiao et al., 2009; Li et al., 2006; Ma et al., 2005; Tang et al., 2005; Yu et al., 2008). The emissions from automobile traffic, coal combustion for domestic heating, and industrial activities are primary sources of PAHs in Beijing (Peng et al., 2011).

2.2. Sampling description

Ninety seven sites where the soil profile had not been recently disturbed were selected for soil sampling. They spread out across the City (Fig. 1) representing the green/open spaces of different vegetation compositions and were located in neighborhoods of different land uses (Table S1). Each collected sample was the composite of five 0–10 cm depth soil cores obtained within a 10 m × 10 m area using a stainless steel hand auger. The sampling areas were at least 10 m away from the edge of the prescribed green space. After removing the vegetative debris, samples were air-dried at room temperature and then ground to pass a sieve of 2 mm openings. The finished soil samples were stored in amber color glass container at −25 °C until time for chemical analyses.

The sampling locations were divided according to eight land use categories namely industries, school grounds, residential communities, roadsides of heavy traffic and light traffic, plantations, and vacant lots and four vegetative cover classes namely greenbelt, tree–shrub–herb composite, woodland, and grassland. The selections were intended to cover all potential PAH emission and receptor sources and all vegetation compositions that might influence its distribution and accumulation in soils of Beijing proper. The locations were categorized as follows. Greenbelts, 15 locations, represented narrow green space along major thoroughfares and promenades that were well landscaped and routinely maintained. Tree–shrub–herb settings, 37 locations, were urban ornamental garden with multilayer composition consisting of trees, shrubs and herbaceous plants that organize as a parterre in residential communities, public parks, and other institutions accessible to the public. Woodlands, 27 locations, consisted of tree stands with little shrub and grass understory. Grasslands, 18 locations, were open space with ornamental lawn or nature grass covers. Industrial facilities, 7 locations, consisted of soils underneath varieties of vegetative covers at 5 just-closed large industrial complexes and two

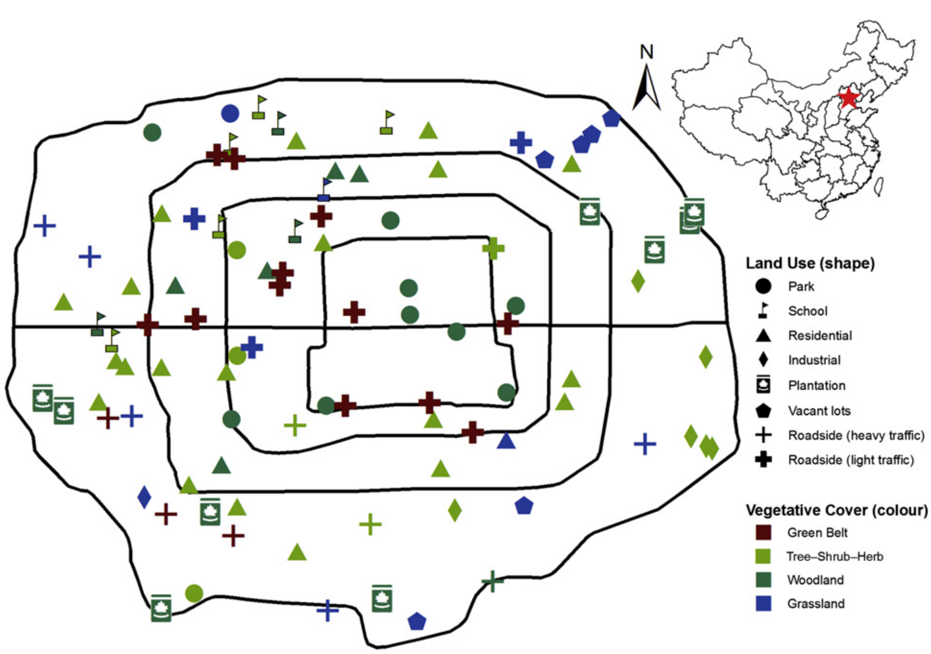

Fig. 1. Location of sample collection sites by land use and vegetative cover.