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Analysis of the influencing factors of PAEs volatilization from typical plastic products

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ABSTRACT

The primary emphasis of this research was to investigate the foundations of phthalate (PAEs) pollutant source researches and then firstly confirmed the concept of the coefficient of volatile strength, namely phthalate total content in per unit mass and unit surface area of pollutant sources. Through surveying and evaluating the coefficient of volatile strength of PAEs from typical plastic products, this research carried out reasonable classification of PAEs pollutant sources into three categories and then investigated the relationship amongst the coefficient of volatile strength as well as other environmental factors and the concentration level of total PAEs in indoor air measured in environment chambers. Research obtained phthalate concentration results under different temperature, humidity, the coefficient of volatile strength and the closed time through the chamber experiment. In addition, this study further explored the correlation and ratio of influencing factors that affect the concentration level of total PAEs in environment chambers, including environmental factors, the coefficient of volatile strengths of PAEs and contents of total PAEs in plastic products. The research created an improved database system of phthalate the coefficient of volatile strengths of each type of plastic goods, and tentatively revealed that the volatile patterns of PAEs from different typical plastic goods, finally confirmed that the coefficient of volatile strengths of PAEs is a major factor that affects the indoor air total PAEs concentration, which laid a solid foundation for further establishing the volatile equation of PAEs from plastic products.

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Introduction

Over the past half-century, in the wake of societal economic development with the improvement of living standards amongst the general populace, there has been a tremendous change in the materials used in internal renovations and decorations, as well as a string of daily items. A new type of semi-volatile organic pollutant, known as phthalate esters (PAEs), has begun to penetrate into people's lives. It acts as an endocrine interferon, and has a disrupting effect on the male hormone testosterone. It can be seen that phthalates have an incredibly harmful effect on the health of the human body, and consequently relevant research has led to the arousal of enormous concern.

Contemporary research on phthalates concentrates on two points: measurement of PAEs concentration level and the pollutant sources investigation. America, Sweden, Japan, Germany, and other developed nations followed closely in

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carrying out indoor phthalate contamination level researches since 1991. Rudel et al. (2003) measured the indoor air samples from 120 American residences, and the study demonstrated that there are 88 types of endocrine interferon, as well as showed that phthalates were a common existence in indoor residential air. Kanazawa et al. (2010) researched the phthalate contamination concentration levels from 41 residences in Sapporo, Japan and assessed their relationship with Sick Building Syndrome. Fromme et al. (2004) measured the concentration levels of phthalate in 59 German apartments, with all samples resulting in finding of diethyl phthalate (DEP), dibutyl phthalate (DBP), and diethylhexyl phthalate (DEHP), amongst which the concentration of DBP was the highest, at 1083 ng/m^3; and within indoor dust, DEHP concentration was the highest, at 703 mg/kg, making up 80% of phthalates in the dust. The data above are the concentration levels of phthalate contamination within residential environments, and of course there also have corresponding researches of phthalate contamination concentration investigation in indoor air from public places, with PAEs concentration levels being equally contemptible. Becker et al. (2009), in a German kindergarten during 2003, discovered that children who are exposed to phthalates are subjected to even larger health effects, its metabolism resulting in concentration levels 3–5 times higher than adults. Henceforth, domestic and international scholars have launched extensive research on phthalate exposure to babies and children. Bergh et al. (2011) undertook research in Stockholm (Sweden), on phthalate levels in indoor air and indoor dust from three different types of indoor environments (residential, kindergarten, office), and discovered uniform detection of phthalate in all samples, with phthalate concentration levels in indoor air from the kindergarten ranging between 1200 and 5600 ng/m^3, and average concentration is 2500 ng/m^3, with total phthalate contamination level both in indoor air and indoor dust being lowest in residences, and highest in offices. These researches well illustrated concentration levels of indoor air phthalates which lead to serious indoor air contamination and thus investigating the PAEs volatilization features from pollutant sources is of great importance and necessary.

The main sources of phthalates in indoor environment mainly are construction materials, renovation and decoration materials, daily items and so on. According to statistics, every year thousand tones of phthalates are added into several hundred types of PVC products, and other consumer goods, from polythene flooring and wallpaper, toys, food packaging materials, medical blood bags to rubber tubing, nail polish, shampoo and so on (Bouma and Schakel, 2002; Kavlock et al., 2002). The content of phthalates in plastic goods exists in the range of 10%–60% (Rudel and Perovich, 2009). Uhde et al. (2001) investigated the emissions of phthalates from plastic wallpapers, with results showing that plastic wallpapers can emit diisobutyl phthalate (DIBP), DBP, DEHP, diisononyl phthalate (DINP), and dipentyl phthalate (DPP), at concentrations of 0.94–5.1 μg/m^3. Afshari et al. (2004) carried out evaluations on the emission concentration of phthalates from PVC flooring and electric cabling materials, with results finding that PVC flooring released higher level concentrations of DBP and DEHP. Stringer et al. (2000) tested types and content distributions of phthalate from 72 types of toys purchased from 17 countries (of which 64 types were PVC materials or possibly contained PVC materials), with results showing that phthalates commonly exist in these toys, mainly DINP and DEHP, while toys from some countries also had the high addition of DIDP. The data from current researches are varied and chaotic, and we preliminary found that the emission concentration was closely related to the surface area of different pollutant sources which can explained why PVC flooring and wallpapers emitted higher PAEs concentration compared to other pollutant sources.

From the practical experience, this study ascertained that pollutant sources can be classified into two categories based on the numerous current researches, namely construction or decoration materials (wallpaper, paintings, PVC flooring, *etc.*), and daily items (packaging materials, plastic cups, plastic bowls, *etc.*). This study chose daily items as research objects.

In summary, the main focus of current research on investigating the pollutant sources was only evaluating the phthalate content in the contamination sources, but as to different contamination sources in varied environmental conditions, the volatility process isnot actually that clear. In other words, these researches did not establish the relationship or mathematical model between the phthalate content in sources and the volatile concentration level from sources in different environmental situation, sometimes only under certain one condition which lacking of universality. From the further exploring, this study found that volatile process and concentration were closely related to the exposed surface area of pollutant sources. Based on the above consideration, this study defined the coefficient of volatile strength of phthalate (K_{vs}) as total phthalate contents from per unit exposed surface area and unit mass of pollutant sources. In addition to comprehensively investigating the effectiveness of this coefficient as well as some environmental factors, this study primarily determined the main factors that affect volatile process and concentrations, which laid a solid foundation for further establishing the volatile models of PAEs from plastic products.

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 flame ionization detector (GC-FID) analysis. Standard mixtures of M-8060 phthalates, including dimethyl phthalate (DMP), DEP, DBP, butylbenzyl phthalate (BBP), di(2-ethylhexyl) phthalate (DEHP) and di-n-octyl phthalate (DnOP), were purchased from AccuStandard (New Haven, CT, USA) as stock solutions in isooctane; all had concentrations of 2.0 mg/mL for each phthalate.

1.2. Indoor air samples collection

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

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