Polychlorinated Dibenzo-p-Dioxins, Furans (PCDD/Fs) and Biphenyls (PCBs), and Polybrominated Diphenyl Ethers (PBDEs) in House Dust

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Introduction

Studies have shown that for individuals, especially children and other sensitive subpopulations, the home environment can be a source of exposure to heavy metals and organic chemicals. Although outdoor contamination by persistent organic chemicals such as polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), polybrominated dibenzo-p-dioxins and dibenzofurans (PBDD/Fs), and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) has been studied extensively, the occurrence and extent of indoor contamination and its significance in terms of overall human exposure has not been investigated until recently.

In this study, the concentrations of PCDD/Fs, PCBs, and PBDEs were measured in house dust collected by air conditioner filters and vacuum cleaners used in residential houses from locations in Wellington, New Zealand and in Michigan, northern California (i.e., Sacramento and San Francisco), North Carolina, and Washington in the U.S. The results were used in a screening-level exposure analysis to calculate theoretical uptake of PCDD/Fs, PCBs, and PBDEs by adults and children from house dust.

Materials and Methods

House Dust Sampling Method

House dust samples were collected and analyzed from (1) air conditioner filters and (2) floors using vacuum cleaners. In-use air conditioner filters were collected from one business and two residential houses in northern California. For each filter sample, dust was scraped off the filter and material transferred to amber glass jars sealed with Teflon lids prior to testing. In 11 of 15 houses, house dust was collected from the collection bag on standard household vacuum cleaners. In 4 of 15 houses, a High Volume Small Surface Sampler (HVS3) cyclone vacuum described in ASTM Method D-5438-00[1] was used as described by Roberts et al.[2,3]. The HVS[3] is capable of capturing 99.95% of particles above 0.3 um aerodynamic mean diameter.

Chemical Testing Method

Chemical testing was performed by Alta Analytical Laboratories (El Dorado Hills, California, USA) using a modification of U.S. EPA Method 1614 for PBDEs and Method 8290 for PCDD/Fs and PCBs. House dust samples were analyzed for 17 PBDEs (BDE-3, BDE-7, BDE-15, BDE-17, BDE-28/33, BDE-47, BDE-66, BDE-77, BDE-85, BDE-99, BDE-100, BDE-138, BDE-153, BDE-154, BDE-183, BDE-207 and BDE-209) and mono through nona homologues. In addition, house dust samples were analyzed for 17 2,3,7,8-substituted PCDD/Fs and tetra through hepta homologues, and 209 PCB congeners.

The quantification of PCDD/Fs, PCBs, and PBDEs was performed by selective ion recording using an AutoSpec Ultima high resolution gas chromatograph/high resolution mass (HRGC/HRMS) spectrometer. A laboratory method blank and ongoing precision and recovery sample were extracted and analyzed along with the dust samples. The recoveries of the internal standards were greater than approximately 85% in all samples. All results are reported in nanograms per gram (ng/g) dry weight.

Risk Assessment

A screening-level exposure calculation was used to determine the theoretical daily uptake of PCDDs, PCBs, and PBDEs from house dust in residential houses by adults and children. The exposure equation and parameters in the equation describing average body weight, skin surface area, dust ingestion rates, and other physiological parameters for different children age groups and adults were based on U.S. EPA guidance[4]. Health risks were calculated and compared to U.S. EPA cancer and non-cancer health benchmarks. For PCDD/Fs and PCBs, theoretical cancer risks were calculated using World Health Organization[5] toxicity equivalency factors (TEFs) for mammals to calculate 2,3,7,8-dioxin toxicity equivalency quotients (TEQs). Carcinogenicity was not included as a health endpoint for PBDEs. Exposure results were compared to 3 alternate non-cancer health endpoints for PBDEs developed by Wenning et al.[6] for the commercial pentaBDE mixture, including changes in thyroid hormone (3,3',5,5'-tetraiodothyronine, or T_4) homeostasis, changes in maternal or fetal body weight, and induction of thyroid hyperplasia.

Results and Discussion

The results of this study indicate that exposure to house dust may contribute to the human body burden of PCDD/Fs, PCBs, and PBDEs (Figures 1 & 2). However, exposure appears likely to represent a small fraction of total human intake of these compounds (Table 1).

Additional work, however, is clearly needed to better understand the significance of the house dust ingestion exposure pathway relative to intake from foods and other potential environmental sources. For example, Hays et al.[7] question whether current estimates and assumptions regarding the amount of house dust ingested by adults and children on a daily basis are correct. It is generally assumed for screening purposes that individuals ingest, on average, approximately one-half of the amount of outdoor soil assumed to ingested every day (200 g/day for children and 50 g/day for adults[4]). Ruby et al.[8] and others further suggest that current estimates of the average daily intake of outdoor soil, as well as indoor house dust, are exaggerated.

Based on the results of this study, decaBDE, as well as lower brominated PBDEs (e.g., tetraBDEs and pentaBDEs), are likely ubiquitous at low levels in residential houses and businesses. The results from this study, with the exception of the single high result for dust from the one business air conditioner filter, compare well to the range found in 17 house dust samples from Stapleton et al.[9], which was 780 to 29,700 ng/g dry weight.

Figure 1. Relative distribution of PBDEs in house dust collected from air conditioner (AC) filters and vacuum cleaners from U.S. houses and businesses.

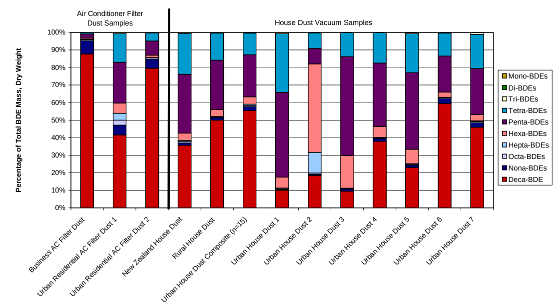

Figure 2. Concentrations of PCDD/Fs and PCBs in house dust from residential houses located in urban and rural environments in Northern California.

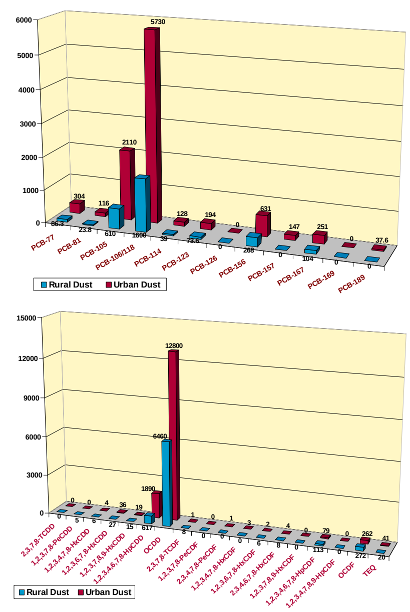

Table 1. Results of the screening-level calculation of theoretical daily intake of PCDD/Fs, PCBs, and PBDEs from house dust in residential houses.

Chemical and Receptor	ADD (mg/kg-day)	Alternative Health Benchmarks		U.S. EPA Benchmarks	
		Benchmark (mg/kg-day)	Hazard Index	RfD (mg/kg-day)	Hazard Index
Dioxin TEQ, Child	4×10^{-10}	--	--	1×10^{-8}	0.04
Dioxin TEQ, Adult	2×10^{-11}	--	--	1×10^{-8}	0.002
DecaBDE, Child	5×10^{-5}	4	0.00001	0.01	0.005
DecaBDE, Adult	3×10^{-6}	4	0.000001	0.01	0.0003
Mono-NonaBDEs, Child	4×10^{-5}	0.04	0.001	0.002	0.02
Mono-NonaBDEs, Adult	2×10^{-6}	0.04	0.00005	0.002	0.001

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This research was funded by: ALTA ENVIRON www.environcorp.com

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