Concentrations of PBDEs in indoor air of daycare facilities and elementary schools

Song-Yee Baek[1], Mingliang Fang[1], Yoon-Seok Chang[1]
[1] School of Environmental Science & Engineering, POSTECH, San 31, Hyoja-dong, Namgu, Pohang, Kyungbuk 790-784, South Korea

Introduction

Polybrominated diphenyl ethers (PBDEs) are one of the most widely used brominated flame retardants (BFRs) in the world. PBDEs have been widely used for decades as flame retardants in products such as textiles, carpet padding, polyurethane foam in furniture, and plastics of electrical household appliances such as TV housing and computer cases.

Many researchers pointed out indoor environments represent the most important potential for total exposure. Furthermore, it has been clearly reported that indoor environments usually have higher concentrations of halogenated compounds than outdoor environments (Takigami, 2009, Harrad, 2006, Hwang, 2008).

Their different types of behaviors—for example more hand-to-mouth exposures—also put them at greater risk than adults (Stapleton, 2008). In Korea, many children (0- to 5- year-old children) are committed to daycare facilities such as nursery school, preschool, and kindergarten, indoor playground. And 6- to11- year-old children spent their time in elementary schools. However, scant data exist on the exposure of children to PBDEs in daycare centers and schools where children spend considerable amount of time. In order to evaluate exposure to children from indoor environment, we collected indoor air samples using high volume samplers from 41 daycare facilities and 15 elementary schools during summer and winter seasons.

Materials and Methods

Sampling

The air samples from 41 daycare centers and 15 elementary schools were collected in during summer and winter of 2007 and 2008, respectively. A HVS (HV-1000F, SIBATA) having 2 polyurethane foam (PUF) plugs in series and 1 glass fiber filter (GFF) was used for indoor air sampling. The air sampling rate (L/min) and duration (h) were adjusted on the basis of the size of the rooms, which mitigated the dilution effects. The HVS set was placed as far from windows or doors as possible, which were kept closed during the sampling.

Cleanup and analysis

Air samples (PUF plugs and GFF) were extracted in DCM using a Soxhlet extractor for more than 20 h. For each batch of 10 air samples, one field blank was performed. ^{13}C-internal standard of PBDEs (^{13}C-BDE-28, -47, -99, -100, -153, -154, -183) were spiked into the sample prior to extraction. Then, a multi-layer silica column (from top to bottom: sodium sulfate, 2 g silica, 8 g sulfuric silica with 44% of H2SO4, 2 g silica, 4 g basic silica with 30% NaOH, 2 g silica, and sodium sulfate) and a gel permeation chromatography (GPC) column (6 g pre-dipped S-X3 biobead was used in each column) were used. ^{13}C-BDE 139 was then added as a recovery standard before instrumental analysis. 7 PBDE congeners (BDE-28, -47, -99, -100, -153, -154, -183) were analyzed using a gas chromatography (Hewlett-Packard 6890)/high-resolution mass spectrometry (Jeol JMS-700T) (GC/HRMS). The

HRMS was performed in the positive electron ionization (EI) mode, and data were acquired in the selected ion monitoring (SIM) mode operating at >10,000 resolutions with a DB-5HT column (15 m * 0.25 mm * 0.1 μm).

Results and Discussion

The concentrations $\sum_7$PBDEs in daycare centers of the summer ranged from 10.1 to 7,260 pg/m^3, this were approximately ten-to hundred-fold of the outdoor concentrations ($\sum_7$ PBDEs = 13.9–18.5 pg/m^3 , summer, n=8), whereas those of the winter ranged from 4.48 to 1,140 pg/m^3.

In case of school, $\sum_7$PBDEs were ND - 1,440 and 0.25 - 376 pg/m^3 for summer and winter, respectively.

Daycare centers have somewhat similar environment with home, while classroom of elementary school is quite simple; only some desk-and-chair sets, some lockers, a TV, and a computer are present in normal classrooms. Although there were considerably less PBDE-treated products in classrooms than those in homes or offices, relatively high levels of PBDEs were detected in classrooms. This may have been partially a result of the personal cloud effect (Allen, 2007), which implies that the resuspension of dust by human activity increases the PBDE concentrations in air.

According to the season, PBDE levels in indoor air were considerably different, which may be affected by indoor temperature (average temp. summer: 27°C, winter: 17°C). During summer season, the concentrations of low brominated congeners, especially BDE-47, BDE-99, and BDE-100, dramatically increased. The concentration ratio of each congener between summer and winter represented Table 1 and Table 2.

In conclusion, PBDE concentrations for air in daycare centers and classrooms varied with wide ranges, which were at similar levels as those of residential environments and offices. Hence, indoor environments of daycare centers and schools can be considered as important sources of potential exposure to children.

Table 1. PBDE concentrations (pg/m^3) in indoor air of daycare centers

	Summer (n = 41)			Winter (n = 41)			Ratio (S/W)	
pg/m^3	range	average	median	range	average	median	average-based	median-based
BDE 28	2.78-90.0	20.1	8.10	0.33-64.0	5.36	2.89	3.8	2.8
BDE 47	2.04-4820	816	88.4	0.78-592	40.7	10.3	20.0	8.6
BDE 100	ND-690	111	4.98	ND-111	6.01	0.81	18.5	6.1
BDE 99	0.90-1600	278	13.6	ND-384	19.4	3.40	14.3	4.0
BDE 154	ND-63.8	8.90	0.79	ND-19.8	1.26	0.43	7.1	1.8
BDE 153	ND-38.5	4.53	1.11	ND-17.2	1.63	0.84	2.8	1.3
BDE 183	ND-123	5.07	0.54	ND-13.2	2.79	0.80	1.8	0.7
SUM	10.1-7260	1240	120	4.48-1140	77.2	22.9	16.1	5.2

ND: <LOD, Ratio (S/W): ratio of concentrations between summer and winter

Table 2. PBDE concentrations (pg/m^3) in classroom air of elementary schools

	Summer (n = 15)			Winter (n = 15)			Ratio (S/W)	
pg/m^3	range	average	median	range	average	median	average-based	median-based
BDE 28	ND-17.0	5.72	3.73	ND - 4.20	0.92	0.39	6.2	9.6
BDE 47	ND-814	218	21.1	ND - 57.7	7.48	ND	29.1	-
BDE 100	ND-254	44.3	0.81	ND - 18.9	2.32	ND	19.1	-
BDE 99	ND-343	67.3	5.98	ND - 86.3	10.0	0.6	6.7	9.7
BDE 154	ND-10.1	3.14	2.75	0.022 - 10.3	1.85	0.63	1.7	4.3
BDE 153	ND-30.4	4.49	2.48	ND - 58.5	6.68	1.09	0.7	2.3
BDE 183	ND-160	17.3	1.01	ND - 307	33.5	0.8	0.5	1.3
SUM	ND-1440	360	223	0.25 - 376	62.8	10.5	5.7	21.2

Acknowledgement

This study was supported by Brain Korea 21.

References

Allen, J.G., Mcclean, M.D., Stapleton, H.M., Nelson, J.W. and Webster, T.F. 2007. Environ. Sci. Technol. 41:4574

Harrad, S., Hazrati, S. and Ibarra, C. 2006. Environ. Sci. Technol. 40:4633

Hwang, H.M., Park, E.K., Young, T.M. and Hammock, B.D. 2008. Sci. Total Environ. 404:26

Stapleton, H.M., Kelly, S.M., Allen, J.G., Mcclean, M.D. and Webster, T.F. 2008. Environ. Sci. Technol. 42:3329

Takigami, H., Suzuki, G., Hirai, Y. and Sakai, S.-I. 2009. Chemosphere 76: 270