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Common SVOCs in house dust from urban dwellings with schoolchildren in six typical cities of China and associated non-dietary exposure and health risk assessment

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ABSTRACT

This paper presents concentrations of common SVOCs in house dusts from urban dwellings with schoolchildren in six typical Chinese cities in winter and summer. Among the detected SVOCs, DBP and DEHP have a higher detection rate. The levels of these two substances contribute an average proportion of over 90% of the total SVOCs' levels, and show a significant correlation in most cities. Based on measured concentrations, schoolchildren's non-dietary exposures to DBP and DEHP at homes are estimated. Due to a longer time spent in child's bedrooms, children's non-dietary exposures to phthalates in child's bedrooms are greatly higher than that in living rooms. As for DBP non-dietary exposure, the most significant pathway is dermal absorption from air, accounting for > 70%, whereas, the most predominant pathway for DEHP non-dietary exposure is dust ingestion, contributing from 61.5% to 91.9%. Based on estimated exposure doses, child-specific reproductive and cancer risk are assessed by comparing the exposure doses with DBP and DEHP benchmarks specified in California's Proposition 65. Owing to the high DBP exposure, nearly all of target schoolchildren appear to have a severe reproductive risk, although only non-dietary exposures at home are considered in this study. The average risk quotient of DBP exposure for child-specific MADL in all cities is 31.27 in winter and 10.35 in summer. Also, some schoolchildren are confronted with potential carcinogenic risk, because DEHP exposure exceeds child-specific NSRLs. The maximum DEHP exposure exceeds the cancer benchmark by over 6 times. These results also indicate that controlling indoor phthalates pollution at home is urgent to ensure the healthy development of children in China.

1. Introduction

Over the past few decades, great changes have taken place in the consumer products use in residential buildings. Personal care products, fragrant detergent, plastic wrapping, indoor furniture, electronic components, and children's toys have become very pervasive in houses. As a major class of indoor pollutants, semi-volatile organic compounds (SVOCs) are usually served as active substances or additives blended into these consumer products to improve the functional performance. Since SVOCs are not chemically bonded to these products, they can be continuously released into the indoor environment over time (Bu et al., 2016). As the major chemical classes of SVOCs in indoor environments,

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phthalates esters (PAEs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) have been reported in numerous studies (Blanchard et al., 2014; Król et al., 2014; Langer et al., 2010; Pei et al., 2013; Rudel et al., 2003; Wang et al., 2015; Wu et al., 2007; Yu et al., 2018; Yu et al., 2012; Zhang et al., 2013). Also, exposure to SVOCs has been confirmed to produce adverse health effects on human. For example, PAEs can disrupt reproductive endocrine production and bring about reproductive health problems (Barlow et al., 2004; Bornehag et al., 2015; Koch et al., 2012; Toft et al., 2012; Wolff et al., 2010); PCBs can produce adverse effects on immune, nervous, and endocrine systems in human (Brody and Rudel, 2003; Carpenter, 2006; Turyk et al., 2007; Van Den Heuvel et al., 2002); PBDEs can interfere with thyroid hormone function and cause bad effects on neurodevelopment (Gascon et al., 2011; Herbstman and Mall, 2014; Lam et al., 2017; Mcdonald, 2005; Rudel and Perovich, 2009). PAHs can lead to chronic respiratory and cardiovascular health problems (Castro et al., 2011; Ma and Harrad, 2015; Maragkidou et al., 2017; Orecchio, 2011).

In comparison to adults, children are undergoing a physical growth and development, and their organs and tissues are not well developed. Also, they have a higher breathing capacity relative to their weight (Faustman et al., 2000). Furthermore, children's behavioral factors (e.g., crawling, frequent mouthing of hands and other objects) make them have more contact with indoor contaminants (Moya et al., 2004). Therefore, children are extremely vulnerable to indoor hazardous substances. In terms of children, moreover, the majority of their time are spent at homes. Thus, indoor SVOCs pollution at homes will have a significant influence on children's health and growth.

To date, there are a few investigations on indoor SVOCs pollution in homes with children (Ait Bamai et al., 2014; Callesen et al., 2013; Hsu et al., 2012; Kolarik et al., 2008; Zhang et al., 2013). These literatures indeed provide some valuable data. Even so, it is still insufficient to assess children's SVOCs exposure in homes, especially for the vast geographic China. During 2013–2014, a systematic nationwide survey on indoor environmental conditions in homes with schoolchildren aged 8–12 years old and children's respiratory and allergic symptoms was conducted. As indoor chemical pollutants in homes, some common SVOCs in house dusts were examined. This paper will mainly focus on SVOCs in house dusts to present indoor SVOCs pollution status in homes with schoolchildren in China and compare SVOCs levels in different cities and seasons. At the same time, based on measured SVOCs levels, children's non-dietary exposures to common SVOCs at homes are estimated. SVOCs levels and SVOC exposures between unhealthy groups (children with respiratory and allergic symptoms) and healthy groups (children without such symptoms) are also compared. Furthermore, to our knowledge, there are few published literatures on Chinese children's health risk assessment by SVOCs exposure. Thus, based on the exposure estimation, we also assess potential reproductive health risk and carcinogenic risk in schoolchildren. This paper will be favorable for understanding residential SVOCs pollution, improving living environment and ensuring the healthy development for children in China.

2. Materials and methods

2.1. Study cities and population

There were a total of six Chinese typical cities, including Shanghai, Beijing, Changsha, Wuhan, Dalian and Harbin, involved in the nationwide survey. These cities located in different climatic zones, as presented in Fig. 1. Among these cities, Harbin, Dalian and Beijing situated in the north of the Qinling Mountain-Huai River (Q-H) divide, while Shanghai, Changsha and Wuhan in the south of the Q-H divide (Huang et al., 2017). Based on this divide, in this study, Shanghai, Changsha and Wuhan were classified as southern cities, while Beijing, Dalian and Harbin as northern cities. China's heating policy allowed building space heating systems only in the north of the Q-H line (Huang et al., 2017).

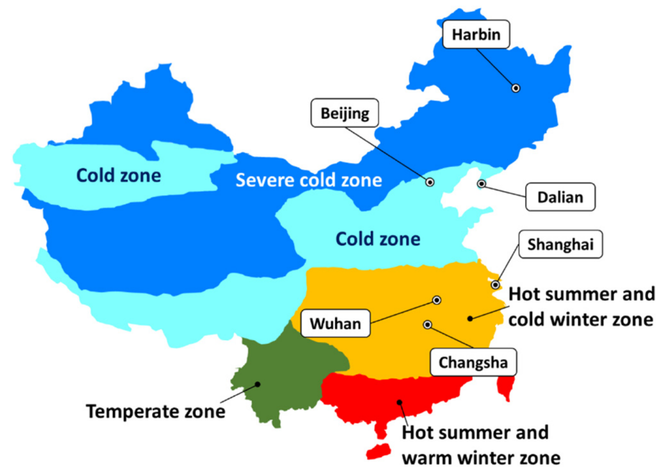

Fig. 1. Target cities and climatic regions for building thermal design in China.

As a consequence, indoor thermal environments differed greatly between northern and southern buildings, especially during heating season.

The research was aimed at schoolchildren aged 8–12 years old. These children were experiencing a shift into preadolescence. At this age stage, their exposure to environmental hazardous substances could produce a lifetime health effect.

2.2. Homes involved in field measurements

As mentioned before, SVOCs data in this study were derived from a systematic nationwide survey on indoor environmental conditions in homes. The nationwide survey consisted of two phases. In phase 1, the questionnaire survey was firstly conducted on schoolchildren in six Chinese cities. In each city, one or two primary schools were randomly selected. With the approval of school consent, fourth and fifth grade students were invited to participate. The questionnaires were distributed to the parents of the participants, and the parents filled in the interview sheet under the guidance of the investigator. The interview sheet was developed from the American Thoracic Society-Division of Lung Disease (ATS-DLD) questionnaires. The contents mainly included child's general information and health status, child's daily time spent indoors (including living room and child's bedroom), occupant's lifestyle, residential HVAC (heating, ventilation and air-conditioning) equipment and living environment. Children's health status referred to respiratory and allergic symptoms, including persistent cough, persistent phlegm, wheezing, eczema, respiratory allergy, pollinosis, allergic disease, asthma symptoms and so on. These symptoms were determined on basis of the answers for some specific questions. In phase 2, considering on children's respiratory and allergic symptoms, both healthy children's houses and unhealthy children's houses were selected to conduct detailed field measurements of indoor environment, in order to compare indoor environmental condition between healthy children's houses and unhealthy children's houses. The selection criteria for the unhealthy children were reports of one or more respiratory and allergic symptoms in phase 1. Inclusion criteria for the healthy children were no such symptoms in phase 1. Among the target houses, unhealthy children's houses were classified as Case Group (i.e. Group A), while healthy children's houses were classified as Control Group (i.e. Group B). In principle, repeated measurement at each selected house should be conducted in winter and in summer. However, individual houses were inconvenient for two measurements, due to some specific reasons. Thus, indoor environments were measured in only one season in some houses. Finally, detailed field measurements were performed in 68 dwellings in winter and 59 dwellings in summer, respectively, as shown in Table 1. All the selected dwellings were apartment houses in urban areas.