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Aggregate risk assessment of polycyclic aromatic hydrocarbons from dust in an urban human settlement environment

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ABSTRACT

Due to the coal-dominated energy structure and increasing numbers of vehicles, gaseous polycyclic aromatic hydrocarbons (PAHs) emissions are increasing in many cities in China. These emissions have the potential to threaten human health, especially when aggregated in human settlement environments located in areas of rapid industrialization and urbanization. In this paper, an urban aggregating health risk assessment framework based on a multiple-pathways exposure model, dose–risk relationships and scenario analysis, using dust as an environmental medium is proposed and examined for future study. In a case study of Nanjing, several dust samples were collected from different functional areas and the aggregate risk of polycyclic aromatic hydrocarbons in each sampling unit was assessed. The results indicated that non-carcinogenic risk and carcinogenic risk in Nanjing are currently acceptable, but cannot be ignored in the long term. The carcinogenic risk in the west of Nanjing was relatively high, but still acceptable, while it was lower in central and southeast Nanjing and lowest in the northeast. These results can be further utilized for urban planning. Future urban construction in Nanjing, especially residential construction, should be expanded to the south of the city rather than the west, to minimize the human health risk caused by industries.

1. Introduction

Healthy human settlement is usually a key criteria to assess sustainable city and eco-city (Li et al., 2009; Tao et al., 2016), and are also essential for long-term social stability and development (Xu et al., 2014; Yin et al., 2015); however, increasing pollutant emissions during rapid urbanization and industrialization processes exacerbate the degradation of residential environments in cities (Kang et al., 2011; Xu and Shu, 2012; Yang and Xu, 2004). In particular, pollutants gradually aggregate in the environment through multiple pathways, after which they are transferred to human bodies through multiple exposure routes and bio-accumulation processes, where they inevitably pose health risks and are detrimental to health. Accordingly, for effective risk management, environmental media need to be controlled (Mannino and Orecchio, 2008; Xu and Liu, 2009; Song and Xu, 2011).

Urban dust is a useful indicator of local air pollutant transport and deposition and can provide useful information about the aggregation of specific particulate materials from local pollution sources over long periods of time (Shu and Xu, 2012; Xu and Shu, 2014). Dust also acts as a sink and source of pollutants, especially atmospheric particles (Keller and Lamprecht, 1995; Adachi and Tainosho, 2005; Xu et al., 2012). High levels of toxic metals and organic contaminants, including polycyclic aromatic hydrocarbons (PAHs), may be contained in the dust, and city residents are exposed to such contaminants via various pathways (Wei et al., 2013; Soltani et al., 2015). Several types of health hazards, including genotoxicity, may be transmitted in this way (Degirmenci et al., 2000; Mohmand et al., 2015). Hence, dust in urban residential areas can be used as an indicator of the aggregation of PAHs in

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atmospheric particulate matters in the environment (Lorenzi et al., 2011; Hussain et al., 2015).

As a set of POPs, PAHs are typical aggregate pollutants that are toxic and have long-term persistence in the environment. The coal-dominated energy structure, consistent rapid growth in the number of vehicles, and some specific industries in Chinese cities have resulted in high levels of PAHs pollution (Song et al., 2015; Wang et al., 2015).

Some quantitative studies of exposure to dust as an aggregating source are currently available (Kang et al., 2011; Brown and Peake, 2006; Wang et al., 2011), and recent studies have documented significantly high PAHs concentrations in settled house dust in living spaces and in soil adjacent to parking lots sealed with coal-tar-based products. To date, no studies have examined the potential human health effects of PAHs from these products in dust and soil (Williams et al., 2013).

In this study, dust was considered to be an indicator of atmospheric particulate material and PAHs were the primary contaminant. Accordingly, we examined the concentration of PAHs in dust and quantified the aggregating risk of PAH contamination in Nanjing, China.

2. Methods

In this section, the Contaminated Land Exposure Assessment model, the risk characterization and quantitative assessment and the study area are introduced.

2.1. Contaminated Land Exposure Assessment model for dust

The Contaminated Land Exposure Assessment (CLEA) model is a multiple-pathway exposure spreadsheet-based application (Fryer et al., 2006). Specifically, CLEA is a multi-media probabilistic risk assessment model based on 10 years of research regarding health risk assessments of contaminated sites in UK (Department of the Environment, Food and Rural Affairs, 2002).

The model estimates the average daily exposure (ADE) to contaminants in soil of adults or children who live and work in places where they are exposed to contaminated soil over a long period. ADE is defined as the average daily amount of a contaminant per kilogram of body weight that a critical receptor might take in over the duration of exposure in a particular land use scenario. It is calculated via ten different pathways of three possible exposure routes including inhalation, ingestion and dermal contact (Fig. 1) (Department of the Environment, Food and Rural Affairs, 2009). The CLEA model considers chronic exposure scenarios, and the exposure duration could be as short as 1 year to as long as a lifetime (75 years). By comparing predicted exposure with health criteria values (HCVs), the model outputs are used to derive Soil Guideline Values (SGVs), which are examples of generic assessment criteria (Department of the Environment, Food and Rural Affairs, 2004).

There is currently no specific exposure assessment model for dust. The CLEA model predicts human exposure to a chemical in the soil by direct contact (such as dust ingestion), or following transport from the soil into another medium (such as homegrown produce or indoor air). Except for ingestion of fruit/vegetables and inhalation of vapors, all exposure pathways include dust as the contamination source, and the dust and soil sources in each exposure pathway are calculated separately. Since most of the exposure routes in the CLEA model involve dust, its parameters can be modified and amended for dust (Fig. 2).

Several categories of parameters are provided by the CLEA model for users to modify the model, such as the land use dataset, which includes parameters about meteorological conditions of the area and physical properties of the soil; the building dataset, which pertains to the effects of building features on land use, the physical and chemical properties of the pollutants and receptor behavior and physiological characteristics. All of these parameters help to specialize the CLEA model for specific sites or areas. In this study, parameter sets were based on the assumption that dust replaces the soil as the source of human exposure to contaminants since most of the urban surface is covered by cement and asphalt, and it plays a similar role as soil in the contaminants transport process in urban area in terms of dermal contact, oral ingestion and inhalation.

The CLEA model is suitable for both probability assessment and uncertainty assessment. In the CLEA model, parameters are expressed as probability distribution functions. Therefore, the model simulation generates a distribution function rather than a specific value. This is a useful method for reducing uncertainty of parameters. In addition, the CLEA model requires fewer input parameters, is easy to operate, and is available for free.

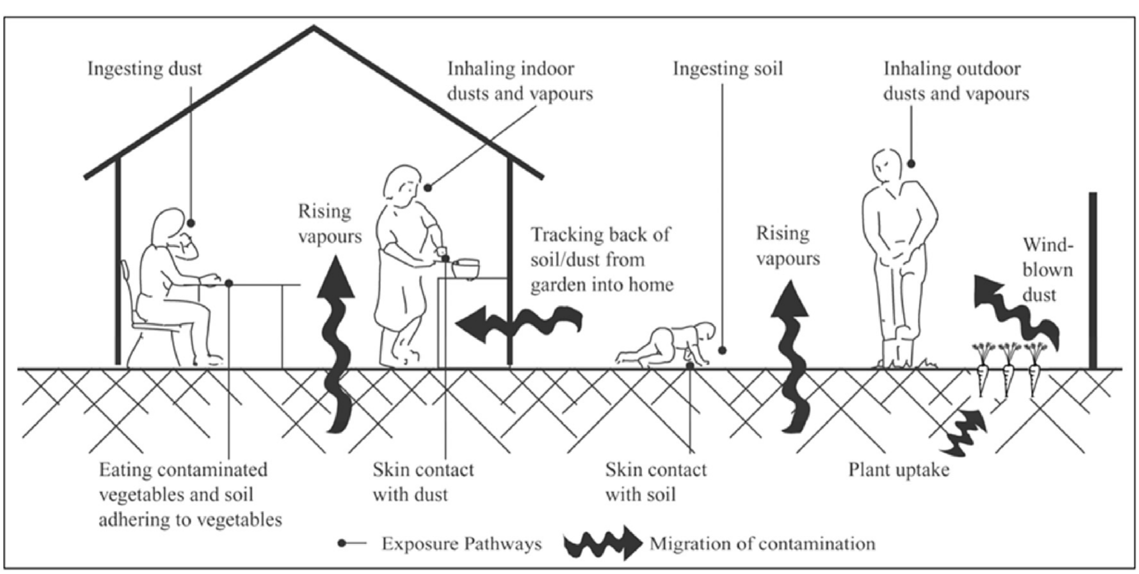

Fig. 1. Illustrates the potential exposure pathways in the CLEA model (Department of the Environment, Food and Rural Affairs, 2009).