

POLYBROMINATED DIPHENYL ETHERS AND POLYCYCLIC AROMATIC HYDROCARBONS IN HOMES IN KUWAIT

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Abstract

This study reports concentration of polycyclic aromatic hydrocarbons (PAHs) and polybrominated diphenyl ethers (PBDEs) in indoor air and dust samples collected from homes in Kuwait. Mean Σ PAHs in indoor air ranged from 1.3 – 16 ng m⁻³ with a mean of 6.5 ng m⁻³, whereas the dust concentrations varied over 3 orders of magnitude, from 3 to 2920 ng g⁻¹ with a geometric mean of 161 ng g⁻¹. The low molecular weight tri- and tetracyclic PAHs dominated the air profile whereas the dust profile was dominated by the high molecular weight PAHs. PBDE concentrations in air ranged from 2.5 - 385 pg m⁻³, and a geometric mean of 10 pg m⁻³. BDE 47 was the most abundant congener representing ~51 % of the Σ PBDEs. The concentrations in dust varied from 1-393 ng g⁻¹ with a geometric mean of 76 ng g⁻¹. The most abundant congener, BDE 209, constituting ca 85±10% to the Σ PBDEs. Estimated human non-dietary exposure on a BaP_{equiv} basis were 239 pg/kg body weight/day and 73 pg/kg body weight/day, for children and adults respectively. In the case of PBDEs, we estimate that children and adults are exposed to 14.8 and 1.5 ng Σ PBDEs respectively on a daily basis.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are by-products of incomplete combustion, and, as a result, these compounds have many current sources, including domestic burning, power generation, and fossil fuel burning. In the indoor environment, PAHs are formed from activities such as tobacco smoke, and the use of gas or electric stoves for cooking and heating¹, candle and incense burning², coal burning for heating and cooking, and from the use of parquet glue in homes with parquet flooring³. In Kuwait, and other Gulf countries, incense (locally called “Bakhoor”) burning may be an important source of PAHs to the indoor environment since this practice is entrenched in the cultural practices of Arabs. PAHs can also be transported into the indoor environment by infiltrating air and soil tracked-in from outdoors⁴.

PBDEs are different from PAHs in that they are deliberately added to commercial and household products such as electronic equipment, furniture foam, and other consumer products as flame retardants. 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 polymers⁵ and contaminate the indoor environment.

Due to extreme weather conditions in Kuwait, approximately 95% of the day is spent indoors; either in the office or at home. To provide effective cooling, particularly during the extremely hot summer months, there is minimal ventilation in homes in Kuwait. This coupled with slow indoor rates of degradation, leads to the build-up of pollutant indoors. Non-dietary exposure to chemicals via inhalation and dust ingestion may therefore constitute an important exposure pathway for humans. The main objective of this study was to establish baseline concentrations of PAHs and PBDEs in indoor environments and to assess the implications for human non-dietary exposure to these compounds in Kuwait. To achieve this, the concentrations of these contaminants were measured in house dust from vacuum cleaner bags from 17 vacuum cleaners. In addition to dust measurements, we used polyurethane foam (PUF) based passive samplers to measure their concentrations in ambient indoor air.

Materials and Methods

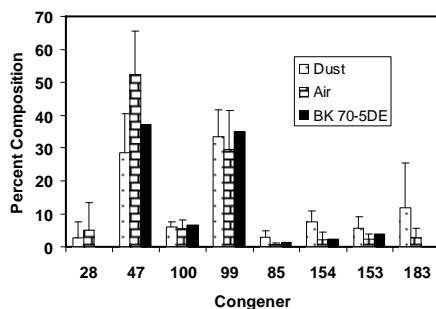
The passive air samplers used in this study consists of a PUF disk housed in stainless steel containers. The sampler has been described in detail previously (Shoeib and Harner, 2002). The samplers were concurrently deployed in 17 homes in Kuwait over six weeks. Dust samples were obtained from vacuum cleaning bags in regular use for the purpose of cleaning homes.

Dust, and PUF disk samples were extracted in a Soxhlet apparatus using 1:1 v/v mixture of DCM:hexane. The sample extracts were analyzed for PAHs using a Shimadzu GC-17A gas chromatograph using splitless injection on a 30 m HP5-ms column (0.25 mm i.d., 0.25 μm film thickness) and helium as carrier gas. This was coupled to a Shimadzu QP-5050A mass selective detector operated in electron impact (EI) mode using selected ion monitoring (SIM). The analyses of PBDEs were carried out with an Agilent 6890N gas chromatograph. This was coupled to an Agilent 5973 MSD, operated in NCI mode, with methane as reagent gas. The ions m/z 79 and 81 were monitored for PBDEs, and 402/404 for Mirex (used as the internal standard for quantitation).

Results and Discussion

The amounts of contaminants sequestered in the passive sampler over the deployment period was converted to approximate air concentrations using a sampling rate of 2.5 m^3 air per day⁶. 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 Σ_8 PBDE.

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



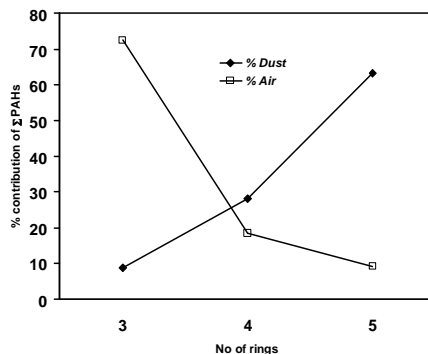
The concentrations of PBDEs in dust were log-normally distributed and varied from 1-393 ng g^{-1} with a geometric mean of 76 ng g^{-1} . The most abundant congener, BDE 209, constituting ca 85% (SD; $\pm 10\%$) to the Σ PBDEs measured in this study. This was followed by BDE 99 (5%), BDE 47 (4.5%), and BDE 183 (2%). Compared with PBDE levels in indoor dust reported from the United States⁷ and the United Kingdom⁸, PBDE level reported here are low. The amounts of Σ PAHs that accumulated in the PUF disk in this study ranged from 164 – 2012 ng/sample which translates to an estimated concentration range of 1.3 – 16 ng m^{-3} . The results from this study are much lower than those reported for indoor air in homes in China (range, 1.4 – 20 $\mu\text{g m}^{-3}$)¹, and in the United States (4.2 – 160 ng m^{-3})⁹.

The Σ PAH concentrations in dust varied from 3 to 2920 ng g^{-1} with a geometric mean of 161 ng g^{-1} . The concentrations reported in this study are lower than those reported by others. Chuang et al (1999) reported concentrations of 4.52 $\mu\text{g/g}$ in dust samples collected from 24 low income homes from the Durham area, USA The

dominant PAHs in dust samples the studies cited above, as is the case in this study, were the high molecular weight four- and five-ring compounds.

Compound profiles. The average compositional profiles in indoor air and dust are given in Figure 3. The low molecular weight tricyclic PAHs were detected in all the samples with the detection frequency decreasing to between 10-20 % for the high molecular weight compounds. The major contributors in order of importance were phenanthrene, (51%); fluorene, (13 %); fluoranthene, (8 %) and pyrene, (7 %). The PAH profile in dust was dominated by the high molecular weight PAHs, with three compounds (Benzo[*a*]pyrene, Benzo[*k*]fluoranthene, and Benzo[*b*]fluoranthene) contributing ca 60% of the average Σ PAHs measured in the samples. Overall, the homologue distribution was as follows: pentacyclic PAHs, 50 %; tetracyclic PAHs, 36%; tricyclic PAHs, 10% and the hexacyclic PAHs, 4%. The dominance of low molecular weight compounds in air is mirrored by the dominance of high molecular weight compounds in the dust (Figure 2). This observation is consistent with temperature dependent gas-particle partitioning behaviour of PAHs.

Figure 2. Contribution to the Σ PAH averaged by the aromaticity of the compounds to measured dust and air samples



3 represents contribution of the tricyclic-PAHs (Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene); 4 represents the contribution of the tetracyclic-PAHs (Fluoranthene, Pyrene, Benzo[*a*]anthracene, Chrysene), and 5 represents the contribution of pentacyclic- and hexacyclic-PAHs (Benzo[*k*]fluoranthene, Benzo[*b*]fluoranthene, Benzo[*a*]pyrene, Dibenz[*ah*]anthracene, Benzo[*ghi*]perylene, Indo(1,2,3,-*cd*)pyrene)

Implications for non-dietary exposure

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

$$\Sigma Exposure = C_h F_h R_r + C_d R_i$$

Where $\Sigma Exposure$ is the daily human non-dietary exposure (amount person⁻¹ day⁻¹); C_h , is the Σ PBDE concentration (amount m⁻³); C_d is the concentration in dust; R_r is the mean respiration rate (m³ day⁻¹); and R_i is the amount of dust ingested (g day⁻¹). A respiration rate of 8.3 m³ day⁻¹ and 20 m³ 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. Exposure in the case of PAHs was expressed in units of benzo[*a*]pyrene equivalent (BaP_{equiv}) concentration. Average exposure from dust ingestion by children is estimated at 0.14 ng BaP_{equiv}/body weight/day representing 57% of their non-dietary daily intake compared to 43% exposure through inhalation of air. In the case of adults, only 18% of their non-dietary exposure (0.013 ng BaP_{equiv}/body weight/day) is from dust ingestion with inhalation of air contributing 82% (0.06 ng BaP_{equiv}/body weight/day) of the total non-dietary exposure. In the case of PBDEs, we estimate that children and adults are exposed to 14.8 and 1.5 ng Σ PBDEs respectively on a daily basis

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