한국대기환경학회지 제 25 권 제 5 호
J. KOSAE Vol. 25, No. 5 (2009) pp. 382∼391
Journal of Korean Society for Atmospheric Environment

Occurrence of Phthalates in Indoor Dust from Children's Facilities and Apartments in Seoul

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(Received 20 March 2009, revised 14 August 2009, accepted 5 October 2009)

Abstract

The aim of the study was to assess the levels in typical central borough of phthalate exposure by monitoring children's facilities (19 kindergartens and 21 elementary schools) and households (17 old apartments and 22 new apartments) via sampling indoor floor dust. A vacuum cleaner specifically prepared for sampling dust was attached to a filter of a vacuum cleaner dust collecting container. During the sample preparation process, containers made of glass were used and analysis was performed using GC-MSD. The mean concentration of DEHP was 412 μg/g, DnBP was 24 μg/g, and BBzP was 10 μg/g dust. The indoor characteristics including floor, wall materials, years after construction, water leakage history for the past three years, and ventilation were also examined to categorize phthalate esters from the dust samples. From the flooring and wallpaper materials of kindergartens and elementary schools, DEHP in the dust sample appeared at a statistically significant level ($p<0.05$) when PVC materials were present. DEHP in the indoor dust also increased significantly ($p<0.01$) during the construction period. The daily intake of DEHP measured from indoor dust was 0.08∼19.7 μg/kg/day for children and 0.02∼1.1 μg/kg/day for adults (women). The results clearly revealed that phthalate exposure is greater in children than in adults (women) due to the indoor dust.

Key words : Phthalates, Dust, Indoor characteristics, Children, Adult, Daily intake

1. INTRODUCTION

Phthalates, well-known endocrine disrupters, are used widely as plasticizer in PVC plastics (Heudorf *et al.*, 2007; Becker *et al.*, 2004). Phthalates display variety of applications, such as in floor, wall coverings, building material, pharmaceutical products, lubricants, perfumes, hairsprays, cosmetics, construction materials, paints, and medical devices including blood bags and tubing (Takamitsu *et al.*, 2004; NTP-CERHR, 2000). Various types of phthalates, including as diethylhexyl phthalate (DEHP), Dibutyl phthalate (DnBP) and butylbengyl phthalate (BBzP), are also being used (NTP-CERHR, 2005). Of these types, DEHP is one of the most widespread phthalate plasticizers (Heudorf *et al.*, 2007). DEP is used as a raw material in cosmetics, while DnBP is used in paints, latex adhesives, and PVC (Kavlock *et al.*, 2002). BBzP are used during tile production, carpets, artificial leather (sofa), adhesives, and sealing agents (Kavlock *et al.*, 2002).

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The use of phthalate is gaining increasing attention since phthalate esters have demonstrated adverse effects on liver, kidney, and reproductive system (IARC, 2000). Some phthalates and associated metabolites are predicted to have carcinogenic and teratogenic effects as well (Booker, 2001). The study by Kleinsasser *et al.* (2001) demonstrated the genotoxic effect of DEHP and DnBP on human lymphocytes and mucosal cells. The Environmental Protection Agency (EPA) has classified di(2-ethylhexyl)-phthalate (DEHP) as a probable human carcinogen (IARC, 2000). In addition, phthalates have been identified as important irritants and immunogens causing respiratory syndromes including asthma/rhinitis, late respiratory systemic syndrome, pulmonary disease-anemia syndrome, and irritant reactions (Bardana and Andrach, 1983). Formaldehyde (HCHO) and volatile organic compounds (VOCs) that are representative of indoor contaminants are recognized as probable candidate for the cause of Sick Building Syndrome (Park *et al.*, 2006; Kim, 1993) and Allergic diseases. Previous studies have suspected HCHO, a typical indoor pollutant, or VOCs as the compounds inducing asthma and atopy, but Hutter *et al.* (2006) reported that dust samples contained high concentrations of phthalates (DEHP: 980~3,000 mg/kg) but fairly low HCHO (0.046~0.051 ppm) and TVOCs (360~740 $\mu g/m^3$) concentrations.

The European Union (EU) has banned the use of these substances in children's toys since 1999, and Japan has also adopted the EU regulations. Phthlates including DEPH, di-n-butyl phthalate (DnBP) and n-butyl benzyl (BBzP) phthalate with DEPH are used most extensively throughout the world and their annual production exceed over 200 million tons. Among 240,000 tons of phthalates used in Korea in 2005, DEPH accounted for 74% in the year that the present survey was done. Recently, phthalate substances were detected from the local and imported cosmetics by civil movement organizations in April, 2003, and DEHP was detected in PVC gloves in March, 2005 in Korea. As for the control of phthalate plasticizers, South Korea prohibited the use of six types of phthalates (DEHP, BBP, DnBP, DINP, DIDP, and DNOP) in oral toys of children below three years old (Quality Management and Industrial Product Safety Control Law). Korea also banned DEHP in food containers or packing materials (Food Sanitation Act), but currently no legal measures have been established to directly regulate the endocrine disruptors. Korea has taken the first position in controlling the amount of production and consumption of DEHP since the major concern of phthalate is not its toxicity but rather the volume of use.

The dominant route of phthalates exposure is through ingestion (Kavlock *et al.*, 2002). More specifically, food intake per body weight and inhalation through dust are the major exposure pathways for children (Huber *et al.*, 1996). In contrast, the levels of phthalates in drinking water or ambient air were estimated to be minimal; thus, exposures through these media were negligible (CERHR, 2000; CEPA, 1994). Phthalates exposure through inhalation of indoor dust is quite important since exposure via ambient air is insignificant. Due to the 80% contribution to total phthalates, DEHP, which account for 80% of total phthalates, is clearly the biggest concern as a household dust contaminant (Fromme *et al.*, 2004). According to recent studies, exposure to phthalates by children is far greater than adults, and the relative amount of exposure is higher among children (Koch *et al.*, 2003).

In this study, exposure to phthalate through the indoor dust will be assessed from children's facilities and households in Seoul, Korea. In addition, daily intake calculations will be performed on children and adults (women).

2. MATERIALS AND METHODS

2.1 Target compounds and indoor place

Diethylhexyl phthalate (DEHP), diethyl phthalate (DEP), di-n-butyl phthalate (DnBP), and butyl benzyl phthalate (BBzP), which are used in the greatest volume when producing PVC related products, have been analyzed in this study.

The situation regarding the exposure to phthalates in representative urban borough apartments was investigated. Furthermore, we suspected that those risk groups are most likely exposed to phthalates through PVC items, and additional dust intake caused by playing on the floor (Koch *et al.*, 2004). In order to examine phthalate elements within kindergartens (N=19), elementary schools (N=21) and homes located across the nation, new apartments (N=22) built within the last six months and old apartments (N=17) built more than six years ago have been selected. Dust samples were collected in spring (from March to May) 2005.

The level of phthalate exposure from indoor dust was compared between children and adults (woman). Daily exposure to phthalates from indoor dust was calculated using the mean values of phthalates obtained from the survey results. For this purpose, we assumed that children and adults (woman) were exposed to phthalates in the same space. Since there were no domestic data related with daily exposure to phthalates, the data (Hawley, 1985) from abroad were used. The national body weight data collected in 2004 by the Korean Agency for Technology and Standards under the Ministry of Knowledge Economy were used to set the average weights for children and adult females.

2.2 Sampling and chemical analysis in dust

A vacuum cleaner specifically prepared for sampling dust was used by attaching a filter (Whatman, 125 mm) to the dust collector. In order to avoid any direct exposure to phthalates, filters were stored in a glass dish (130 mm) specially designed for this study. The samples were transferred to the laboratory, and stored at ambient temperature. After measuring the weight of reagent paper and removing no less than 25 mg of dust (Bornehag *et al.*, 2004), the amount of dust prior to examination was weighed. Dust was removed by placing a funnel against a 10 mL vial and sonicating for 30 minutes after sufficiently soaking the dust in 4 mL of dichloromethane (DCM). The sonicated dust was filtered by applying a filter to 10 mL vial. After condensing for 30 minutes (Rotation 4~5, heating at 40~45°C) using an evaporator and filtering with a DCM solution, samples were moved to a vial (1.5 mL) for GC analysis. Samples were packed and stored under a vacuum condition in a freezer after adding 1 mL of methanol. During the sample preparation process, glass containers were used and subsequent analysis by GC-MSD was performed (HP 6890 series, Hewlett Packard, USA).

In order to prepare a standard solution, the glass tube was washed to remove dust. The standard solution was prepared by melting DEHP, DEP, DnBP, and BBzP at 1 mg/mL in methanol and storing at 4°C. The standard material was then diluted at 10, 20, 50, 100, 200, 400, 800, 1,000 μg/mL and stored again at 4°C. A 25-m capillary column (HP 1C; Agilent, Folsom, CA, USA; inner diameter, 0.2 mm; stationary phase, polydimethyl siloxane) was used for the GC analysis. The injector and column temperatures were kept at 280°C and 300°C respectively, in which the column temperature was raised at a rate of 8°C per minute after three minute exposure to 100°C. The analysis was performed for 20 minutes. The initial temperature was maintained at 80°C for five minutes, then raised by 30°C per minute up to 160°C, and then by 15°C per minute up to 320°C. Most sample materials were removed in this temperature range. The materials were analyzed using a total ion chromatogram and measured phthalates, while improving the signal-to-noise ratio (S/N ratio) by programming a selective ion monitoring mode. The limits of detections (LOD) of material were 12.1 μg/g for DEHP, 17.2 μg/g for DEP, 19.2 μg/g for DnBP, and 13.99 μg/g for BBzP.

2.3 Statistical analyses

Statistical calculations were performed with SAS version 9.0. The phthalate concentrations in the dust samples were log-normally distributed (Bornehag *et al.*, 2004). For the comparison of the phthalate concentrations observed in dust, building characteristics were recorded using nonparametric tests (Mann-Whitney-U test, chi-square and Kruskal-Wallis test).

3. RESULTS AND DISCUSSION

3.1 Monitoring of phthalates

Four types of phthalates were analyzed by collecting the indoor dust samples. The study was to assess

Table 1. Concentration of phthalate in indoor dust.

Phthalate dust (μg/g)	Mean	Median	95th percentile	Minimum	Maximum	Std. deviation
DEHP	412	439	804	<LOD	1,053	241
DEP	1	–	–	<LOD	56	6
DnBP	241	143	844	<LOD	924	256
BBzP	105	45	610	<LOD	800	180

DEHP: Diethylhexyl phthalate, DEP: Diethyl phthalate, DnBP: Di-n-butyl phthalate, BBzP: Butyl benzyl phthalate, LOD: Limit of detection

Table 2. Phthalate concentrations (μg/g dust) measured in indoor dust from different buildings.

	Kindergarten (n=19)			Primary school (n=21)			Old Apt (n=17)			Newly built Apt (n=22)		
	Mean	95th	Detection (%)	Mean	95th	Detection (%)	Mean	95th	Detection (%)	Mean	95th	Detection (%)
DEHP	591*	972	100	418	662	95	403	748	94	259	525	82
DEP	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1	–	6	3	–	5
DnBP	216	719	79	181	476	86	226	686	82	233	766	77
BBzP	299	797	37	50	307	24	63	131	88	117**	638	82

*<0,0001, **<0.01 (Kruskal-Wallis test), DEHP: Diethylhexyl phthalate, DEP: Diethyl phthalate, DnBP: Di-n-butyl phthalate, BBzP: Butyl benzyl phthalate, LOD: Limit of detection

Table 3. Comparison of the indoor dust mean concentration of phthalates (μg/g dust).

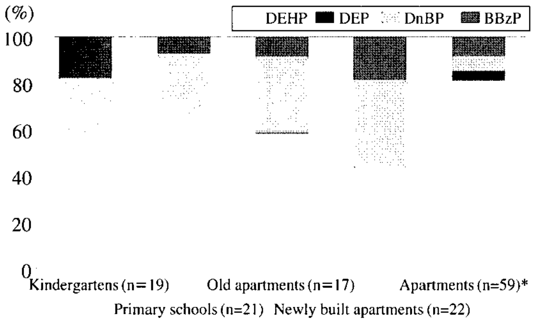
	Butte *et al.* (2001)	Rudel *et al.* (2001)	UBA (2002)	Fromme *et al.* (2004)	This study			
	House (n=286)	House (n=6)	House (n=199)	House (n=30)	Kindergarten (n=19)	Primary school (n=21)	Old Apt (n=17)	New Apt (n=22)
DEHP	740	315	416[a]	776	591	418	403	259
DEP	–	2.2	3.3	45	<LOD	<LOD	1.0	3.0
DnBP	49	27	42	56	216	181	226	233
BBzP	31	117	15	86	299	50	63	117

[a]Median values, DEHP: Diethylhexyl phthalate, DEP: Diethyl phthalate, DnBP: Di-n-butyl phthalate, BBzP: Butyl benzyl phthalate, LOD: Limit of detection

the levels in typical central borough of phthalate exposure by monitoring apartments (old and new) and children's facilities (kindergarten and elementary school) via sampling indoor floor dust. The concentration distribution in all materials except for DEHP appeared to be the highest in kindergartens (n=19) which have expected to provide the largest amount of phthalates exposure as shown by the relative phthalate levels of kindergartens > elementary schools > old apartments > new apartments (Tables 1, 2). In this study, phthalate levels obtained from indoor dust samples were similar to or slightly less compared to previous studies (Table 3).

Bornehag *et al.* (2004) proposed the mean concentration of DEHP as 770 μg/g from dust of children's bedrooms within the general Swedish households. In this study, the distribution ratio of DEHP appeared to be the highest in four indoor spaces.

In the case of DnBP, the measurements from other studies of general households appeared to be similar to the data of old (71 μg/g DBP dust) and new apartments (113 μg/g DnBP dust) of current study. Pohner *et al.* (1997) and Mattulat (2001) have revealed 87 μg/g and 98 μg/g DnBP dust respectively through previous studies. Although DEHP holds the highest distribution ratio in this study, the proportion of DnBP was also somewhat higher compared to the results of other studies. The study by Fromme *et al.*



*Fromme *et al.* (2004)

Fig. 1. Contribution of single phthalates to the total content in indoor dust.

(2004) demonstrated the highest DEHP value by examining phthalate within household dusts. The order of phthalate was also identical to this study, which was DnBP > BBzP (Fig. 1). As for the distribution of phthalates in the household dust, Fromme *et al.* (2004) reported that DEHP accounted for 80% of phthalates. Although DEHP held the highest distribution ratio, the distribution ratio of DnBP was somewhat higher compared to other studies.

The Ministry of Environment announced that it push a bill on limiting the usage of phthalates in Ringer bags, blood bags, containers, and toys and children's products by February 2007. In March, the Ministry of Environment also forced to put regulation on stationary products and arts/crafts materials, on top of toys. However, the bill was not passed due to opposition from the Ministry of Knowledge Economy and related companies. It was instead agreed that related businesses would voluntarily limit the usage. In this study, kindergartens that were expected to have many sources of such exposure demonstrated the highest DnBP density (239 μg/g DnBP dust) as with general households. The results of the present study also showed the highest composition of DnBP. DnBP displays versatile use such as in printer ink, adhesives, sealants, paints, film coating and glass fibers. It is also used in many consumer goods such as cosmetics, perfumes, hairsprays, lubricants, skin toners and nail polishes (CIR, 1985). We are planning to perform additional investigations to determine the reason for such high composition of DnBP by asessing different indoor characteristics.

The concentration of BBzP within the dust was detected at relatively low levels since butyl benzyl phthalate (BBzP), which has low-molecular-weight, is mainly (> 80%) in the gas-phase within the air (Bornehag *et al.*, 2004). Moreover, according to the study by Bornehag *et al.* (2005a), BBzP level in dust is roughly 5 ~ 10 times lower than the DEHP level. Generally, the property of butyl benzyl phthalate (BBzP) allows excellent processing ability and oil-resistance. Although there is no quantitative data, the previous studies on BBzP was resulted from carpets (Bayer *et al.*, 1990), PVC flooring materials (Bremer *et al.*, 1993), and vinyl wallpapers (Etkin, 1995).

DEP, used mainly during cosmetic production, was found to be below the detection limit in kindergartens and elementary schools, but significant in general households (82% of old apartments and 18% of new apartments).

3.2 Associated indoor characteristics

To evaluate the level of phthalates from the dust samples according to indoor characteristics, floor, wall materials, year of construction, water leakage in the past three years, and ventilation have been examined in this study. Old and new apartments were excluded in the evaluation of phthalates by the type of flooring material since PVC was used in all flooring materials. The concentrations of phthalates are represented in Table 4, and categorized by different flooring materials of kindergartens, and elementary schools.

It is expected that phthalates are most likely exposed from products including plasticizers of vinyl wallpapers and flooring materials. Polyvinyl chloride (PVC) within the indoor environment was generally used for floor-covering and wall-covering products (Wensing and Salthammer, 1999). The wall and floor represent a large area within the indoor space and are; therefore, the major sources of phthalate exposure (Salthammer *et al.*, 1993). The content of plasticizer from the wallpaper made of PVC materials is approximately 30%, and di-(2-ethylhexyl) phthalate (DEHP) and di-n-butyl-phthalate (DnBP) are also commonly used. Several researchers have suggested

Table 4. Distribution of building characteristics among concentration (μg/g dust) of phthalates in dust.

Factor		DEHP Mean (n)	p-value	DnBP Mean (n)	p-value	BBzP Mean (n)	p-value
Type of floor	No PVC	423 (17)	0.03	359 (15)	n.s	110	n.s
	PVC	583 (22)*		223 (19)		173	
Type of wall	No vinyl	406 (12)	0.05	266 (11)	n.s	63 (10)	n.s
	Vinyl	561 (27)*		292(23)		180(22)	
PVC flooring *Vinyl/Paint wall	Category1[a]	376* (10)	0.0003	311 (9)	n.s.	56 (10)	n.s.
	Category2[b]	354 (49)		285 (45)		109 (47)	
	Category3[c]	602 (19)		229 (16)		185 (14)	
Construction period	< 2 years	289 (29)	0.001	282 (27)	n.s.	110 (28)	n.s.
	3 ~ 10 year	385 (14)		243 (13)		96 (12)	
	> 10 year	538 (35)**		284 (30)		130 (31)	
Water leakage	No	416 (72)	n.s.	266 (64)	n.s.	117 (66)	n.s.
	Yes	431 (6)		382 (6)		113 (5)	
Ventilation rate	1st quartile	414 (33)	n.s.	293 (32)	n.s.	160 (29)	n.s.
	2nd quartile	461 (23)		288 (17)		66 (21)	
	3rd quartile	376 (22)		239 (21)		107 (21)	

*P < 0.05, Mann-Whitney-U (Wilcoxon Rank-Sum)test, **P < 0.01, ANOVA-test
[a]Category 1: No PVC and vinyl/paint, [b]Category 2: PVC and vinyl/paint wall one use, [c]Category 3: PVC and vinyl/paint wall all use
DEHP: Diethylhexyl phthalate, DnBP: Di-n-butyl phthalate, BBzP: Butyl benzyl phthalate

that, "use of PVC flooring materials can increase the indoor density of phthalates" (Reitzig *et al.*, 1998; Jann *et al.*, 1997; Bortoli *et al.*, 1993; Pleil and Whiton, 1990). From the indoor spaces where vinyl wallpaper was used, a significant amount of phthalates has been detected (Wilkins *et al.*, 1993). According to the study of Saarela *et al.* (1989), DEHP among other phthalates is used for PVC and vinyl chloride resin, and is generally regarded as the main cause of plasticizer exposure in residence. According to the study by Bornehag *et al.* (2005a), the level of phthalates was significant in old buildings that utilized PVC flooring materials and vinyl wallpaper, probably due to old PVC products containing higher levels of DEHP among phthalates.

In this study, significant amounts of DEHP were detected in sites using PVC flooring materials and vinyl wallpaper/paint, as well as from sites constructed since 10 years ago or having a recent history of water leakage. Additionally, DEHP was found to be the major component of phthalate exposed from PVC flooring materials. DEHP was observed at statistically significant levels, while BBzP appeared to increase, though not found in statistically significant levels compared to locations not using PVC flooring materials.

In this study, the levels of DEHP and DnBP were not statistically significant in dust samples with a water leakage history and ventilation rate. Bornehag *et al.* (2005b) suggested that the mean concentration is associated with an elevated BBzP in dust. The association could be the result of degradation of PVC floors by moisture/water and, in some cases, highly basic (high pH) moist concrete surfaces. For example, a higher ventilation rate is associated with an earlier construction period as well as several other building-related factors as described. We believe that no clear evidence was obtained on water leakage during the survey due to the differences in leakage sites and the degree of leakage.

3.3 Daily intake of phthalate

Phthalates exposure by inhalation of indoor dust is important since exposure via air is relatively low. DEHP, which contribute to approximately 80% of total phthalate, is clearly the most concerned contaminant in household dust (Fromme *et al.*, 2004). Considerable exposure to the general population has been a concern since tolerable daily doses have been exceeded (Koch *et al.*, 2003). Therefore, exposure

Table 5. The comparison with per phthalate intake for children and adult (μg/kg/day).

	Children			Adult (Woman)		
	DEHP	DnBP	BBzP	DEHP	DnBP	BBzP
Mean (μg/g)	591	216	299	331	229	90
Ingestion[a] (mg/day)		3 ~ 100			3 ~ 10	
Body weight[b] (kg)		22.65			56.01	
Daily Intake (μg/kg/day)	0.08 ~ 19.70	0.03 ~ 7.20	0.04 ~ 9.97	0.02 ~ 1.10	0.01 ~ 0.76	0.005 ~ 0.30
TDI	37	750	200	37	750	200

[a]Range from Hawley, 1985, [b]Mean from KATS, 2004
DEHP: Diethylhexyl phthalate, DnBP: Di-n-butyl phthalate, BBzP: Butyl benzyl phthalate

to children, which is twice as high as the exposure of adults with respect to their body weight, warrants immediate action (Koch *et al.*, 2004). Fromme *et al.* (2004), also mentioned cases where children were exposed at a higher level compared to the adults, probably because of the children's play habits such as licking hands and crawling or rolling around the floor.

The daily intake of indoor household dust was calculated using the mean value of phthalates obtained by sampling indoor dust. For children, the mean value of kindergartens (19 places), was used, while assuming that the children are most likely to be exposed to dust in kindergarten. For adults (women), the mean value of old and new apartments was used, assuming that the adults (women) are primarily exposed from residential spaces. In this study, all the kindergarten teachers were female, and assumed that women would stay longer in the apartment, making them more susceptible to the exposure of phthalate. Since no domestic data could be found for the daily digestion of dust, a previous literature reference was utilized (Hawley, 1985).

The intake of dust during indoor activities by children of six years old was 3 mg/day and infants of 2.5 years old was 50 mg/day (summer) and 100 mg/day (winter). Similar to the study by Fromme *et al.* (2004), an assumption was made that the adults would take up 1/5 of phthalate compared to children. For the body weight, the value of 22.6 kg was used for male/female children six to seven years old, and 56.0 kg for women 25 ~ 45 years old according to the national body dimensions survey of Korean people (2004) conducted by the Korea Agency for Technology and Standards (KATS). The average weight of participants was 20.7 kg (standard deviation of 3.6 kg) for children, and 52.7 kg (standard deviation of 6.2 kg) for adults (women). The daily intake of DEHP through the indoor dust was 0.08 ~ 19.7 μg/kg/day for children and 0.02 ~ 1.1 μg/kg/day for adults (women). Whereas, the daily intake amount of DnBP was 0.03 ~ 7.20 μg/kg/day and 0.01 ~ 0.76 μg/kg/day for children and adults (women) respectively. Lastly, BBzP demonstrated daily intake amount of 0.04 ~ 9.97 μg/kg/day for children and 0.005 ~ 0.30 μg/kg/day for adults (women). The results suggest that the daily intake of phthalates is higher in children than in adults (women) from all the materials examined (Table 5).

The daily intakes of phthalates were higher in children than adults for all of the materials examined. Fromme *et al.* (2004) reported the daily intakes of DEHP from the indoor dust as 5.97 μg/kg/day for children and 0.11 μg/kg/day for adults and 0.43 μg/kg/day and 0.008 μg/kg/day for children and adults respectively for DnBP. Lastly, the daily intake of BBzP, was 0.66 μg/kg/day for children, and 0.01 μg/kg/day for adults. It is, again, clear from these results that children have higher phthalate intake than adults.

DEHP was ingested through food at a maximal daily intake of 4.9 ~ 18 μg/kg/day (MAFF, 1996), medical tools (maximal daily intake 9.5 μg/kg/day), adults (0.1 mg/kg/day) and children (2.5 mg/kg/day). The US Food and Drug Administration (2001) reported that DEHP was more harmful to children than adults since children are being exposed more often to DEHP. People are exposed most frequently to DEHP through food. Meek and Chan (1994) reported the daily DEHP exposure to be 10 μg/kg/day. Exposure through toys was estimated to be 5.7∼44 μg/kg/day through mouthing activities of children.

Phthalates are exposed to the environment through various media. The study by the NTP Center for US (CERHR, 2000) shows that phthalate levels found in drinking water or air are very low. Nevertheless, according to the current toxicity data, phthalates can have a harmful influence on human health. Exposure can occur through breathing, eating, drinking, and skin contact, and the impact can vary with diverse conditional factors. The conditional factors can change by the amount, duration and frequency of the contact. The impact of phthalates can also differ by age, sex, diet, lifestyle, and health state of people (ATSDR, 2002). Nevertheless for children and adults, exposure to phthalates through food can be an important issue, although this study does not consider the exposure to phthalates through food. Furthermore, non-dietary ingestion, presumably from the dust and children's hand-to-mouth activities, may play a role in potential exposure of phthalates to these young children to the phthalates (Wilson *et al.*, 2001).

It is generally estimated that the total daily intake of DEHP through food products ranges from 0.27 mg/kg/day (3.8 mg/kg/day) to as high as about 2.0 mg/kg/day (30 mg/kg/day) (Huber *et al.*, 1996). In comparison to the ingestion patterns, DEHP exposures through ambient air and drinking water are very small (Huber *et al.*, 1996), which provide an insignificant contribution to the total daily intake to the general population (Doull *et al.*, 1999). The survey on phthalates or DEHP ingestion through oral intake of indoor dust is important for the study of phthalate exposure and accumulation within the human body, particularly in children (Kavlock *et al.*, 2002). Koch *et al.* (2005, 2003) mentioned that 75% of DEHP exposure is by oral intake. Despite several limitations, the concentration of phthalates in the dust of various indoor facilities surveyed in this study was not high compared to those of other countries.

It is expected that further study on phthalates in the indoor dust and air will help to investigate the source of phthalates exposure through consumables and living goods, and monitor their impact on the human body according to the age distribution as well.

4. CONCLUSIONS

Regarding the flooring and wallpaper materials of kindergartens and elementary schools, the DEHP concentration in the dust appeared at statistically significant level ($p < 0.05$) when using PVC materials. The concentration of DEHP in the indoor dust significantly increased ($p < 0.01$) in older buildings with respect to the construction age. As for the daily intake amounts of DEHP, 0.08∼19.70 μg/kg/day for children and 0.02∼1.10 μg/kg/day for adults were observed. The results have clearly revealed that the exposure to phthalate through indoor dust was greater in children compared to the adults.

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