The Significance of Indoor Air Inhalation as a Pathway of Human Exposure to PCBs

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Abstract

PCB concentrations were measured in air from a total of 9 different indoor environments. The results showed elevated levels (1.4 - 19.1 ng ΣPCB m^{-3}, mean = 7.1 ng ΣPCB m^{-3}) compared to those determined in outdoor air (0.77 - 0.87 ng ΣPCB m^{-3}, mean = 0.82 ng ΣPCB m^{-3}). These data indicate mean background UK PCB intake *via* inhalation to be 103.5 ng ΣPCB/person/day, with a range of 37.9 - 176.5 ng ΣPCB/person/day. Based on this relatively limited data set, inhalation may represent a significant exposure pathway for some individuals, given that current UK exposure *via* diet is estimated at 340 ng ΣPCB/person/day.

Introduction

Although the use of PCBs in new products has been banned, some items manufactured before the introduction of restrictions on their manufacture remain in use today - *inter alia* sealants and small capacitors in electrical equipment such as refrigerators and starter motors for fluorescent light switches. As a result, there remains the possibility of PCB contamination of indoor microenvironments where such items are located. Although there have been several reports of elevated levels of PCBs in indoor air[1,2,3,4], to date little consideration appears to been given to the potential impact of these elevated concentrations on human exposure. Indeed, it is generally assumed that non-occupational exposure to PCBs occurs predominantly *via* dietary ingestion. To illustrate, one of the most recent exposure estimates for the UK estimated that *ca* 97% of ΣPCB intake occurs *via* diet, with inhalation contributing the majority of the remainder[5]. This paper reports the concentrations of PCBs found in air samples taken from a variety of buildings in Birmingham and the West Midlands area, and assesses the potential significance of inhalation as a pathway of human exposure to PCBs.

Experimental Methods

Buildings

Two laboratories and two offices at Birmingham University were investigated. These were located in three separate buildings on the campus; one built in the late 1800s and two built in the 1960s. Both laboratories had been used for PCB analysis for the previous 2 years. Five houses in Birmingham and the West Midlands area were also sampled. These were not pre-selected and covered a range of different house types and ages. Outdoor air samples were taken on the campus of Birmingham University.

Air sampling

Air samples were taken using a Graseby-Andersen Hi-Vol sampler modified to hold a glass-fibre filter (GFF, 0.6 μm pore size) and a pre-cleaned polyurethane foam (PUF) plug. For each indoor microenvironment, duplicate samples were taken from each location on the same day, each for a sampling period of 2-3 hours at a flow-rate of 0.7 - 0.9 m^3 min^{-1} yielding sample volumes of 80 - 170 m^3, with the windows closed. Outdoor samples were taken using the same equipment but for periods of approximately 24 hours (sample volume approximately 1000 m^3). Flow-rates were measured directly using a Kurtz portable Hi-Vol calibrator.

Sample purification and analysis

All PCB analyses were conducted using well-validated, containment-enrichment, GC/MS procedures reported in detail elsewhere[6]. Recoveries of quantitation standards added to check analyte losses during both sampling and analysis ranged between 47 and 89% for all samples.

Results and Discussion

Comparison of indoor and outdoor air PCB concentrations

As can be seen in Figure 1, ΣPCB concentrations found in the air samples collected in this study were between 2 and 19 times higher than equivalent outdoor concentrations. The overall range of indoor air concentrations found was 1.4 - 19.1 ng ΣPCB m^{-3} (mean = 7.1 ng ΣPCB m^{-3}), compared to 0.77 - 0.87 ng ΣPCB m^{-3} (mean = 0.82 ng ΣPCB m^{-3}) for outdoor air. From these results, it is clear that levels of PCBs in air from all of the laboratories, offices, and homes studied to date are higher than those in outdoor air. Table 1 compares average concentrations of individual PCB congeners in both indoor and outdoor air in the West Midlands conurbation.

Figure 1: ΣPCB Concentrations in Indoor and Outdoor Air Samples

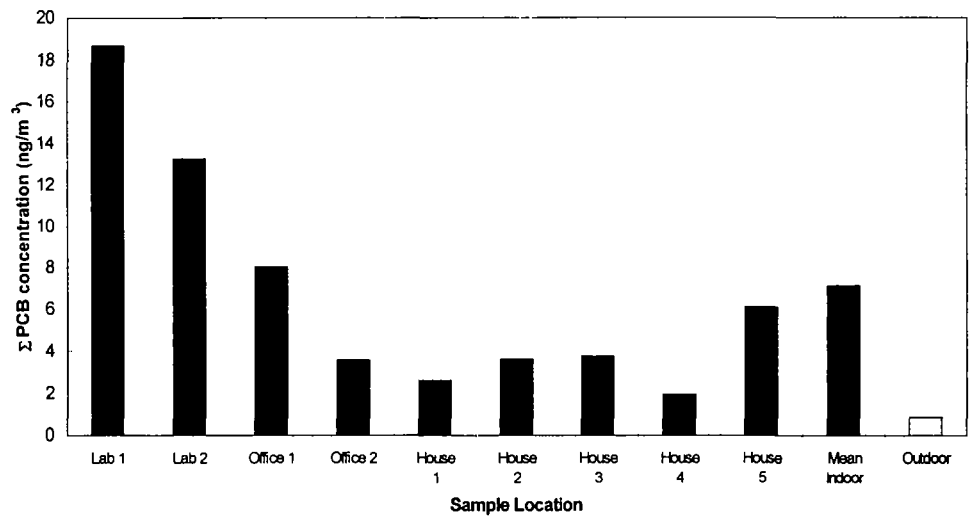

Table 1: Average Concentrations of Selected PCB Congeners in both Indoor and Outdoor Air

Average PCB Air Concentrations (pg m^{-3})					
Congener	**Indoor (n=17)***	**Outdoor (n=3)***	**Congener**	**Indoor**	**Outdoor**
18+17	508	123	87	115	13
32+16	232	60	110	310	25
28+31	651	122	118	172	14
33	251	48	105	48	5
22	152	28	148	33	4
37	98	10	149	129	13
51	28	2	153	99	8
52	870	54	163	27	4
49	226	17	138+164	116	11
47	106	11	128+162	21	2
44	283	27	156	20	1
41+64+71+72	184	18	179	10	3
74	93	11	187+182	11	3
70+76	392	29	174	8	2
66	112	10	177	4	1
95	363	30	180	20	6
90+101	415	26			
99+113	160	9	**ΣPCB**	**7094**	**856**

* denotes number of samples. ΣPCB given as sum of ALL congeners detected.

Possible sources of PCBs in indoor air

The highest levels of PCBs in air were detected in laboratories 1 and 2, both located in buildings constructed in the 1960s. As both laboratories had been used to prepare environmental samples for PCB analysis, or to handle concentrated PCB standard solutions, we originally suspected that these high concentrations were associated with such activities. This was discounted by analysing a sample from laboratory 1 which had not had any internal standards added. Our analytical methodology uses as internal standards, non-isotopically labelled PCB congeners that are essentially absent from environmental samples and PCB formulations. The presence of elevated levels of these congeners in this sample - quantified *via* the external standard technique - would thus confirm our experimental activities as the source of the high levels of PCBs in these laboratories. However, Table 2 shows the level of these congeners to be very low compared to other congeners in laboratory 1, and suggests the existence of another - as yet unidentified - source of PCBs in these rooms. Indeed, the high concentration of PCBs found in office 1 (located in the same building as laboratory 1) indicate that the elevated levels of PCBs detected were not confined to the laboratory alone, and may be present throughout the building. Levels in homes were lower than those detected in offices and laboratories (1.4 - 6.2 ng m^{-3}), but all were above outdoor air levels. We are currently investigating possible sources of these elevated concentrations of PCBs in indoor air, but it would appear significant that the lowest levels found

(1.4 ng ΣPCB m^{-3}) were detected in house 4, constructed in 1995, and thus highly unlikely to contain any PCB-treated products.

Table 2: Concentrations of Selected PCB Congeners in Air from Laboratory 1 Determined in the Absence of Internal Standards

PCB Concentrations in Air (pg m^{-3})			
Congener	**Laboratory 1**	**Congener**	**Laboratory 1**
19*	0.37	28+31	1012
119*	0.06	52	2775
147*	0.05	90+101	1650
157*	0.02	138	337
173*	0.06	180	33

*denotes congeners used in standards

Significance of indoor air as a source of human exposure to PCBs

The UK Ministry for Agriculture, Fisheries and Food (MAFF) estimated that in 1992, the UK mean dietary intake of 53 PCB congeners was 340 ng/person/day[7]. On the basis of the data reported here, we have estimated the likely range and arithmetic mean of daily human intake of PCBs *via* inhalation. On the basis of studies on 47 UK individuals designed to monitor personal exposure to VOCs[8], we have assumed that the typical percentage of time spent outdoors is 8.3%. We have also assumed that 24% of time spent indoors is spent in the workplace, with the remainder at home. Minimum, mean, and maximum daily exposures *via* inhalation have subsequently been calculated using the algorithm below:

$$\Sigma Exposure_i = ([C_w * F_w] + [C_h * F_h] + [C_o * F_o]) * R_r$$

Where $\Sigma Exposure_i$ = Daily adult human exposure through inhalation (ng/person/day)
$C_{w/h/o}$ = ΣPCB concentration in workplace/home/outdoor air respectively (ng m^{-3})
R_r = Adult respiration rate (20 m^3 d^{-1})
$F_{w/h/o}$ = Respective fraction of day spent at workplace/home/outdoors

Human exposure to PCBs through inhalation was therefore estimated to fall within the range 36.9 - 176.5 ng/person/day, with a mean of 103.5 ng/person/day. For a typical UK individual receiving 340 ng day^{-1} from dietary sources, inhalation could thus represent between 10 and 33% of overall human exposure to PCBs. If PCB levels in foodstuffs continue to fall (reported human exposure in 1982 was 1 μg/person/day[7]) then the significance of inhalation as a human exposure pathway is likely to increase, suggesting that current strategies to limit human exposure to PCBs *via* reducing levels in foodstuffs may require revision.

Summary

The results presented in this paper, show that levels of PCBs in air sampled within a variety of workplace and domestic indoor environments, are significantly higher than those present in outdoor air. The sources of these elevated levels have not yet been elucidated, but the high levels found in one of our laboratories could not be attributed to the use of PCBs in our experimental

studies. Given the recent fall in UK human exposure to PCBs *via* dietary ingestion, inhalation may well constitute a much more significant human exposure pathway than has been previously widely accepted. Further, more detailed studies of PCB levels in different indoor microenvironments coupled to personal exposure studies are needed to fully assess the range of human exposure arising from inhalation.

References

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