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Pollution levels and characteristics of phthalate esters in indoor air in hospitals

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ABSTRACT

The concentrations of phthalate esters (PAEs) in Chinese hospitals were investigated by simultaneously determining concentrations of gas- and particle-phase PAEs. PAEs were detected in two third-class first-grade hospitals, two second-class first-grade hospitals, and a community health service center. Hospital drugstores had the highest concentration (24.19 μg/m^3), which was 1.54 times that of newly decorated houses. The second highest concentration was found in the transfusion rooms, averaging 21.89 μg/m^3; this was followed by the concentrations of PAEs in the nurse's workstations, the wards, and the doctor's offices, with mean concentrations of 20.66, 20.0, and 16.92 μg/m^3, respectively. The lowest concentrations were found in the hallways (16.30 μg/m^3). Of the six different kinds of PAEs found, major pollutants included diethyl phthalates, dibutyl phthalates, butylbenzyl phthalates and di(2-ethylhexyl) phthalates, comprising more than 80% of all PAEs present. Meanwhile, a comparison between different wards showed that PAE concentrations in the maternity wards were 1.63 times higher than in the main wards. Based on known health hazards, our results suggest that the PAEs seriously influence the health of the pregnant women and babies; therefore, it is of great importance to take the phthalate concentrations in hospitals into consideration. In addition, hospital indoor air was more seriously contaminated than the air of newly decorated houses.

Introduction

Phthalate esters (PAEs) are widely used in the chemical industry as additives to polymers. They can increase a product's ductility and plasticity, and are applied in hundreds of different fields, primarily in the production of wallpaper, flooring, and in packaging material for food, plastic film, blood bags, and rubber tubing (Afshari et al., 2004; Wang et al., 2013; Pors & Fuhlendorff, 2001; Peters, 2003). Because PAEs are not chemically bound as parts of chemical compounds in products, various products continuously emit PAEs over time. There are many plastic products in hospitals. With the widespread application of these products, PAEs can enter into the environment during their use and disposal (Kong et al., 2012), forming a common component of indoor air and dust fall (Rudel et al., 2003; Fromme et al., 2004; Hwang et al., 2008; Weschler et al., 2008; Lin et al., 2009; Schripp et al., 2010; Pei et al., 2013; Das et al., 2014), and may pose a threat as

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pollutants that may be harmful to human health (Colon et al., 2000; Stringer et al., 2000; Lovekamp-Swan & Davis, 2003; Ma et al., 2003; Peñalver et al., 2003; Xu et al., 2006).

PAEs with low molecular weight are believed to be endocrine-disrupting compounds, which function much the same as female sex hormones. Some PAEs can destroy testicular tissue (Swan et al., 2005), inhibit the formation of sperm (Silva et al., 2005; Hauser et al., 2006), affect reproductive functions (Foster et al., 2001), and damage the reproductive system (Ema & Miyawaki, 2001; Saillenfait et al., 2001; Lovekamp-Swan & Davis, 2003). A considerable amount of research (Colon et al., 2000; Adibi et al., 2003) indicates that PAEs may greatly damage both male and female sex organs. PAEs may cause precocious puberty in females (Colon et al., 2000; Adibi et al., 2003), and increase the risk of breast cancer (Lovekamp-Swan & Davis, 2003). Moreover, PAEs may affect the reproductive system of any future baby boy (Swan et al., 2005).

PAEs primarily enter the human body through the respiratory and digestive tracts as well as skin, and a certain concentration of PAEs has been detected in human urine, blood, milk and many other body fluids (Mortensen et al., 2005; Hines et al., 2009a,2009b). Air is an important medium that cannot be ignored, as it relates to the uptake of PAEs by humans. Hospitals use a wealth of plastic infusion bags, blood bags, plastic film, injectors, and rubber tubing that often contain many types of PAEs (Afshari et al., 2004; Wang et al., 2013; Pors & Fuhlendorff, 2001; Peters, 2003); therefore, hospital air inevitably contains undesirable levels of many PAEs. In addition, aside from the effects of PAEs on medical workers themselves, a large group of patients, especially babies and pregnant women, have weak immune systems and may easily suffer adverse reactions to PAEs.

Currently, some developed countries have started to pay close attention to pollution from PAEs, with a year-to-year increase in the number of research reports published. Afshari et al. (2004) reported the emission of phthalates from PVC products and other materials. Weschler et al. (2008) reported the partitioning of phthalates into gaseous substances, airborne particles and dust settling in indoor environments. Schripp et al. (2010) and Schossler et al. (2011) studied mass-transfer of di(2-ethylhexyl) phthalate (DEHP) and di-n-butyl phthalate (DnBP) from emission sources into house dust. However, Chinese researchers had a rather late start and fewer published reports have appeared addressing conditions in China. Lin et al. (2009) reported on PAE concentrations in indoor dust. Wang et al. (2010) analyzed indoor exposure to PAEs. Chen et al. (2012) assessed the exposure of non-occupational populations in China to phthalates; Pei et al. (2013) reported on PAE concentrations in indoor air and dust in newly decorated houses. The status and characteristics of PAE pollution in hospitals remain unclear, and no research has simultaneously addressed gas and particle phase PAEs in indoor air within hospitals. In this paper, two third-class first-grade hospitals (China's best), two second-class first-grade hospitals (good Chinese hospitals), and a community health service center that provides primary health care in China were selected as sample sites. This study used repeated sampling and, to the best of our knowledge, provides the first documentation of the concentration and characteristics of the distribution of PAEs in different hospital departments in China. In addition, a comparison is provided for PAE content and concentration, comparing hospitals and newly decorated houses. Lastly, conclusions are drawn related to the pollution status of PAEs to offer a scientific basis for the control of PAEs in indoor hospital air.

1. Materials and methods

1.1. Chemicals and materials

High performance liquid chromatography (HPLC) grade chemicals and solvents were used for all extraction and gas chromatography (GC) analysis. Standard mixtures of M-8060 phthalates, including dimethyl phthalate (DMP), diethyl phthalate (DEP), dibutyl phthalate (DBP), butylbenzyl phthalate (BBP), DEHP and di-n-octyl phthalate (DnOP), were purchased (AccuStandard, New Haven, CT, USA) as stock solutions in isooctane; all had concentrations of 2.0 mg/mL for each phthalate.

1.2. Sample analysis

1.2.1. Sample collection

Before sampling, all the sampling tubes and the glass fiber filters were baked at 400°C in a muffle furnace (KS60-6.5-12G, Shanghai Y-feng Electrical Furnace CO, CN) to remove any previously adsorbed organic compounds, and these instruments were then stored wrapped in aluminum foil.

Indoor air samples were collected daily from several indoor sites within five hospitals (denoted as A, B, C, D and E) of different types, from the fall of 2012 to the spring of 2013. The samples were collected into a plexiglass sampling head with a glass fiber filter (37 mm in diameter, pore size of 0.45 μm (1820-037, Staplex, USA)) and subsequently a glass tube packed with 2 g XAD-2 adsorbent (1-0357, Sigma-Aldrich, St. Louis, MO, USA), using an electronically controlled air sampler (PC-A, Zhejiang Hengda Instrument Co., CN). The sampling device was set 1.5 m above the floor, with a sampling time of 8 to 10 hr, and sampling flow of 1.0 L/min (air pump changes before and after sampling were in the range of less than 5%). When sampling was completed, both ends of the sampling device remained sealed, and samples were returned to the laboratory for immediate processing. Temperature, humidity, and air pressure were synchronously recorded using an electronic temperature and humidity instrument (HTC-1, Zhengzhou Beyond Instrument Co., CN) and digital air pressure equipment (BY-2003P, Suzhou Taishi Electronic Co., CN).

1.2.2. Sample pretreatment and analysis

Samples were extracted from the XAD-2 adsorbent and glass fiber filters using an ultrasonic cleaner (SK250HP, Shanghai Kudos Ultrasonic Equipment Co., CN) for 30 and 25 min, respectively, with a 10 mL mixture of dichloromethane/acetone (1:1) as the extraction solvent. Then 5 mL of supernatant was transferred into a cuvette with addition of 30 μL dimethylsulfoxide into the solution before evaporation by a high purity nitrogen concentrator (MTN-2800W, Tianjin Automatic Science Instrument Co., CN); then 970 μL methyl alcohol was added into the cuvette. The solution was filtered with a 0.22 μm organic filter, and transferred