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Polycyclic aromatic hydrocarbons in house dust and surface soil in major urban regions of Nepal: Implication on source apportionment and toxicological effect

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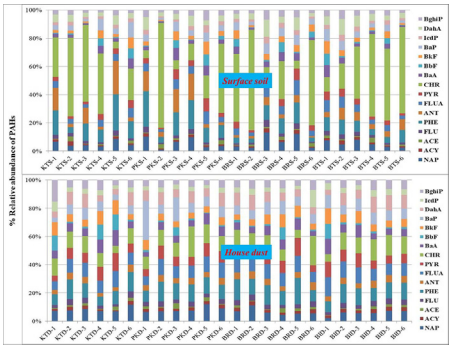
HIGHLIGHTS

- Concentration of $\sum_{16}$PAH in soil was 1.5 times higher than dust.
- HMW-PAHs were most abundant than LMW-PAH both in soil and dust.
- PAH chemicals both in soil and dust showed weak correlation with TOC/BC.
- Source apportionment study found mixed source from pyrogenic and petrogenic release.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban centers have turned to be the provincial store for resource consumptions and source releases of different types of semi-volatile organic compounds (SVOCs) including polycyclic aromatic hydrocarbons (PAHs), bringing about boundless environmental pollutions, among different issues. Human prosperity inside urban communities is unambiguously dependent on the status of urban soils and house dusts. However, environmental occurrence and sources of release of these SVOCs are challenging in Nepalese cities, as exceptionally very limited data are accessible. This motivated us to explore the environmental fate, their source/sink susceptibilities and health risk associated with PAHs. In this study, we investigated the contamination level, environmental fate and sources/sink of 16 EPA's priority pollutants in surface soil and house dusts from four major cities of Nepal. Additionally, the toxicological effect of individual PAH was studied to assess the health risk of PAHs. Generally, the concentrations of $\sum_{16}$PAHs in surface soil were 1.5 times higher than house dust, and ranged 767–6770 ng/g dry weight (dw) (median 1810 ng/g dw), and 747–4910 dw (median 1320 ng/g dw), respectively. High molecular weight-PAHs both in soil and dust were more abundant than low molecular weight-PAHs, suggesting the dominance of pyrogenic source. Moderate to weak correlation of TOC and BC with PAHs in soil and dust suggested little or no role of soil organic carbon in sorption of PAHs. Source diagnostic ratio and principal component analysis indicated fossil fuel combustion, traffic/vehicular emissions and combustion of biomass are the principal sources of PAHs contamination in Nepalese urban environment. The high average TEQ value of PAHs in soil than dust suggested high risk of soil carcinogenicity compared to dust.

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1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are semi-volatile organic compounds (SVOC). They are a class of persistent organic pollutants (POPs), and are omnipresent ecological contaminants. Some of them have been recognized as a cancer-causing and mutagenic substance (De La Torre Roche et al., 2009; IARC, 2010; Wang et al., 2011; Blokker et al., 2013; Shen et al., 2013; Lemieux et al., 2015). Likewise, they are an endocrine disrupting chemicals (EDCs) and can cause potential health hazards, including abnormalities in reproductive function, hormonal imbalance, testicular damages, development of cancer, neurological disorders, pre-mature birth, skin allergies, asthma, and several neuro developmental disorders (Bostrom et al., 2002; Deziel et al., 2013; Kim et al., 2013; Yang et al., 2015). Realizing the severe health risks and environmental threat concerned with PAHs, USEPA has categorized 16 different PAHs as priority pollutants that need further monitoring in different environmental matrices. These 16 EPA's priority pollutants are naphthalene (NAP), acenaphthene (ACE), acenaphthylene (ACY), fluorene (FLU), phenanthrene (PHE), anthracene (ANT), fluoranthene (FULA), pyrene (PYR), benzo[a]anthracene (BaA), chrysene (CHR), benzo[*b*]fluoranthene (BbF), benzo[*k*]fluoranthene(BkF), benzo[*a*]pyrene (BaP), dibenz[a,h]anthracene (DahA), indeno[1,2,3-*cd*]pyrene (IcdP), and benzo[*g*,*h*,*i*]perylene (BghiP) (Kwon and Choi, 2014). Besides, the International Agency for Research on Cancer (IARC) has also recommended eight PAHs (BaP, BaA, BbF, BkF, CHR, IcdP, DahA, and NAP) as category-II pollutants in light of their cancer causing characteristics and mutagenic potential (IARC, 1987).

Despite PAHs enter into the environment by both natural processes (forest fires and volcanic activities), and the anthropogenic sources (traffic, fossil fuel combustion, and industrial processes)(Aydin et al., 2014; Wang et al., 2015), notwithstanding, the most widely recognized source of PAHs are anthropogenic origin. It results from partial combustion or pyrolysis of fossil fuels and biomass, together with the spillage of petroleum (Bamford and Baker, 2003; Dong and Lee, 2009; Wang et al., 2011). Anthropogenic sources of PAHs can be separated into two groups, i.e. petrogenic and pyrogenic. Burning of biomass generates pyrogenic PAHs, while petrogenic PAHs originates from oil-based commodities, including kerosene, gasoline, diesel fuel, lubricating oil, and asphalt (Baek et al., 1991; Yunker et al., 2002).

Atmospheric PAHs can also enter surface soil by wet and dry deposition (Kaya et al., 2012), and are promptly adsorbed by soil particles and soil organic matter (SOM). Following changes in environmental conditions, soil may re-emit the previously adsorbed PAHs into the air (Tao et al., 2008). A crop being the primary food source, an uptake of PAHs from polluted soil and their subsequent consumption leads to bioaccumulation of PAHs in human by means of food chain (Li et al., 2008). Therefore, profound understanding of the concentrations and dispersion of PAHs in soil may boost pollution control, reduce crop damage, and minimizes the human exposure. Soil contaminated with PAHs is a significant environmental problem worldwide. It is viewed as a steady indicator of the level of environmental pollution (Wild and Jones, 1995; Liu et al., 2001; Mueller et al., 2006; Wang et al., 2012) and has attracted considerable attention worldwide (Bourotte et al., 2005; Callen et al., 2011). On the other side, PAHs in indoor environments are released from different activities, for example, utilization of electric or gas stove for heating and cooking, coal and candle burning, smoking and parquet flooring (Huynh et al., 1991; Turner et al., 1992; Chao et al., 1997; Heudorf and Angerer, 2001; Huali et al., 2002; Guo et al., 2003; Ohura et al., 2004; Chen et al., 2005; He et al., 2005; Li et al., 2005). Incense burning is another essential source of PAHs in many South Asian countries. Moreover, the penetration of air and soil loaded with PAHs inside indoor environment from outdoor may also marginally influence indoor concentration (Chuang et al., 1995; Sanderson and Farant, 2004). Organic pollutants are known to build up in indoor environment due to the limited ventilation and lack of direct sunlight (Butte and Heinzow, 2002; Santillo et al., 2003). The house dust in such indoor environment may archive, hence, the analyses of organic pollutants in house dust can give a reliable indication of the extent of indoor contaminations (Butte and Heinzow, 2002).

Past investigation have discovered that high level of PAHs in surface soil and house dusts not only influence the physicochemical characteristics of soil, but also equally impact the environment and the human population living there (Blake et al., 2007; Haugland et al., 2008; Jiao et al., 2009; Mostert et al., 2012). Thus, knowledge about the dissemination of PAHs in surface soil and house dusts together with their likely sources of release are basic to limit the ecological dangers. Evidence suggests that anthropogenic activities identified with industrializations and urbanization intensely impact pollution levels in urban areas (Liu et al., 2010; Pataki et al., 2011; Luo et al., 2012; Vane et al., 2014; Gu et al., 2016a; Jiang et al., 2016; Marquez-Bravo et al., 2016). Urban centers have turned to be provincial store for asset utilization and sources of chemical emissions, bringing about boundless environmental pollutions among different issues (Chung et al., 2007; Cachada et al., 2016; Gu et al., 2016a). Human health inside urban communities is unequivocally reliant on the status of urban soils and house dusts (Imperato et al., 2003; Gu et al., 2016b). Therefore, understanding the behavior of organic pollutants, determining their spatial assortment and source/sink susceptibilities will help to shape an extremely conclusive approach in urban areas to avert contamination. Moreover, the knowledge about organic pollutants in soil will additionally help to evaluate health risks, to drive their environmental fate and to improve the air quality. The assurance of the levels and the spatial conveyance of these SVOCs are challenging in Nepalese cities, as exceptionally restricted data are accessible. Detailed about PAHs concentrations and environmental fate in the urban soil and dust of Nepal have not been studied so far. This absence of information poses troubles for pollution control and management. In this manner, this study investigates the environmental concentrations, spatial distribution pattern, and emission sources of PAHs in soil and house dusts from four major urban region of Nepal. The database generated from this investigation will be significantly useful in characterizing urban soil and dust with respect to PAHs emissions in Nepal. Knowledge about PAHs source comprehends the regional and global dynamics of their movement through various environmental compartments. Additionally, this study would be able to assess the quality of soil on regional scale which will be useful for making decision in land use planning for urban region.

2. Materials and methods

Detailed descriptions of the materials and methods are described in supporting information.

2.1. Soil and dust sampling

Details about study area, sampling locations and pretreatment methods are well discussed in our previous studies (Yadav et al., 2016, 2017a, 2017b). Briefly, four major cities of Nepal were selected for the collection of surface soil and house dusts. Both the surface soil and house dusts were collected during October 2014 using stainless steel shovel at depth of 0–15 cm (vegetation removed). Altogether 72 surface soil samples were acquired and mixed to make 24 representative samples. Hence, each sample was a combination of at least 3 sub samples obtained in different direction at distance of 5 m. Likewise, 24 house dusts were gathered from 24 different households in in all four cities (6 each) considering domestic, educational, residential, commercial, public places and office premises. Both the surface soil and dust samples were wrapped in aluminum foil and packed in zipper bag, and transported by air-mail to Organic Geochemistry Laboratory of Guangzhou Institute of Geochemistry, Guangzhou, China keeping in ice-box.