

## ASSESSMENT ON HEALTH RISK OF POLYBROMINATED DIPHENYL ETHERS (PBDES) FOR CHILDRENS IN CHILDCARE-FACILITIES AND INDOOR-PLAYGROUNDS

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### Introduction

PBDEs utilized for the flame retardant effect of various products such as electronic goods and curtains are economical and effective. Their toxicity has been studied since they were detected in human bodies in the 2000s, and they have been recently regulated around the world<sup>1,2</sup>. The products of PBDEs are PentaBDE, OctaBDE and DecaBDE and all of the three types are known to provoke hepatic toxicity, endocrine disorder, neurodevelopmental disorder and development and reproductive disorder<sup>3</sup>. According to 『Enforcement Ordinance of Act on Installation and Maintenance of Fire Fighting System and Safety Management (Presidential Decree No. 19488)』 (revised on 30 May 2006) of Korean Ministry of Gender Equality & Family about flame retardant products in childcare-facilities, products with over standard flame resistant performance should be installed in childcare-facilities to 30 May 2007.

It has been reported that children take more dust incidentally than adults and they can be exposed to PBDEs through incidental dust ingestion as a primary route<sup>4,5</sup>. However, studies on PBDEs and their risk in activity places for children have been rarely conducted in South Korea. This study aims to investigate exposure pathway of PBDEs as Endocrine Disrupting Chemicals (EDCs) from products in representative major activity places for childcare-facilities and indoor-playgrounds and to determine their total risk through multiple route exposure by using Health Risk Assessment (HRA).

### Materials and methods

We investigated the childcare-facilities (20 play-rooms, 20 day-care centers, 20 kindergartens) and 20 indoor-playgrounds, which located in three cities around the nation (Seoul, Busan and Yeosu). A primary survey was conducted to recruit the facilities and to measure the indoor environment for three months from July to September 2007 in summer, and a secondary survey was done to assess the exposure two times by facilities from January to February, 2008 in winter. We measured PBDEs (TeBDE, PeBDE, HxBDE and DeBDE) in indoor air, house dust, surface wipe of interior products and toys, and hand wipe of children in the childcare-facilities and indoor-playgrounds. We examine into details the use of facility, time activity patterns and exposure characteristics of children by interview of managers (teacher, leader, supervisor, etc.) for facility, questionnaire, and video recording about 1 hour playing time in the facility for 16 children.

The all samples were performed extraction, clean-up and fractionation process. The quantitative assessment was analyzed by high-resolution gas chromatography and high-resolution mass spectrometry (HRGC-HRMS) according to the US EPA 1614 method<sup>6</sup>. The School of Environmental Engineering, Pohang University, conducted the instrumental analysis and the Fisheries & Oceans Laboratory of Canada collaborated with our teams in the quality assurance/quality control (QA/QC) program.

Average daily exposed dose (ADD), hazard quotients (HQs) and hazard index (HI) of PBDEs for children through multimedia and multiroute exposure scenarios in the facilities were calculated by the US EPA formula<sup>7</sup>. We assumed the four exposure scenarios including inhalation of indoor air, ingestion of house dust, ingestion by hand-to-mouth for toys, and dermal contact by the interior products and toys to four age group (first 2 years old, 2-4 years old, 5-6 years old, and 7-9 years old). The exposure factors for play patterns were used survey data in this study, and other exposure factors were cited the 'Korea Exposure Factors Handbook<sup>8</sup> and the "Child-specific

exposure factor handbook<sup>9</sup>. RfDs (Reference doses) of 4 PBDEs were cited the IRIS (Integrated risk information system) database<sup>10</sup>.

### Results and discussion:

The all samples were detected PBDEs and the average levels of PBDEs in indoor air was the highest in indoor-playground(1,440.33pg/m<sup>3</sup>), and kindergartens (1,021.00 pg/m<sup>3</sup>)> day-care centers(789.21 pg/m<sup>3</sup>)> play rooms (366.80 pg/m<sup>3</sup>) followed it. The PBDEs levels in the house dust were ranged from 561 to 32,830 ng/g. When wipe samples of representative items in childcare-facilities such as TV, mats, computers and monitors were analyzed, it recorded ND~2070.55 pg/m<sup>2</sup>. The PBDEs levels on hand wipe samples found that it ranged from 0.12 to 453.41 pg/m<sup>2</sup> and it was the highest in indoor-playgrounds by recording 387.56 pg/m<sup>2</sup> (Table 1). The results of the current study were slightly lower than levels in the USA<sup>11-12</sup>. Out of the eight isomers the concentration of BDE-209 accounted for over 90% of the total one and that was similar with the finding of previous studies. Leisa-Maree et al.<sup>13</sup> also revealed that BDE-209 was detected most largely. Stapleton and Dodder<sup>14</sup> recently reported evidence of photodegradation of BDE 209 in house dust under controlled exposure to sunlight. The detection rates of BDE-28 and others were 35% and 100%, respectively.

Average daily exposure dose and HI for non-carcinogenic toxicity of PBDEs was calculated by considering physiological and ethological characteristics of children in the facilities (Table 2). There was no facility with HI of over 0.1 and 50 percentile (median) values of HI were 0.0007, 0.001, 0.0004, and <0.0001 in play-rooms, day-care centers, kindergartens and indoor-playgrounds, respectively, and 95 percentile values of HI were 0.003, 0.01, 0.002 and 0.002, respectively. The percentage of intake dose via ingestion and mouthing of house dust, interior products, and toys to the average daily exposure dose of PBDEs were 71.4~96.1% and the percentage of uptake dose via inhalation to the average daily exposure dose of PBDEs in indoor air were 3.7~28.2% (Figure 1). Because PBDEs were detected continuously on all routes (indoor air, dust, surface wipe and hand wipe), the existence of the pollutants was confirmed clearly. When the risk of PBDEs was assessed by reflecting exposure patterns based on contamination by activity spaces, there was no facility exceeding 1.0 of non-carcinogenic risk. However, the risk of play rooms and day-care centers was relatively high. That is considered to be because the facilities are used mainly by sensitive age groups aged 0.5(6 months)~2 years for a long time (6~10 hours), exposure patterns (sucking, rolling and dust ingestion) are various and many toys and education materials work as indoor pollutants.

Although their risk was not high in facilities for children like childcare-facilities, kindergartens and indoor-playgrounds, continuous effects of monitoring the indoor environment through multiple exposures and studying the correlation between accumulation through multi-route of exposure and diseases are necessary in terms of prevention.

### Acknowledgements:

This Study was a part of project supported by Korean Ministry of Environment (Environmental Health Policy Division Office of Environmental Health), "Risk Assessment in Facilities for Child" ('07~'08) and we appreciate the support.

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Table 1. Concentrations of the PBDEs in the children's facilities

Sites	Compounds	Indoor air(pg/m <sup>3</sup> )		Floor Dust(ng/g)		Product surface(pg/cm <sup>2</sup> )		Hand surface(pg/cm <sup>2</sup> )				
		n	Mean	Range	n	Mean	Range	n	Mean	Range		
Play-room	pentaBDE											
	BDE28		8.75	1.36–24.96		18.60	<LOD~55.81	0.46	<LOD~1.40	0.04	<LOD~0.19	
	BDE47		220.34	<LOD~1111.6		45.21	5.79~118.03	17.29	<LOD~62.89	<LOD	-	
	BDE99		76.08	<LOD~387.5		23.73	8.59~50.91	11.40	<LOD~31.02	<LOD	-	
	BDE100		32.52	<LOD~163.9		3.48	1.38~6.35	2.26	<LOD~8.24	<LOD	-	
	BDE153		1.92	<LOD~7.47		26.87	17.30~44.30	1.71	<LOD~10.23	0.86	<LOD~4.31	
	BDE154		2.93	<LOD~13.99		5.58	2.93~10.07	0.76	<LOD~3.39	0.14	0.08~0.19	
	octaBDE											
	BDE183		1.36	<LOD~6.61		125.96	105.21~165.94	4.46	0.07~29.93	5.90	0.29~25.09	
	decaBDE											
BDE209		22.90	<LOD~84.92		1307.15	705.36~2328.69	185.6	3.97~1153.56	28.25	22.68~42.02		
Total PBDEs	20	366.80	6.87~1793.98	6	1556.59	861.06~2780.12	6	224.0	4.07~1206.38	6	35.20	23.08~52.26
Day-care center	pentaBDE											
	BDE28		12.66	0.47~66.58		0.82	<LOD~2.93	0.01	<LOD~0.03	<LOD	-	
	BDE47		427.23	1.25~3374.10		77.03	5.82~260.10	1.65	<LOD~5.29	<LOD	-	
	BDE99		159.42	0.95~1425.99		100.64	7.35~342.63	2.50	<LOD~7.94	<LOD	-	
	BDE100		64.43	0.2~578.54		17.81	1.19~61.62	0.41	<LOD~1.26	<LOD	-	
	BDE153		1.05	<LOD~5.17		31.52	3.01~98.49	2.94	<LOD~13.48	0.20	<LOD~0.81	
	BDE154		4.46	<LOD~35.17		18.37	1.02~63.97	0.39	0.04~1.12	0.11	<LOD~0.24	
	octaBDE											
	BDE183		1.85	<LOD~10.94		345.63	13.71~1177.25	24.31	0.11~119.15	3.36	0.28~12.02	
	decaBDE											
BDE209		118.11	4.99~5490.78		7742.29	525.44~26607.30	566.2	4.40~1936.81	26.70	11.43~44.06		
Total PBDEs	20	789.21		6	8334.11	560.95~28614.29	6	598.4	5.07~2070.55	6	30.37	12.31~57.12
Kinder-garten	pentaBDE			0.33~77.12								
	BDE28		8.03	<LOD~4818.8		<LOD	-	0.02	<LOD~0.13	<LOD	-	
	BDE47		278.85	<LOD~1593.71		7.13	2.85~13.82	1.03	<LOD~6.17	<LOD	-	
	BDE99		87.78	<LOD~667.54		8.79	4.93~13.59	0.95	<LOD~5.70	0.45	<LOD~2.25	
	BDE100		35.56	<LOD~29.78		1.79	0.78~3.48	0.18	<LOD~1.10	0.08	<LOD~0.38	
	BDE153		2.52	<LOD~63.79		43.25	7.25~68.58	0.11	<LOD~0.66	<LOD	-	
	BDE154		3.70			6.54	1.31~10.40	0.08	<LOD~0.37	0.08	<LOD~0.20	
	octaBDE											
	BDE183		3.08	<LOD~15.33		259.45	37.14~409.37	0.55	<LOD~2.36	0.19	<LOD~0.41	
	decaBDE											
BDE209		601.49	<LOD~11727.8		5831.09	1899.10~12102.8	61.31	<LOD~259.3	16.36	0.12~27.76		
Total PBDEs	20	1021.00	4.50~12000.88	6	6158.03	1953.35~12604.8	6	64.23	<LOD~275.8	6	17.15	0.12~30.35
Indoor play ground	pentaBDE											
	BDE28		16.31	0.85~59.99		26.15	<LOD~58.30	0.01	<LOD~0.03	<LOD	-	
	BDE47		590.06	<LOD~4530.78		103.57	3.25~209.88	0.28	<LOD~1.39	<LOD	-	
	BDE99		294.40	0.58~1962.86		48.52	6.62~96.43	0.52	<LOD~1.90	<LOD	-	
	BDE100		95.69	<LOD~729.57		5.09	1.00~15.17	0.06	<LOD~0.28	<LOD	-	
	BDE153		7.31	0.10~30.30		43.05	8.39~83.72	0.21	<LOD~0.83	0.14	<LOD~0.27	
	BDE154		10.80	0.07~81.03		14.32	1.75~34.90	0.11	0.04~0.31	0.09	<LOD~0.13	
	octaBDE											
	BDE183		10.38	0.21~122.97		331.58	40.75~628.4	0.99	0.13~3.25	1.66	1.13~3.20	
	decaBDE											
BDE209		415.38	9.12~3574.28		16329.6	912.27~31757.0	93.12	35.20~203.88	385.67	27.20~456.12		
Total PBDEs	20	1440.33	23.44~7510.77	6	16901.9	974.03~32835.8	6	95.29	35.58~208.29	6	387.56	273.42~453.41

Table 2. Exposure factors of children by video observation

Site	Factor	Age groups (years)	Activity Type	Exposure routes	Specificity
Play-room		0.5-2	Sitting/lying	Inhalation, Dermal(object), Ingestion(dust, hand)	Mean time spent 5~10hrs/day (frequency of activity time 2~7)
		2	Sitting/lying/ Standing/ Walking	Inhalation, Dermal(object), Ingestion(dust, hand)	Mean time spent 5~10hrs/day (frequency of activity time 5~7) * sleeping/meal time average time 3
Day-care center		3-4	Sitting/lying/ Standing/ Walking/Running	Inhalation, Dermal(object), Ingestion(dust, hand)	Mean time spent 5~10hrs/day (frequency of activity time 5~7) * sleeping/meal time average time 3
		5	Sitting/lying Standing/ Walking/Running	Inhalation, Dermal(object), Ingestion(dust, hand)	
Kindergarten		6-7	Sitting/lying Standing/ Walking/Running	Inhalation, Dermal(object), Ingestion(dust, hand)	Mean time spent 5hrs/day *except sleeping
Indoor-playground (Charged)		3-4	Sitting/lying Standing/ Walking, Running/Wallow	Inhalation, Dermal(object), Ingestion(dust, hand)	Weekday time spent 1~2time/wk
		5-9	Sitting/lying Standing/ Walking, Running/Wallow	Inhalation, Dermal(object), Ingestion(dust, hand)	Weekday time spent 1~2time/wk, except exposure hand-to-mouth

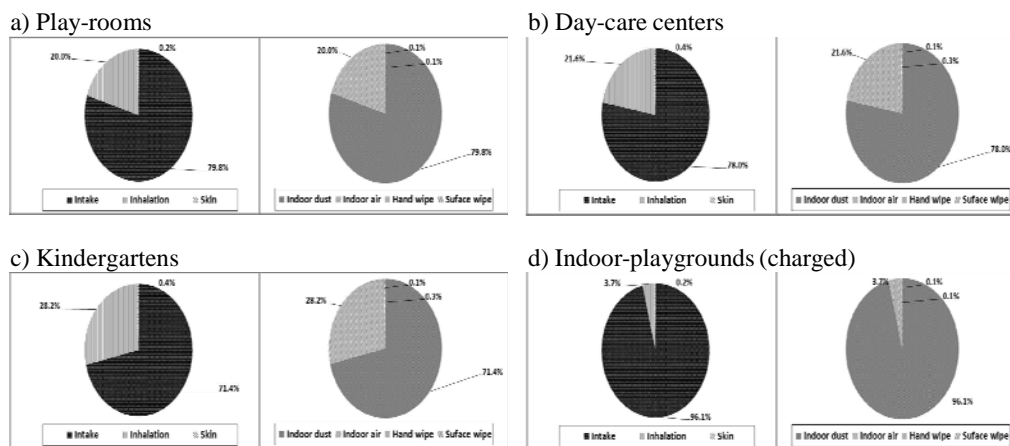


Figure 1. Contribution rates of exposure route and media to children's daily exposure dose of PBDEs.