CHARACTERIZATION OF POLYCHLORINATED BIPHENYLS IN BUILDING MATERIALS AND EXPOSURES IN THE INDOOR ENVIRONMENT

KM Coghlan*, MP Chang, DS Jessup, MA Fragala, K McCrillis, and TM Lockhart

Environmental Health and Engineering, Inc., Newton, MA, USA

ABSTRACT
The accidental discovery of PCB contamination in a university office building triggered an extensive sampling program to define the nature and extent of the indoor contamination. PCBs were detected in air samples (111 – 393 ng/m^3) and in dust samples collected from the unit ventilators (<1 ppm – 81 ppm). Surface samples were at or below the limit of detection (2 ng/cm^2). Aroclor 1254 was the principle PCB mixture detected in all samples. While PCB concentrations remained below regulatory limits for air samples, source materials found in the building contained PCB concentrations well above the EPA approved limit of 50 ppm for non-liquid PCB products. Left in place, any of these sources of PCBs would continue to contribute to the low-level concentrations of PCBs found in environmental sampling. This data suggests the need for further study of potential PCB exposures and associated health implications for occupants in buildings constructed with PCB-containing products.

INDEX TERMS
PCBs, Regulatory Strategies and Implications, Remediation, Building Products

INTRODUCTION
PCBs, or polychlorinated biphenyls, are a mixture of individual chemicals no longer produced in the United States, but which are still found in the environment. The manufacture of PCBs stopped in the United States in 1977 because of evidence that they accumulate in the environment and that these compounds have the potential to negatively impact human health. PCBs were primarily used in transformers, capacitors, and other electrical equipment as coolants and lubricants due to their excellent electrical and thermal resistance properties. PCBs were also used in plasticizers, surface coatings, inks, flame retardants, adhesives, paints, and pesticides.

Dust samples were collected from the study building for pesticide testing. Pesticide application in surrounding agricultural fields was originally thought to have impacted the building. A number of occupants were concerned about potential long-term exposures to pesticides. In addition, a number of cancer cases were reported on some floors of the building. PCBs were not suspected contaminants, but they were detected during the pesticide testing. Pesticides were near or below the detection limit; no chlorinated pesticides were detected.

At the request of university officials, additional testing was undertaken to characterize the recently identified PCB contamination within the building. Current and historical uses of the building did not point to an obvious source of PCBs within the building. Additional samples confirmed the presence of PCBs, but questions remained as to the possible source(s) of the

---

* Contact author email: kcoghlan@eheinc.com

discovered PCBs. Additional sampling was required to identify the sources of PCBs found in the building.

METHODS

Air samples were collected and analyzed using National Institute for Occupational Safety and Health (NIOSH) Method 5503, using a glass filter and florisil sampling train. Personal sampling pumps were used to draw the air through the sampling train at approximately 1 liter per minute (lpm) to collect a nominal total air sample volume of approximately 1 cubic meter. Replicate and blank samples were collected for quality control purposes. All samples were analyzed using a gas chromatography/electron capture detector. Results are reported in nanograms of PCB mixture per cubic meter of air (ng/m^3). The type of PCB mixture noted in the samples is also reported.

Wipe samples were collected using pre-cleaned hexane soaked gauze pads. One square foot transects were sampled on high contact surfaces with visible dust accumulation. Samples were stored in glass vials and transported to the laboratory for analysis using U.S. Environmental Protection Agency (EPA) Method 8082, as described in EPA Test Methods SW-846. Sample results are reported in nanograms of PCB mixture per square centimeter sampled (ng/cm^2). The type of PCB mixture noted in the samples is also reported.

Dust samples were collected using sterile disposable forceps or by collecting dust in an extraction thimble fitted into a portable high efficiency particle air vacuum unit. Dust was transferred to glass vials for transport to the laboratory. Bulk materials were similarly sampled and placed in glass vials. Samples were weighed in the field to insure a minimum sample amount (approximately 15 grams). All samples were analyzed using EPA Method 8082 and results were reported in milligrams of PCB mixture per kilogram of dust or material (mg/kg or ppm).

Two comparison buildings were also included in the assessment. One building, located across campus, was built in the same decade as the study building (1960s). This building was selected to control for location. Another building nearby the study building was selected to control for age as this building was built in the 1980s. Air and wipe samples were collected from these two buildings and the results were compared to the study building. The sampling in these buildings occurred contemporaneously with the sampling in the study building.

DISCUSSION

The presence of PCBs in building materials has not been extensively characterized in the United States, although the presence of PCB-containing materials has been documented (ATSDR, 1996) (Vorhees, 2001). While observations have been made about building age and indoor PCB concentrations, most of what is known about indoor PCB contamination in the U.S. has mainly come from acute events involving the release of liquid PCBs (i.e., fires and spills) or the influence of external sources (i.e., plumes, spills, etc) (Wallace, 1996) (Oatman, 1986). Research on the effects of PCB-containing building materials and the remediation of such materials from the building environment has been documented in the European literature (Sundahl, 1999) (Fromme, 1996) (Balfanz, 1993). These studies have focused on the effects installed PCB-containing building materials (caulking, mastic, and gasket material) on the indoor environment.

During the indoor environmental sampling program conducted in December, 2000, nineteen (19) air samples, twelve (12) bulk material samples, nine (9) bulk dust samples, and thirtyfour (34) wipe samples from various locations throughout the building were collected. Locations that would best confirm and characterize the scope of possible PCB contamination, based on earlier sampling in the building, were chosen for sampling. Rooms that had detectable concentration of PCBs in dust during the initial sampling were re-sampled. Interviews with maintenance workers and university staff were conducted to determine possible source(s) of the observed PCBs. Table 1 summarizes the data.

Table 1. Sample frequencies and sample results range.

Sample	*Number of Samples*	*Range in concentration*
Air	16	ND<38.2 to 393 ng/m^3
Air: Comparison Bldg. (1980s)	2	ND<49.2, ND<52.1 ng/m^3
Air: Comparison Bldg. (1960s)	2	111, 203 ng/m^3
Wipe	34	BRL to 2 ng/cm^2
Bulk	12	BRL to 30 ppm
Dust	9	BRL to 81 ppm
ND: not detected ng/m^3: nanograms per cubic meter BRL: below reporting limits ng/cm^2: nanograms per square centimeter ppm: parts per million		

Initial results confirmed the existence of PCBs in 44% (7/16) of the air samples, 25% (3/12) of the bulk materials samples, in 78% (7/9) bulk dust samples and in 5.9% (2/34) of the wipe samples taken.

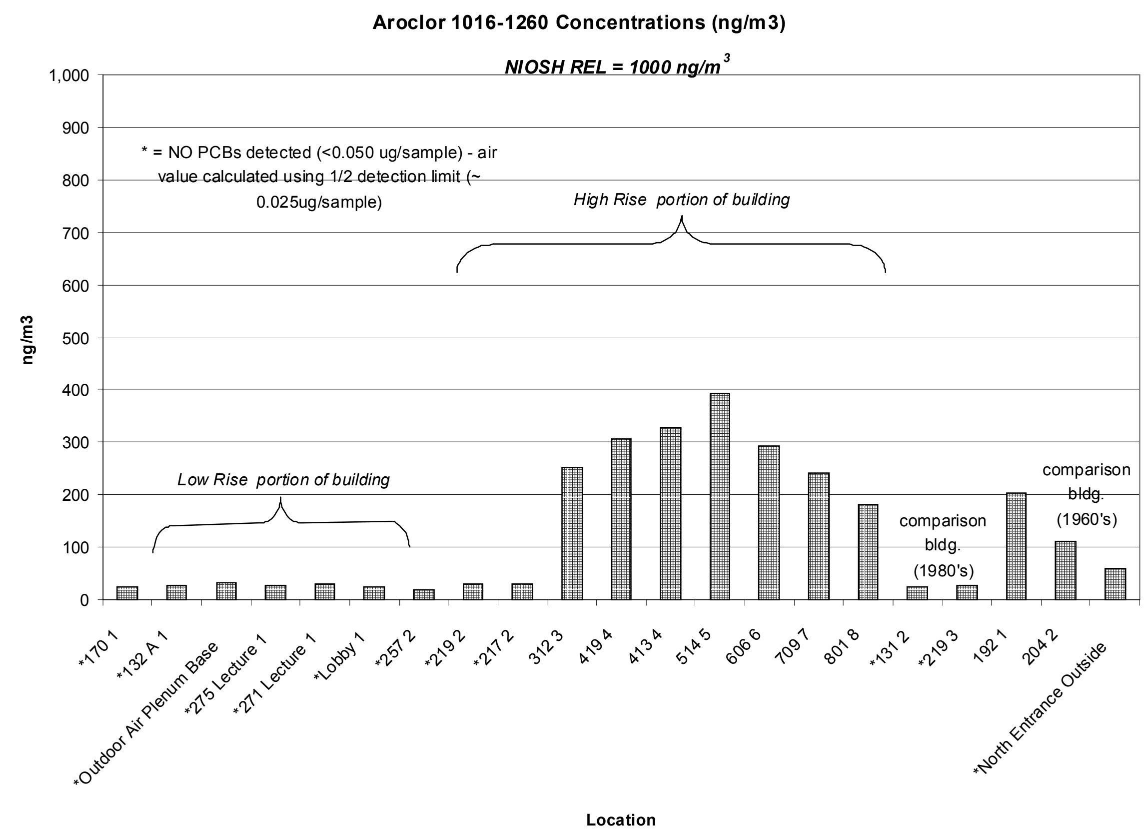

Figure 1. Airborne PCB concentrations.

Detectable concentrations of airborne concentrations for PCBs in the study building ranged from 180 ng/m^3 to 393 ng/m^{3}in the study building. A building of comparable vintage (1960s), but located across campus contained indoor PCB concentrations of 111 ng/m^3 and 203 ng/m^3. However, in a building near the study building, but of newer construction (1980s), PCBs were not detected in the air (< 50 ng/m^3). This building was chosen to reflect ambient PCB levels found in office environments following the discontinuation of PCB usage in construction materials. This finding confirms the importance of building age in determining the likelihood of finding PCBs in the indoor environment and may relate to the use of PCB-containing building products in construction. Concentrations of PCBs in the indoor air environment were comparable to other results reported in indoor environments (Marco Currado, 1998) (Wallace, 1996).

Another interesting feature of the air sampling data set is that PCBs are detected in the high-rise section of the building, with slightly higher concentrations noted on the mid-level floors. The low-rise section is non-detect for the air samples. It was later observed that a relatively new caulking material was applied from the inside at the window frame/masonry interface. This essentially sealed in one of the building products that contained relatively high levels of PCBs. Although unintentional, this seal created a vapor barrier against the evaporation and diffusion of PCB vapors into the indoor environment. The performance of this caulking in reducing the transfer of PCBs into the building's environment was not specifically tested, although it presents a potential approach to mitigate the influx of PCB vapors released from envelope caulking products.

To assess potential exposures via the dermal and ingestion routes, wipe samples were taken from high contact surfaces from a number of areas that had visible accumulations of dust. These surfaces included desktops, bookshelves, and file cabinets. All but two samples were non detectable for PCBs (2 out of 34 samples). These two samples had reported PCB levels of 1.4 and 1.5 ng/cm^2, near the detection limit for the method. The wipe sample results indicate that PCBs are not depositing and concentrating on exposed work surfaces in the building.

Unit ventilators were sampled on each floor and on all sides of the building. The unit ventilators recirculate a portion of the supply air from each room individually, so that accumulated dust represents a fairly good time integrated sample of PCB-contaminated dust. In addition, dust from several computers were also sampled in the same manner. These results confirmed earlier tests in that the concentration range of PCBs varied between approximately eight (8) and eighty (80) ppm for seven of the nine dust samples. These results clearly demonstrate a release and accumulation of PCBs in the indoor environment, and these levels are significantly above EPA's clean up criterion of one (1) ppm.

Bulk material samples were taken from materials that may be a source of PCB exposures. These materials included ceiling tiles, filter components from the air handling units, window gaskets, duct and tile mastic, and brick and mortar. Samples taken from a ceiling tile indicated a PCB concentration of 0.4 ppm, while samples from exterior window gaskets produced concentrations of 4.2 and 30 ppm. It was also determined through visual inspections that the light ballasts in the offices were mostly PCB-containing ballasts, although no reports of leaks or fires were noted and no visible evidence of leaking fluid was observed (e.g., stains on ballast or light lenses).

These samples identified that a source of PCBs existed in the building, and possible exposure routes were identified. Inhalation was the principal exposure route for the building occupants and exposure to PCB-containing dust was an additional exposure route for the building's operation, maintenance, and janitorial staff. However, the material samples did not identify the likely source(s) of the PCBs detected in the environmental samples. The level of PCBs in the bulk material samples appeared too low in order to generate the level of contamination observed in the dust samples. A more detailed sampling regime was initiated to further investigate building materials that could be the source of the detected levels of PCBs found in the environmental samples. Although the building had PCB transformers (which were removed several years earlier) and light ballasts, there were no reported or observed releases of PCBs that could explain the environmental findings in this study.

A thorough review of architectural plans and building specifications helped to create a list of materials suspected of containing PCBs. These materials included sealants, tiles, paints, flooring, tack coats, carpeting, and mastics used during construction. During the walk-through, some materials on the list were eliminated as these products were removed and replaced during renovations. 54 samples were eventually taken from various locations throughout the building. These samples fell into ten broad categories. Concentrations of PCBs in these samples varied widely.

Table 2: Building Material PCB Source Samples

Category	*Number of Samples*	*Range of Sample Results (ppm)*
Caulking Material	9	BRL – 33,000
Fill Material	1	BRL
Gasket Material	18	1.1 – 4,300
Insulation Material	6	BRL – 310*
Mastic Material	4	BRL – 3.9
Tile Material	1	0.2
Unit Ventilator Components	3	3.7 – 63
Vinyl Material	7	0.8 – 14
Dielectric Fluids	2	970,000**
Other Material	1	BRL
ppm: parts per million, Aroclor 1254 BRL: below reporting limit Results in Aroclor 1254, unless noted. *Result in Aroclor 1221 **Results in Aroclor 1242 Aroclors 1016, 1232, 1242, 1248, and 1260 also tested		

Gasket, foamboard insulation, and caulking material consistently demonstrated high concentrations of PCBs. Because these materials contained PCB concentrations higher than allowable limits under EPA Toxic Substances Control Act legislation, an abatement and decontamination program would be necessary to remove the PCB-containing building materials from the building.

CONCLUSIONS AND IMPLICATIONS

The use of PCBs as a dielectric fluid is widely known. The nature and extent of PCB-containing building products is less well understood, especially with respect to the potential impact these materials may have on the indoor environment. The data in this study establish that the age of a building can be critical in determining if a structure is likely to contain PCB building products. Further, the data show that PCBs from these products can be released to the indoor environment and can accumulate in dust deposits over time. The most likely exposure pathway for occupants is through inhalation, although maintenance and janitorial personnel may have additional dermal and/or ingestion exposures due to handling the contaminated dust during maintenance and repair work.

The levels measured in the dust were well above EPA's criterion of 1 ppm for the clean-up of PCB contaminated materials. The airborne results show levels below the NIOSH recommended exposure limit of 1,000 ng/m^3, although the samples were collected in the winter season and the literature suggests an increase in indoor PCB concentrations when ambient temperatures rise (Benthe, Heinzow, Jessen, *et al.*, 1992). Wipe samples on high contact surfaces were essentially non-detect; therefore, dermal contact does not appear to be a significant source of exposure for the typical office occupant.

Further research is required to assess any long-term health implications from these potential exposures, especially for the dioxin-like PCBs. Guidance at the federal regulatory level is needed to prevent unnecessary expenditures for mitigation and abatement measures that may be driven by regulatory statutes. Specifically, a review of current regulations governing the use of non-liquid PCBs in buildings is warranted to better understand the risk, if any, of these products.

REFERENCES

ATSDR. 1996. *Toxicological profile for polychlorinated biphenyls*, Atlanta: U.S Department of Health and Human Services.

Balfanz E, Fuchs J, and Kieper H. 1993. Polychlorinated biphenyls (PCB) and polychlorinated dibenzofurans and dibenzo(p)dioxins (PCDF/D) in indoor air due to elastic sealants and coated particle boards. In *Dioxin '93: 13th International Symposium on Chlorinated Dioxins and Related Compounds, Vienna, 20-24 September 1993,* Fielder H, *et al.*, eds. Vienna: Austrian Federal Environment Agency, Vol 13, pp 115-118.

Benthe C, Heinzow B, Jessen H, *et al*. 1992. Polychlorinated biphenyls, indoor air contamination due to thiokol-rubber sealants in an office building, *Chemosphere*, Vol 25, Nos 7-10, pp 1481-1486.

Marco Currado G, and Harrad S. 1998. Comparison of polychlorinated biphenyls concentrations in indoor and outdoor air and the potential significance of inhalation as a human exposure pathway, *Environmental Science and Technology,* Vol 32, pp 3043-3047.

Oatman L, and Roy R. 1986. Surface and indoor air levels of polychlorinated biphenyls in public buildings, *Bulletin of Environmental Contamination and Toxicology,* Vol 37, pp. 461-466.

Pitulle H, Mohr S, Benthe C, *et al.* 1995. Sanitation of a PCB-contaminated building, *Organohalogen Compounds.* Vol 26, pp. 435-439.

Sundahl M, Sikander E, Ek-Olausson B, *et al.* 1999. Determination of PCB within a project to develop cleanup methods for PCB-containing elastic sealant used in outdoor joints between concrete blocks in buildings, *Journal of Envrionmental Monitoring,* Vol 1, pp. 383-387.

Vorhees D. 2001. Polychlorinated Biphenyls. In *Indoor Air Quality Handbook,* Spengler J, Samet J, and McCarthy J, eds. New York: McGraw-Hill, pp 36.1-36.24.

Wallace J, Basu I, Hites A. 1996. Sampling and analysis artifacts caused by elevated indoor air polychlorinated biphenyl concentrations. *Environmental Science and Technology,* Vol 30, pp 2730-2734.