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Surface and Indoor Air Levels of Polychlorinated Biphenyls in Public Buildings

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Polychlorinated biphenyls (PCBs) are a family of over 200 chlorinated aromatic hydrocarbons; approximately half of the PCBs were used commercially. Since PCBs are poor conductors of heat and electricity, do not break down readily, and are fire-resistant, they were used primarily as coolant insulation fluids in electrical transformers and capacitors. Between 1929 and 1977 approximately 1.2 billion pounds of PCBs were manufactured in the United States (Miller 1983). They are relatively insoluble in water and have a high solubility in lipids; as a result they tend to accumulate in the food chain. Studies have shown that PCBs have toxic effects on animals and humans (Calabrese 1977, Kimbrough et al. 1975, Maroni et al. 1981). An additional concern is that the heating of PCBs can change them into more toxic compounds such as polychlorinated dibenzofurans.

In 1976 Congress passed the Toxic Substances Control Act which requires the Environmental Protection Agency (EPA) to regulate all chemicals which present an unreasonable risk. PCBs were the only chemicals singled out by Congress for regulation. The EPA banned the manufacture, processing, distribution, and use of PCBs (except in a totally enclosed manner) in 1977 (Code of Federal Regulations 1977). Over 750 million pounds are still in use (Miller 1983).

During the early 1980's, Minnesota experienced several spills involving PCBs. Most of these spills received extensive publicity and Minnesota residents became concerned about PCB levels in public buildings. While standards or guidelines exist for occupational exposure to PCBs and for PCB levels in drinking water and certain food products, there are no generally accepted guidelines for surface or air exposure to PCBs in public buildings. Staff of the EPA and the National Institute for Occupational Safety and Health recommended that the contaminated areas should be returned to the pre-existing PCB levels as nearly as possible. However, limited information was available on background levels of PCBs for indoor air and surfaces (Kominsky 1982, MacLeod 1981). Such uncertainly on background levels increased the cost of remedial action. The clean-up in one

St. Paul school district building was 700,000 dollars, and resulted in allegations that the clean-up standards were arbitrary and excessive.

Of the several possible approaches to developing clean-up criteria for buildings, the Minnesota Department of Health decided that a survey of background concentrations of PCBs in Minnesota buildings would be the most effective approach. The purpose of the study was to determine the level of PCB exposure that occurs in public buildings. Air samples and surface wipe samples were taken in 5 state-owned office buildings and 2 elementary schools during August and September of 1984. One office building included a laboratory that had previously used PCB-containing immersion oil for its microscopes.

MATERIALS AND METHODS

A surface wiping technique which utilizes surgical gauze as the collecting medium was used in this study (*Kominsky Personal Communication 1984*). This technique provided a fast, efficient, and economical method for the collection of surface PCB residues.

Gauze strips (2 inch by 4 inch, double layered) were cut from individually wrapped gauze pads. The strips were Soxhlet extracted for 8 hours in 300 ml of 5 percent diethyl ether in n-hexane to remove existing contaminants. After solvent evaporation, the gauze strips were put into hexane-rinsed, disposable test tubes (16 x 100 mm). The tubes were given identification numbers and capped with aluminum foil.

A 10 cm by 10 cm template was used to outline the surface area to be sampled. A fresh, disposable latex glove was placed on one hand of the sampler. The treated gauze was removed from the test tube with a hexane-rinsed forceps, wrapped into a wad around the forcep tips with the gloved hand, and moistened with hexane. The sample was taken by wiping the complete area within the template with a horizontal motion and then with a vertical motion. The completed sample was returned to the test tube and sealed with aluminum foil. Field blanks were obtained by following the above procedure with the exception that the hexane-moistened gauze wad was held on the forcep tips for 10 seconds before being replaced in the test tube. All surface wipe samples were collected by the same individual and stored in a refrigerator until analyzed.

Air samples were taken by using a modified Bendix high volume pump. The modifications consisted of a cylindrical teflon tube (5.5 cm i.d. x 30.5 cm long) fastened to the intake end of the pump and an aluminum cylinder (10 cm i.d. x 8 cm long) attached to the teflon tube's free end. These modifications were necessary to accomodate the polyurethane plugs and glass fiber filter, respectively. The pump was calibrated directly with a Roots rotary positive displacement meter. Air flow through the pump, including the plugs and filter, was read from a rotameter placed ahead of the restricting orifice; air volumes of 34.3 m^3 to 35.5 m^3 were sampled at flow rates of 0.57 to 0.59 m^3/minute. During sampling, the pump was placed on a 0.75 meter high portable table.

Polyurethane foam has been shown to be an efficient collector of airborne PCBs (Bidleman et al. 1974, Lewis et al. 1977). A 3 inch (7.6 cm) sheet of polyurethane foam was obtained from an upholstery shop and cylindrical plugs with a 6.0 cm diameter were cut using a circular copper template. Prior to use, each plug was Soxhlet extracted for separate periods of 4 and 12 hours in 300 ml of 5 percent diethyl ether in n-hexane. The plugs were allowed to air dry while loosely wrapped in hexane-rinsed aluminum foil and were then wrapped in the foil until use. Glass fiber filters, MFS 110 mm, were heated overnight in a furnace at 400°C to remove organic material and then wrapped in aluminum foil until use.

Basic alumina, 60 mesh, was weighed into an Erlenmeyer flask and deactivated by adding distilled water equal to 6 percent by weight of the alumina. The flask was stoppered, shaken, and allowed to equilibrate for at least 15 hours prior to use. Chromatography columns were prepared by placing a wad of hexane-washed glass wool into the bottom of a disposable test tube (0.8 cm i.d. x 14.5 cm long) and packing the column with the deactivated alumina to a depth of 2.5 cm. Approximately 0.2 cm of sodium sulfate (Na_2SO_4) was added to physically stabilize the top of the alumina bed.

The gauze wipes to be extracted were warmed to room temperature and 4 ml of n-hexane was added to each tube. Three times during the next 30 minutes each tube was gently vortexed for a period of 5 seconds. A 2 ml sample was withdrawn, added to an alumina column, and eluted with n-hexane to a final volume of 4 ml.

Foam plugs and glass fiber filters were individually placed into Soxhlet extractors with 300 ml of 5 percent diethyl ether in n-hexane and extracted for 18 hours. To remove any moisture, the extracts were put over individual Na_2SO_4 columns prepared by packing a glass frit chromatography column to a depth of 7.5 cm with anhydrous Na_2SO_4 and washing with 75 ml of 5 percent diethyl ether in n-hexane. The eluates were collected into 500 ml Kuderna-Danish flasks and then concentrated over steam to approximately 5 ml. The samples were then evaporated to 3 ml under a gentle stream of air. A 1 ml sample was withdrawn, added to an alumina column and eluted with n-hexane to a final volume of 4 ml.

All analyses were carried out with a Varian 3700 gas chromatograph equipped with a ^{63}NI electron capture detector. The column was packed with 3 percent OV-1 on Gas Chrom Q 100/200 mesh; the column had a 2 mm i.d. and was 1.83 meters (6 feet) long.

Pre-extracted polyurethane foam plugs and gauze wipes and furnaced glass fiber filters were used as field blanks and analyzed with the samples. Recovery efficiency of PCBs from polyurethane plugs, gauze wipes, and alumina was determined. Gauze wipes were spiked with known amounts of Aroclor 1242, 1254, or 1260 and Soxhlet extracted alongside the air samples. Recovery of PCBs from alumina was determined by adding a known amount of Aroclor to the column and eluting with n-hexane to a final volume of 4 ml.

RESULTS AND DISCUSSION

The collection efficiency of the foam plugs was 99±13 percent for Aroclor 1242, 99±10 percent for Aroclor 1254, and 104±13 percent for Aroclor 1260. The gauze wipe collection efficiencies were 79±14 percent, 89±10 percent, and 92±11 percent for Aroclor 1242, Aroclor 1254, and Aroclor 1260, respectively.

The detection limit for the airborne PCBs was 20 ng/m^3; for the surface wipes it was 10 µg/100 cm^2. All field blanks were below the limits of detection. In addition, surface wipes of the latex gloves used during sample collection were less than 10 µg/100 cm^2.

Office buildings 1-4 are located in St. Paul and are all connected by an underground tunnel system. The laboratory is located in a state-owned building (office building 5) in Minneapolis and the two elementary schools are located in a suburb of St. Paul. Office buildings 1, 2 and 5 all contained PCB transformers; the schools and office buildings 3 and 4 did not. All buildings used fluorescent lighting.

MacLeod (1981) found airborne levels of PCBs in offices that ranged from 44-80 ng/m^3 and in laboratories from 200-240 ng/m^3. Table 1 summarizes the indoor air PCB levels found during this study. In general, the levels found in the Minnesota buildings were higher than those reported by MacLeod. The average level of airborne PCBs in buildings with PCB transformers was nearly twice the level in the buildings without transformers (457 and 229 ng/m^3, respectively). The results indicate there is a difference between the indoor air levels of PCBs measured in buildings that contain transformers when compared to buildings without a transformer (t-test, $p=0.01$).

The wipes were taken from several different surface types (carpet, concrete, marble, tile) and the results are shown in Table 2. For data analysis, the surface wipes that were below the detection limit were assumed to be 0.05 µg/100 cm^2. The mean of the surface wipes taken in buildings without PCB transformers was 0.17 µg/100 cm^2 (the standard deviation was 0.19 and the median was 0.05 µg/100 cm^2). With the exception of the laboratory surface wipes, the average level in the buildings with transformers was 0.23 µg/100 cm^2 (the standard deviation was 0.27 and the median level

Table 1. Airborne PCB Concentrations*

Location	Number of Samples	Range ng/m^3	Mean ng/m^3	Standard Deviation
		Buildings with PCB Transformers		
Office 1	3	192-215	206	13
Office 2	3	448-881	653	217
Laboratory	4	355-628	498	118
All Locations	10	192-881	457	223
		Buildings without PCB Transformers		
Office 3	5	202-384	327	72
Office 4	3	78-139	117	34
School 1	3	114-215	157	52
School 2	2	220-303	262	59
All Locations	13	78-384	229	106

*Concentrations are Aroclor 1242 and Aroclor 1254 and were detected on front plug only; rear foam plugs and filters were all below detection limit of 20 ng/m^3.

Table 2. Surface PCB Concentrations*

Location	Number of Samples	Range µg/100cm^2	Mean µg/100cm^2	Standard Deviation
		Buildings with PCB Transformers		
Office 1	43	0.05-0.32	0.10	0.07
Office 2	42	0.05-1.20	0.34	0.30
Office 5	22	0.05-1.47	0.31	0.34
All Locations**	107	0.05-1.47	0.23	0.27
Laboratory	46	0.05-9.10	0.80	1.75
		Buildings without PCB Transformers		
Office 3	32	0.05-0.80	0.09	0.14
Office 4	38	0.05-0.66	0.12	0.12
School 1	13	0.05-0.49	0.21	0.13
School 2	17	0.05-1.00	0.37	0.28
All Locations	100	0.05-1.00	0.17	0.19

*Concentrations are Aroclor 1242, Aroclor 1254 and Aroclor 1260.
**Excludes laboratory surface wipes.

was 0.12 µg/100 cm^2). A comparison of the two means did not show a significant difference (z-test, $p=0.06$). However, a PCB transformer leak had been discovered in office building 1 in the early 1980's. As a result, many of the floor surfaces in the building had received special cleaning and sealants. When the surface wipes of office building 1 were excluded from the results, a difference in surface levels was seen in a comparison of the buildings with and without transformers (z-test, $p=0.002$).

A report by Kominsky (1982) suggests that 0.5 µg/100 cm^2 is the upper limit of background in buildings and the data support this view. Over 90 percent of the surface wipes collected were less than 0.5 µg/100 cm^2 regardless of whether the building contained transformers.

A laboratory located in office building 5 had previously used PCB-containing immersion oil for its microscopes. Even though most uses of this oil were discontinued in late 1976, the concern over PCB contamination in laboratories continues (Nashel and Fischman 1983). Of the 45 samples collected, 34 were in the background range of less than 0.5 µg/100 cm^2. However, several of the wood drawers and shelves and the benchtops located near the microscopes had levels greater than 1 µg/100 cm^2.

In summary, using 0.5 µg/100 cm^2 as the upper limit of background for PCB wipe samples is acceptable for establishing post spill clean-up levels. Background levels of airborne PCBs varied widely between the different buildings and may be influenced by the presence of PCB-containing transformers. Additional surveys of indoor air PCB levels are needed. The sampling of a laboratory which previously used PCB immersion oils demonstrated the persistence of PCB contamination eight years after the termination of the use of these oils.

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