Pollution characteristics and health risk assessment of phthalate esters in household dust in Chengdu, China

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ABSTRACT
The characteristics and health risks of 15 phthalate esters in household dust and the association with household attributes were investigated in Chengdu, China. The concentrations of total phthalate esters ranged from 87.9 to 3623 μg/g. Di (2-ethylhexyl) phthalate (DEHP) was the dominant compound of phthalate esters with a median of 151 μg/g. The statistical analysis result showed that household products and synthetic polymer emission were the main sources of phthalate esters. Smoking, cooking, keeping pets and the use of wooden floor and plastic wallpaper might increase the concentrations of phthalate esters in household dust, but opening windows frequently, and increasing the sweeping frequency might cause the decrease of phthalate esters in the indoor environment. The hazard indexes (HI) values of phthalate esters were all below 1, indicated that there are not non-carcinogenic of phthalate esters in household dust for the residents in Chengdu. However, the carcinogenic risk of DEHP was $2.54 \times 10^{-6}$, implying that the carcinogenic risks via exposure to DEHP from Chengdu household dust were noticeable.

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Introduction
Phthalate esters are extensively used in various plastic products and consumer products (Gómez-Hens and Aguilar-Caballos 2003; Zhu et al. 2019). In China, the production of plasticizers more than 2.1 million tons per year and phthalate esters contributed to >70% of the annual production in 2014 (Zhu et al. 2019). With the widespread production and applications, phthalate esters are almost everywhere in the environment (Chen et al. 2012). Because phthalate esters do not bind to polymers with chemical bonds, they are easily released into the environment during manufacturing, storage, and usage (Guo and Kannan 2013; Koniecki et al. 2011; Net et al. 2015). The occurrence of phthalate esters in various environmental matrices has been investigated such as urban soil and street dust (0.0002–4.82 μg/g) (Škrtčič et al. 2016), surface water (nd-16.10 μg/L) (Luo et al. 2021), sediments (1.69–36.6 μg/g) (Cheng et al. 2019), as well as tobacco cultivation soils (0.22–1.17 μg/g) (Song et al. 2021), food packages (Di-2-ethylhexyl phthalate (DEHP) 0.3–103.33 μg/dm) (Jarošová and Bogdanovičová 2015), and cosmetics and personal care products (nd-25542 μg/g) (Koniecki et al. 2011). In addition, many studies have observed...
DEHP, di-n-butyl phthalate (DBP) and butyl benzyl phthalate (BBP) and their metabolites may abnormal internal secretions and procreation when long-term exposure, even low concentrations (Hauser and Calafat 2005; Lovekamp-Swan and Davis 2003).

In general, humans spend nearly 90% of their time in indoor environments including home, office, and classroom (Başaran et al. 2020; Xia et al. 2018; Zhu et al. 2019). The occurrence of phthalate esters in household dust from the United States, Italy and Sweden and the megacities in China (e.g., Beijing, Guangzhou, and Shanghai) have been reported (Gevao et al. 2013; Guo and Kannan 2011; Kang et al. 2012; Orecchio et al. 2013). The previous studies observed there were strong associations between phthalate esters concentration in settled dust and household consumer products such as DEHP-leather polish, di-iso-butyl phthalate (DIBP), BBP, DINP-flooring materials, and BBP-modern window frame (Zhang et al. 2020). Besides, resident personal habits (e.g., smoking sweeping, cooking), indoor environment and activities (e.g., decoration, the number of residents and pets), and characteristics of the building (e.g., age, storey, and height) are also factors that affect the phthalate esters in indoor dust (Wang et al. 2013).

Chengdu is one of the new first-tier cities (i.e., a metropolis where play an important role in the economy and politics of the country) and the most livable cities in China and a key hub under the Belt and Road initiative (Li et al. 2017; Xu et al. 2018). According to the “2018 World Urbanization Prospects”, there will be 10.7 million population in Chengdu in 2030 (UNDESA, 2018). The total area of residential land reached 5282 ha in Chengdu in 2017, including commercial housing (53.28%), housing of limited property rights (23.17%), resettlement housing (21.78%), and affordable housing (1.77%) (Yang et al. 2017). Since 2005, the resettlement housing and affordable housing was increasing, mainly in eastern part of Chengdu (Yang et al. 2017). Affordable housing is the low-cost/leasing of commercial housing mainly provided for low-income urban populations and migrant workers (Man 2011; Shi et al. 2016). Previous studies have shown that low-income population smokes and use chemicals relatively frequently, which may cause poor indoor environmental quality and human health threat (Kolokotsa and Santamouris 2015; Lam et al. 2017). Therefore, with the growth of population the proliferation of housing in Chengdu, there is an urgent need to better understand how the relationship between phthalate esters loads in household dust and household attributes and the effects on human health in Chengdu. The objectives of this study were: (1) to investigate phthalate esters concentrations and congener profiles in household dust collected from Chengdu; (2) to assess the relationships among phthalate esters in the household dust and building characteristics and resident habits; and (3) to estimate the potential health risks of phthalate esters.

**Materials and methods**

**Sample collection**

Household dust samples were collected by a pre-cleaned small vacuum cleaner from the floor in the living room and bedrooms in 23 households in the downtown of Chengdu (Figure S1). All samples were sieved to remove large debris, and homogenized with the 154 µm sieve and stored at desiccator until further analysis. A questionnaire was
designed to gather more information from the inhabitant to evaluate their living habits, and the details of the questionnaire are found in Table S2.

**Chemical analysis**

Freeze-dried household dust samples (~3 g) were spiked with 250 ng of internal standards (DMP-d4, DBP-d4 and DEHP-d4) and equilibrated at room temperature for 3 h. Then, dust samples were extracted with 110 mL acetone/dichloromethane/n-hexane (1:1:1, v/v/v) in a Soxhlet extractor (USEPA 1996a), and the extracts were purified according to florisil cleanup method (USEPA 1996b). Fifteen phthalate esters were measured from the sample extracts by a GC 6890/MS 5973 with 30 m HP-5MS column (0.25 mm diameter and 0.25 mm film thickness). Details about the phthalate esters analyses, QA/QC and calculation are described in the Supplementary material.

**Data analysis**

Statistical tests were conducted with SPSS 23.0 for Windows. Principal component analysis (PCA) and Spearman’s correlation coefficient analysis were carried out to identify the possible sources and the relationships between dust-phthalate esters and household factors.

**Results and discussion**

**Phthalate esters in household dust**

The concentrations of phthalate esters in household dust collected from Chengdu are shown in Table S1. Fifteen phthalate esters were detected in household dust samples with a detection frequency from 52.2 to 100%. The concentrations of total phthalate esters varied from 87.9 to 3623 µg/g with a median of 290 µg/g and a mean of 733 µg/g.

Comparison with other first-tier cities in Eastern China (e.g., Beijing, median 255 µg/g and Shanghai, median 401 µg/g and Guangzhou, median 173 µg/g) (Guo and Kannan 2011) (Figure 1), there may not be a significant difference of phthalate esters levels in household dust samples between Chengdu and these cities. Compared with the first-tier cities in Western China (e.g., Chongqing, median 1751 µg/g and Xi’an, median 1149 µg/g) (Bu et al. 2016; Wang et al. 2014) and other cities other city around the world, (e.g., the USA, median 396 µg/g; Kuwait, median 2384 µg/g; Italy, mean 1289 µg/g and Sweden, mean 1055 µg/g) (Gevao et al. 2013; Guo and Kannan 2011; Orecchio et al. 2013), Chengdu has lower concentrations of phthalate esters in the household dust. However, it is worth noting that the extremely high phthalate esters concentrations (exceed 3000 µg/g) were found in some sampling sites in the eastern of Chengdu. According to the function distribution of main districts of Chengdu, the main industrial, logistic, metallurgy and chemical industry were located in the eastern of Chengdu (Peng et al. 2015; Yin et al. 2019). The industrial production and the usage of PVC and other plastic materials were relatively large, which resulted the higher level of phthalate esters in these areas. Meanwhile, Yang et al. (2017) founded that more affordable housing is distributed in the east of Chengdu city, where affordable housing is mainly provided for low-income urban
residents and rural migrant workers in the process of urbanization. The wide and frequent use of plastic products and other daily chemicals (e.g., printing, pharmaceuticals, inks and coatings, personal care products) in the area would be released into the indoor environment via direct release, leaching, evaporation, and abrasion (He et al. 2020; Yang et al. 2018).

Composition profiles of phthalate esters

Consistent with that was reported in other studies (Abdi et al. 2021; Guo and Kannan 2011; Zhang et al. 2013), the dominant compound of phthalate esters in all dust samples collected from Chengdu was DEHP, which ranged from 48.2 to 2621 µg/g, with a median of 151 µg/g and a mean of 452 µg/g (Table S1). The concentrations of DEHP were 2–14 times higher than the concentrations of DCHP (median 89.2 µg/g), DBP (median 31.2 µg/g) and DIBP (median 11.5 µg/g), and 100–1000 times higher than other phthalate esters (Figure 2 and Table S1). DEHP is widely used in plastic products and decoration materials (e.g., floor and wall covering, toys, and adhesives) and can be released into the indoor environment through evaporation, aging, and abrasion (Bornehag et al. 2005; Zhang et al. 2020). While DBP and DIBP also showed relatively higher levels in the household dust, which might be associated with that DBP and DIBP as the main additives used in personal care products (e.g., cosmetics and pharmaceutical coatings) (Li et al. 2021; Net et al. 2015). In addition, the low levels of other phthalate esters such as DEP and DMP were observed in this study, which is consistent with the

Figure 1. Concentrations (µg/g) of phthalate esters in household dusts in Chengdu and other cities around the world.

Note: Median values of the studied phthalate esters were used for this figure. dimethyl phthalate (DMP); diethyl phthalate (DEP); diallyl phthalate (DAP); diisobutyl phthalate (DIBP); di-n-butyl phthalate (DBP); bis(2-ethoxyethyl) phthalate (DEEP); dipentyl phthalate (DPP); di-n-hexyl phthalate (DHP); butyl benzyl phthalate (BBP); bis(2-n-butoxyethyl) phthalate (DBEP); bicyclohexyl phthalate (DCHP); di-2-ethylhexyl phthalate (DEHP); di-n-octyl phthalate (DNP); diisononyl phthalate (DINP) and dinonyl phthalate (DNP). (a) Guo and Kannan (2011); (b) Zhang et al. (2013); (c) Bu et al. (2016); (d) Wang et al. (2014); (e) Başaran et al. (2020); (f) Gevao et al. (2013); (g) Abb et al. (2009); (h) Abdi et al. (2021).
reported results from indoor dust samples in other cities (Guo and Kannan 2011; Orecchio et al. 2013), that could be due to the high volatility and high vapor pressure causing the low molecular weight phthalate esters mainly in gas phase than that in dust phase (Başaran et al. 2020; Bergh et al. 2011). Noteworthy, although it’s consistent with the profile in many cities all over the world that DEHP showed the largest proportion in Chengdu household dust (Figure 1), DEHP concentrations in this study were 10 to 15 times lower than the results reported in previous studies, such as Chongqing, China (median 1543 µg/g) (Bu et al. 2016), and Kuwait (median 2256 µg/g) (Bergh et al. 2011) (Figure 1). The relatively lower concentrations of DEHP in this study might reflect the trend of decreasing DEHP due to worldwide regulations or restrictions on the use of DEHP (Salthammer et al. 2018; Zhang et al. 2020). In particular, DCHP contributed 30.7% to the total phthalate esters in this study, the result was different from previous reports from China (Beijing, Guangzhou, Shanghai), the USA, and Kuwait (0 to 1.8%) of the total phthalate esters in household dust (Gevao et al. 2013; Guo and Kannan 2011). DCHP is a common plasticizer ingredient for ethyl cellulose, nitrocellulose, vinyl acetate, polyvinyl chloride, and resins, usually be added to the polymers to make these polymers more flexible (Lv et al. 2019; Schecter et al. 2013). DCHP can also be used with nitrocellulose and some natural resins to make moisture-proof coatings (He et al. 2020). The climate of Chengdu is characterized by humid air, with an average annual relative humidity of 79–84% (Chen et al. 2016). In the past ten years, Chengdu has widely used moisture-proof coatings in the decoration of new houses, which may be one of the reasons why DCHP is higher than other areas. The reasons underlying the high DCHP Chengdu household dust are unknown at present, but it should be drawn a lot of attention due to growing evidence demonstrated that DCHP had similar potency to DEHP or DBP in the induction of adverse effects on mammalian development and reproductive system (Aydoğan Abbab and Barlas 2013; Li et al. 2016; Lv et al. 2019).
Possible sources of phthalate esters

Principal component analysis (PCA) has been widely used to elucidate the relationship among contaminants and identify their probable sources in various environmental mediums (Cheng et al. 2019; Gu et al. 2018). Kaiser-Meyer-Olkin (KMO) and Bartlett’s sphericity test results were 0.75 and 297.91, respectively (df = 105, p < 0.01), indicating PCA may be a helpful tool in the identification of distinct phthalate esters sources. As shown in Figure 3, the first-two principal components (PC1 and PC2) were extracted and collectively explained more than 81.0% of the total variance of the phthalate esters in all household dust samples. PC1 (57.4%) was heavily loaded by DBP, DEP, DINP, DAP, DMP, DIBP, DPP and BBP. The lower molecular weight phthalate esters, such as DMP, DEP, DBP and BBP, are typically used in cosmetics and personal care products, BBP also widely used in construction materials and home furnishings such as vinyl flooring, adhesives, and synthetic leather (Gómez-Hens and Aguilar-Caballos 2003; Ma et al. 2020; Net et al. 2015). PC2 contributed to 23.6% of the total variance with strong positive loadings of DNOP, DCHP, DEHP, DNP and DEEP. These high-molecular weights phthalate esters were widely used as plasticizers to impart flexibility and general handling properties to PVC and synthetic polymer (Net et al. 2015; Schecter et al. 2013; Zhang et al. 2020). The multiple linear regression (MLR) analysis is performed on the factor scores of PCA and then quantitative evaluation of the relative contribution of each identified source of pollutants (Cheng et al. 2019; Ke et al. 2017). In this study, the regression equations are expressed as follow:

\[
\text{Standardized phthalate esters} = 0.868 \times \text{PC1} + 0.373 \times \text{PC2} \quad (R^2=0.870, \ p < 0.001)
\]

The relative contributions of PC1 and PC2 to the total phthalate esters burden in household dust from Chengdu were calculated from the coefficients, showing PC 1

![Figure 3. Principal component analysis of phthalate esters in the household dusts.](image-url)
(personal care products and household chemicals emission) to contribute 69.9%, whereas PC 2 (PVC and other synthetic polymer emissions) contributed 30.0% of phthalate esters in household dust from Chengdu.

In addition, a recent study demonstrated that strong associations between phthalate esters in Chinese household dust and household consumer products such as flooring materials and modern window frame (Zhang et al. 2020). Thus, based on the data from the questionnaire, a total of 13 household factors were defined and calculated the possible relationship with phthalate esters concentrations in Chengdu household dust (Table S2 and Figure 4). According to the statistical results can identify three categories (e.g., living habits, decorations, and others) of the household factors were found strong associations ($p < 0.05$) with dust-phthalate esters (Figure 4). The living habits included smoking, sweeping frequency, window opening habits, and cooking frequency in this study. Strong positive correlations were observed between smoking and DMP, DEP, and DIBP ($p < 0.01$), and DBP, DEHP, DINP, and total phthalate esters ($p < 0.01$), DEEP, DCHP, and DNOP ($p < 0.05$) (Figure 4). These results indicated smoking may be one of the most important sources of phthalate esters in household dust in Chengdu. Wang et al. (2020) observed pregnant women exposure the environmental tobacco smoke (ETS) may increase the concentrations of phthalate esters (DIBP, DBP, DPP, and DINP) in their urinary. Song et al. (2021) found the long-term application of plastic film and agricultural inputs (irrigation water and fertilizers) might increase phthalate esters concentrations in tobacco cultivation soils, and then cause the accumulation of

![Figure 4. Relationships between the household factors and phthalate esters concentrations in the household dust.](image)

Note: Red, orange and navy rectangle highlights the strong correlations between phthalate esters in the household dust and living habits ($p < 0.05$), decorations and others, respectively. See Table S2 for the definite values of the household factors.
phthalate esters in tobacco leaves. In addition, phthalate esters may be released into the household environment from cigarette packaging and printing ink (Gong et al. 2018). Meanwhile, sweeping frequency showed a strong correlation with DMP, DEP, and total phthalate esters \((p < 0.01)\), with DIBP, DBP, DCHP, DINP, and DNP \((p < 0.05)\) (Figure 4), indicating the higher sweeping frequency to be effective in reducing the accumulation of phthalate esters in household dust. Furthermore, window opening habits also have a strong influence on phthalates esters concentration in the household dust. Pei et al. (2018) found the emission rate of phthalate esters could be increased from the source materials with indoor temperature increasing and the ventilation could reduce the phthalate esters concentration in the dust-phase, so increasing the time to open windows for ventilation and the frequency of house cleaning, which is beneficial to maintaining a good indoor environment. Noteworthy, there were positive correlations among cooking frequency and DEHP, DCHP \((p < 0.01)\), DNOP, and total phthalate esters \((p < 0.05)\), indicated that cooking also was a contributor to phthalate esters in household dust, which could be explained by synthetic condiments and food packaging would be used during the cooking (Fierens et al. 2012; Jarošová and Bogdanovičová 2015; Schecter et al. 2013).

Consistent with previous studies (Ait Bamai et al. 2014; Li et al. 2021; Zhang et al. 2020), strong associations were found between home decorations (e.g., floor cover and wall cover) and phthalate esters in the household dust \((p < 0.05)\). The ranges of associations were observed between floor cover and DCHP, and DEHP \((p < 0.01)\), and DEEP, DNOP, and total phthalate esters \((p < 0.05)\) (Figure 4), implying the wooden floors might be found higher concentrations of phthalate esters in the household dust, corroborating wooden floors especially laminated wood floors suspected as the source of phthalate esters (Zhang et al. 2013; Zhang et al. 2020). Plenty of phthalate esters were added as adhesives in the manufacturing process of laminated woods to improve the adhesion property (Ait Bamai et al. 2014; Zhang et al. 2020). In addition, wall covers were associated with DIBP, DEHP, DNOP, DINP, and total phthalate esters \((p < 0.001)\), with DMP, DBP, DCHP, and DNP \((p < 0.01)\) (Figure 4), the results might provide further evidence that plastic wallpaper and latex paints were the important sources for phthalate esters in the household dust (Shinohara et al. 2019).

The results also showed that positive correlations between pets and phthalate esters in this study (Figure 4). The high-molecular weight phthalate esters (e.g., DEHP and DINP) are restricted in children’s toys and child-care articles in the US, Europe and China, but there are no restrictions on pet toys (Wooten and Smith 2013). Many previous studies had reported the detection of high-molecular weights phthalate esters in pet toys, such as, concentrations of DEHP (4 out of 13) and DINP (10 out of 13) in 13 pet toys ranged from 6.9 to 54% \((v/v)\) in Denmark, and 5 out of 6 phthalates were detected in canine toys and training devices in the US (Müller et al. 2006; Wooten and Smith 2013). Notably, the correlations between DCHP and household factors were similar to that of DEHP, indicating DCHP not only had similar potency to DEHP in the induction of adverse effects on the reproductive system, but also might have similar sources in the indoor environment (Aydoğan Ahbab and Barlas 2013; Lv et al. 2019).

In this study, although non-significant correlations were found between building characteristics (e.g., floor level, age of building, and area of building) and phthalate
esters in the household dust, previous studies found that phthalate esters might accumulate especially high-molecular weights phthalate esters in household dust in the older house since the erosion and abrasion of building materials with time (Bornehag et al. 2005; Shinohara et al. 2019). In addition, the high-rise and large dwelling-size houses have a stronger inhibitory effect on the accumulation of phthalate esters in household dust. The high-rise building causing the pollutants (e.g., heavy metals, polycyclic aromatic hydrocarbons, and phthalate esters) loaded in the particulates would be difficultly resuspended in vertical directions, and large size house enhancing horizontal diffusion space of pollutants, resulting in the decrease of pollutants concentrations in the indoor environment (Bornehag et al. 2005; Hang et al. 2012).

**Human health risks of phthalate esters**

To estimate the risks of phthalate esters exposure in household dust from Chengdu, the average daily doses (ADD, \( \mu g/kg-bw/day \)) of DMP, DEP, DIBP, DBP, BBP, DEHP and DNOP via accidental dust ingestion, inhalation, and dermal absorption pathway were estimated for children and adults (Table 1). The ADDs of phthalate esters for children and adults via accidental dust ingestion were 2–7 orders of magnitude higher than dermal adsorption and dust inhalation, indicating the accidental household dust ingestion was the principal pathway for inhabitant exposure to phthalate esters. The results were consistent with previous reports (Li et al. 2021; Zhu et al. 2019).

Furthermore, the values of HI for all phthalate esters were all below 1 suggesting that no non-carcinogenic risks of phthalate esters in household dust were found for Chengdu inhabitants (Table 1). The HI values of individual phthalate ester in the household dust samples in the decreasing order as follows: DEHP > DBP > DIBP > BBP > DNOP > DEP > DMP (Table 1). The carcinogenic risk for human exposure to phthalate esters was calculated by the lifetime average daily exposure doses (LADD) of the carcinogenic phthalate esters (CR). The values presented in Table 1 are calculated based on the 95% upper confidence limit of phthalate ester concentration in household dust sample (\( \mu g/g \)).

### Table 1. Risk assessment of human exposure to phthalate esters via household dust.

|       | DMP     | DEP     | DIBP     | DBP     | BBP     | DEHP    | DNOP    |
|-------|---------|---------|----------|---------|---------|---------|---------|
| **ADDing**  
Children | 4.68E-04 | 1.03E-03 | 5.69E-02 | 3.42E-01 | 9.39E-03 | 1.83E+00 | 4.30E-03 |
| Adults | 6.24E-05 | 1.37E-04 | 7.58E-03 | 4.56E-02 | 1.25E-03 | 2.44E-01 | 5.73E-04 |
| **ADDinh**  
Children | 4.36E-11 | 9.58E-11 | 5.30E-09 | 3.18E-08 | 8.74E-10 | 1.71E-07 | 4.01E-10 |
| Adults | 3.06E-11 | 6.72E-11 | 3.72E-09 | 2.23E-08 | 6.14E-10 | 1.20E-07 | 2.81E-10 |
| **ADDder**  
Children | 4.37E-06 | 9.60E-06 | 5.31E-04 | 3.19E-03 | 8.76E-05 | 1.71E-02 | 4.01E-05 |
| Adults | 8.30E-07 | 1.82E-06 | 1.01E-04 | 6.06E-04 | 1.66E-05 | 3.25E-03 | 7.63E-06 |
| **HQing**  
Children | 4.68E-08 | 1.29E-06 | 5.69E-04 | 3.42E-03 | 4.69E-05 | 9.16E-02 | 1.08E-05 |
| Adults | 6.24E-09 | 1.71E-07 | 7.58E-05 | 4.56E-04 | 6.26E-06 | 1.22E-02 | 1.43E-06 |
| **HQinh**  
Children | 4.36E-15 | 1.20E-13 | 5.30E-11 | 3.18E-10 | 4.37E-12 | 8.53E-09 | 1.00E-12 |
| Adults | 3.06E-15 | 8.41E-14 | 3.72E-11 | 2.23E-10 | 3.07E-12 | 5.99E-09 | 7.03E-13 |
| **HQder**  
Children | 4.37E-10 | 1.20E-08 | 5.31E-06 | 3.19E-05 | 4.38E-07 | 8.55E-04 | 1.00E-07 |
| Adults | 8.30E-11 | 2.28E-09 | 1.01E-06 | 6.06E-06 | 8.32E-08 | 1.62E-04 | 1.91E-08 |
| **HI**  
Children | 4.72E-08 | 1.30E-06 | 5.74E-04 | 3.45E-03 | 4.74E-05 | 9.25E-02 | 1.09E-05 |
| Adults | 6.32E-09 | 1.74E-07 | 7.68E-05 | 4.62E-04 | 6.34E-06 | 1.24E-02 | 1.45E-06 |
| **LADD** | 9.30E-07 | 1.81E-04 | 3.42E-03 | 1.83E-02 | 2.44E-01 | 6.24E-05 | 1.43E-06 |
| **CR** | 1.77E-09 | 2.54E-06 | 4.30E-03 | 1.83E-02 | 2.44E-01 | 6.24E-05 | 1.43E-06 |

Note, ADDing, ADDinh, and ADDder indicates the average daily dose (\( \mu g/kg-bw/day \)) of individual phthalate esters via accidental dust ingestion, inhalation, and dermal absorption exposure; HQing, HQinh, and HQder suggests hazard quotient of individual phthalate esters by accidental dust ingestion, inhalation, and dermal absorption exposure; HI represents hazard index; LADD denotes the lifetime average daily exposure doses of the carcinogenic phthalate esters; CR is carcinogenic risk; Bold indicates the values above 1 \( \times 10^{-6} \), which might pose health risk to inhabitants.
BBP and DEHP in the household dust was $1.77 \times 10^{-9}$ and $2.54 \times 10^{-6}$, respectively (Table 1), which cancer risk of DEHP was in the range of $10^{-6}$–$10^{-4}$. When calculated based on the median and average concentrations, the carcinogenic risk values are $1.07 \times 10^{-6}$ and $1.92 \times 10^{-6}$, respectively, which were also in the range of $10^{-6}$–$10^{-4}$. Therefore, there might be an acceptable potential carcinogenic risk of DEHP in household dust in Chengdu.

**Conclusions**

This study investigated the concentrations of phthalate esters in household dust from Chengdu. DEHP was the largest proportion of phthalate esters in this study, but its concentrations were 10 to 15 times lower than the results reported in previous studies. Besides DCHP contributed 30.7% to the total phthalate esters in this study, the result was different from previous reports from China. Living habits (smoking, sweeping frequency, window opening habits, and cooking frequency), home decorations (floor cover and wall cover) and other factors such as pets can significantly affect the concentrations of phthalate esters in household dust in Chengdu. Particularly, the inhabitants in Chengdu might face the potential carcinogenic risk of phthalate esters in household dust. Thus, some suggestion to the general population in Chengdu, (1) Smoking less and opening windows frequently to maintain the indoor air circulation; (2) The pet supplies need to be stocked in a fixed place; (3) Increasing the sweeping frequency of indoor environment, especially the older houses.

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**Consent for publication**

The manuscript does not contain any individual person data.

**Disclosure statement**

The authors declare no competing interests.

**Ethics approval and consent to participate**

The manuscript did not contain any reporting studies involving human data.

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Data availability

All data generated or analyzed during this study are included in this published article.

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