Non-dietary Human Exposure to Polybrominated Diphenyl Ethers in Kuwait

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Introduction

Chemicals are usually added to a wide range of household items during their manufacture to perform various desirable functions. Some of the chemical additives are can escape from the products to which they are added during normal use, or through wear and tear, and contaminate the indoor environment. It is becoming increasingly clear that some of these additives have inherent toxicity and persist in the indoor environment where degradation rates are very slow [1]. This coupled with limited ventilation, leads to a build-up of pollutants indoors.

Polybrominateddiphenyl ethers (PBDEs) are one such class of chemicals. They have been added to a wide range of consumer products, including electrical component, household appliances, furniture, textiles etc for their flame retandant properties [2]. These chemicals were manufactured at three degrees of bromination as technical formulations; i.e., penta-, octa-, and deca-PBDE [2]. The Penta-product is added principally to polyurethane foams that are used in household furniture, and also used in carpet underlay and on bedding. The deca-product is used primarily in textiles and denser plastics such as housings for a range of electrical products particularly TV sets and computers. The octa-product, a mixture of different homologues, is used primarily in plastics. PBDEs have a high potential to leach out of the polymers to which they are added since they are not covalently bonded into the fabric of the polymers. House dust acts as a sink and repository for semivolatile organic compounds [3]. Non-dietary exposure to chemicals in the indoor environment occurs via two principal routes, inhalation and dust ingestion.

In this study, we used polyurethane foam (PUF) based passive samplers to measure the concentrations of PBDEs in 17 homes. Together with dust measurements, the objective of this study was to assess the implications for human non-dietary exposure to these compounds in Kuwait. Passive samplers have become increasingly popular for monitoring organic contaminants in the environment [4]. When properly calibrated, they are as accurate as active sampling devices and it obviates the need for expensive and sometimes cumbersome, and noisy active sampling equipment. Passive samplers are non-invasive which makes them attractive for indoor air measurements.

Materials and Methods

The passive air samplers used in this study consists of a PUF disk housed in stainless steel containers. The sampler has been described in detail previously [5]. The samplers were concurrently deployed in 17 homes in Kuwait over six weeks, between 29th February and 11th April 2004. Participants were advised to install the samplers in a frequently used room of the home, such as the living room or the family room.

Dust samples were obtained from vacuum cleaning bags in regular use for the purpose of cleaning homes. The vacuum cleaners deployed in this study were of different makes and models. The residents were provided with new bags for use during the duration of the passive sampling campaign. They were instructed to continue cleaning their homes as normal over the six week study period. At the end of the sampling period the bags were sealed and returned to our laboratory for processing.

Dust, and PUF disk samples were extracted in a Soxhlet apparatus using 1:1 v/v mixture of acetone:hexane. The clean-up process are similar to those reported by Wilford et al.(2004)[4]. Sample extracts were analyzed with an Agilent 6890N gas chromatograph using splitless injection on a 30 m HP5-ms column (0.25 mm i.d., 0.25 mm film thickness) and helium as carrier gas. This was coupled to an Agilent 5973 inert mass selective detector, operated in NCI mode (using selected ion monitoring), with methane as reagent gas. The ions m/z 79 and 81 were monitored for PBDEs, and 402/404 for Mirex (which was used as the internal standard for quantitation).

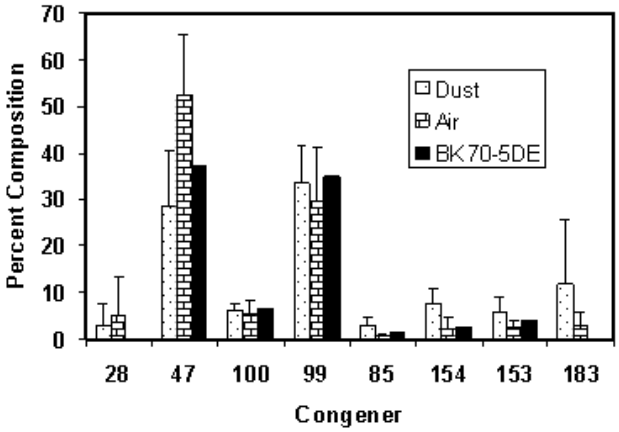
Results and Discussion

The amounts of PBDEs sequestered in the sampling medium over the deployment period was converted to

approximate air concentrations using a sampling rate of 2.5 m^3 air per day. This sampling rate is derived from an indoor calibration study against an active sampler [4]. The sampling rate has been shown to be linear for compounds, like PBDEs, with K_{OA} larger than $10^{8.5}$ for the first 100 days [5].

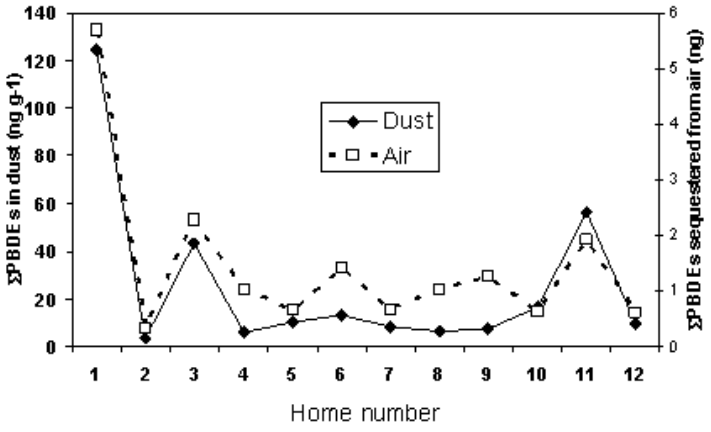
PBDE concentrations in air were log-normally distributed with concentrations ranging from 2.5 - 385 pg m^{-3}, and a geometric mean of 10 pg m^{-3}. BDE 47 was the most abundant congener representing, on average, 51 % of the total PBDE concentration measured. The next most abundant congener, BDE-99, represented about 28% of the S_8PBDE.

Figure 1. The congener composition expressed as percent of the ΣPBDEs, compared to the composition in a penta technical mixture (Bromkal 70-5DE) [6].



The SPBDE concentrations measured in house dust during this campaign varied over 3 orders of magnitude, from 0.2 – 124 ng g^{-1} (geometric mean, 9 ng g^{-1}) and are log-normally distribution as is the case for air samples. The congener distribution in dust and air resembled that in the penta technical mixture (Figure 1) (Bromkal 70-5DE)[6]. Although the concentration of SPBDEs in air tracked the measured concentration in dust collected from the same homes (Figure 2), the correlation between the two was not apparent.

Figure 2. Graph of ΣPBDEs in house dust and air from the same homes showing air concentrations tracking dust concentrations



Compared with PBDE levels in indoor dust reported from the United States [7], Germany [8], and the United Kingdom [9], PBDE level reported here are very low. The most abundant congener in all these studies, BDE 209, has not been analyzed in the samples because we did not have the standards and appropriate analytical column. The samples are currently being analysed for BDE 209 and it is our view that the current estimates underestimate the true exposure values in this manuscript.

Implications for Non-dietary Exposure.

Concentrations in dust and air were used to estimate human exposure to PBDEs from non-dietary sources using the following algorithm:

$$SExposure = C_h F_h R_r + C_d R_i$$

Where *SExposure* is the daily human non-dietary exposure (pg person^{-1} day^{-1}); C_h, is the SPBDE concentration (pg m^{-3}); C_d is the concentration in dust; R_r is the mean respiration rate (m^3 day^{-1}); and R_i is the amount of dust ingested (g day^{-1}). A respiration rate of 8.3 m^3 day^{-1} and 20 m^3 day^{-1} for children and adults respectively, were used in the calculations. The amount of dust ingested was assumed to be 100 mg day^{-1} for children and 10 mg day^{-1} for adults. In the absence of human absorption efficiency data for PBDEs, 100% absorption efficiency was assumed. It was assumed that adults in Kuwait spend 95 of their time indoors. Because people in Kuwait spend only about 5% of their time outdoors the estimates are not likely to be significantly altered by excluding it from the calculations, particularly when various studies has suggested that concentrations of PBDEs are higher indoors than in outdoor air [4, 9].

Table 2. Estimates of human non-dietary exposure to PBDEs in Kuwait

Exposure pathway	Group	Mean	Median	Maximum	5th percentile	95th Percentile	% Non-dietary exposure
Inhalation	Children	173	61	3400	17.3	572	8
	Adults	399	140	7853	40	1321	66.4
Ingestion of dust	Children	2018	980	15239	127	7539	92
	Adults	202	98	1524	12.7	754	33.6
Total exposure	Children	2191	1041	18639	144.3	8111	
	Adults	601	238	9377	52.7	2075	

Table 2 presents the mean, median, and maximum exposure scenarios together with the 5th and 95th percentiles levels. At median levels, for instance, the ΣPBDE non-dietary exposure is 238 and 1041 pg day^{-1} for adults and children respectively. These estimates indicate that inhalation and dust ingestion contribute 6 and 94 % for inhalation and dust ingestion respectively, to the overall median daily non-dietary exposure for children; while in the case of adults 41 % of the daily non-dietary uptake is from inhalation with dust ingestion contributing ca 59 %. Although dietary intake has been reported to be the most significant human exposure route for lipophilic pollutants, like PBDEs, this study supports the growing body of evidence for the ubiquitous presence of these compounds in indoor air and the potential for continuous, low-level exposure both at work and home.

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