POLYCHLORINATED BIPHENYLS (PCBS) AND INDOOR AIR: SOURCE INVESTIGATION AND REMEDIAL APPROACH FOR A PUBLIC SCHOOL BUILDING IN NEW BEDFORD, MASSACHUSETTS, USA

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Introduction

TRC Environmental Corporation (TRC) was retained by the City of New Bedford (City) to perform indoor air sampling and other environmental testing for polychlorinated biphenyls (PCBs) in the interior of New Bedford High School (NBHS) in New Bedford, Massachusetts, USA, and to implement remedial actions. TRC's retention followed the detection of PCBs in indoor air by others at concentrations of ranging from 0.0043 micrograms per cubic meter ($\mu g/m^3$) to 0.0519 $\mu g/m^3$ as total PCBs. One result (0.0519 $\mu g/m^3$) exceeded an Environmental Protection Agency (EPA) established site-specific Action Level of 0.05 $\mu g/m^3$, prompting further investigation.

We conducted additional indoor air monitoring to evaluate if detectable concentrations of PCBs were persistent and evaluate if the concentrations posed a potential risk to the school's occupants. Since NBHS was constructed prior to 1978 (when PCB production was banned) and since PCBs were identified in air within NBHS, EPA requested supplemental investigations to identify potential PCB source materials within the school. Historical review and research by Kohler et al (2005) suggested that NBHS may have been built during peak years of PCB usage (late 1960s/early 1970s) in certain building materials, such as joint sealants[(1)]. We developed the sampling program for building materials in collaboration with the EPA, the Massachusetts Department of Environmental Protection (MassDEP), and the City's Department of Environmental Stewardship to screen for potential PCB contamination within NBHS and to diagnose potential sources of airborne PCBs[(2)].

Materials and Methods

Site Description. NBHS is an approximately 535,000 square foot (sq. ft.) building of principally concrete and masonry construction built during the late 1960s and early 1970s. The building can house a maximum of 4,000 students, but current enrollment is approximately 3,300 students[(3)]. The building ventilation system consists of 20 central Heating, Ventilation, and Air Conditioning (HVAC) components, fan coils and intakes, and approximately 13,572 linear feet of duct with an approximate internal surface area of 96,171 sq. ft. There are also an estimated 570 supply and exhaust diffusers, 250 perimeter univent induction units and heating ventilators, and 120 return air exhaust vents. All return vents are ducted.

Remedial Approach. We proposed removal of contaminated ventilation system dust and dust in areas of long-standing accumulation as a first phase to improve the indoor air quality and reduce airborne PCB concentrations. We prepared bid specifications for the cleaning of air handling systems, ductwork, and surfaces; helped with contractor selection; oversaw implementation; and conducted verification sampling (surfaces/indoor air).

A qualified specialty contractor cleaned the ventilation system using mechanical source removal and cleaning methods designed to extract contaminated surface dust deposits and render the HVAC system visibly clean and capable of passing cleaning verification methods consistent with national standards and other specified tests (e.g., wipe sampling).

Sampling and Analysis. We collected air and wipe samples to evaluate the remedy outcome. Indoor air samples were collected via EPA Method TO-10A, *Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using Low Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD)*[(4)]. Wipe sampling was performed using a 10 cm by 10 cm template consistent with American Society for Testing and Materials *Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling*[(5)], with analysis for PCB Aroclors by SW-846 Method 8082[(6)]. Northeast Analytical Laboratories of Schenectady, New York, USA, performed all analyses.

Results and Discussion

The air monitoring that signaled the need for remedial action took place in August 2006, wherein air samples from NBHS ranged in concentration from 0.0024 $\mu g/m^3$ to 0.31 $\mu g/m^3$. One result exceeded a site-specific EPA risk-based Acceptable Long-Term Average Exposure Concentration of 0.3 $\mu g/m^3$. Several exceeded EPA's 0.05 $\mu g/m^3$ Action Level, prompting further investigation. Our data suggested PCB-contaminated ventilation system dust was an important contributor to the levels of indoor air PCBs. PCBs were detected in 18 of 19 dust samples from the HVAC system at concentrations as high as 36 milligrams per kilogram (mg/kg), with an average total PCB concentration of 6.7 mg/kg.

Building materials were also determined to be an important, but not exclusive, source of PCBs in indoor air, especially caulking and mastics. Other sources are present (paint, hydraulic oil, a few remaining light ballasts). Local/regional PCB contamination also contributes to indoor air levels. Airborne PCB concentrations detected in NBHS are similar to other schools and public buildings, and the NBHS data agree with prior published data that highlight a global issue with PCBs in indoor air attributable to PCB-contaminated building materials[(7, 8)]. The results of our initial source screening are summarized in Table 1.

Initial remedial activities were undertaken during the summer 2007 school break consisting of the following:

- **Ducts:** Cleaned all supply, return, and exhaust ducts in the school (13,572 feet of ductwork).
- **HVAC Components:** Cleaned 20 central HVAC components, fans coils, and intakes.
- **Perimeter Univent and Corridor Heaters:** Cleaned and replaced filters for 250 units.
- **Return Exhaust Vents:** Cleaned 120 return air exhaust vents (approximately 8,700 linear feet).
- **Surface Cleaning:** Cleaned approximately 93,000 sq. ft. of dusty surfaces.
- **Sub-locker Space:** Cleaned enclosed spaces under 4,000 hallway lockers with long-standing reservoirs of dust.
- **Wood/Auto Shops:** Cleaned unique dusty locations of fixed surfaces.
- **Filter Replacement:** Replaced all filters within the HVAC system no matter the age or condition.

The remedial activities significantly reduced the PCB burden associated with dust deposits (see Figure 1). This included removing approximately 3,400 pounds of PCB-contaminated solid material (e.g., dust) from the air handling system and spent HVAC filter media. Total PCB concentrations found in these dusts ranged from 0.78 mg/kg to 36.5 mg/kg (average 7.4 mg/kg) and were attributable to:

- Off gassing of PCBs from building materials with adsorption onto surfaces and/or dust deposits.
- Dusts/solids resulting from abrasion or physical breakdown of pre-existing building materials containing PCBs.
- PCB-contaminated dusts entering the building via HVAC intake (air handling system).
- PCB-contaminated dusts/soils entering the building from > 30 years of "foot traffic".
- PCBs in gaseous phase entering air intakes and sorption onto surfaces/dusts in the building.

All but three of the 207 post-remedial wipe samples were non-detect for PCB Aroclors. The concentrations of the three detected samples were significantly lower than the EPA unrestricted use standard of 10 $\mu g/100\ cm^2$ for high occupancy areas demonstrating cleaning technique effectiveness.

The results from post-remedial air monitoring conducted in summer 2007 were varied. In some locations, reductions in air phase PCB concentrations were observed, while in other locations concentrations remained essentially the same or increased when compared to air-phase PCB data collected in summer 2006 prior to the implementation of remedial actions (see Figure 2).

Further investigation found that 20 out of 120 (approximately 17-percent) of the roof exhaust vents were not working during the August 2007 PCB air sampling events. Over 40-percent of perimeter univents were found to be non-functioning, many of which were operating during air sampling conducted in August 2006. The lack of a fully functioning ventilation system contributed to the unchanged or increased air phase PCB concentrations given that PCB-containing building materials are still present in the building. A third round of PCB indoor air monitoring conducted in February 2008, following the restoration of the HVAC system to full operational capacity and system re-balancing, showed dramatic improvements in indoor PCB air quality (see Figure 2).

We undertook supplemental diagnostic PCB source sampling, including targeting additional bulk sampling in the two classrooms with the highest concentrations of indoor air PCBs, in August 2006 to clarify the relative contributions of potential PCB sources present at these locations. This sampling was conducted to help identify remedial actions for PCB-containing bulk materials. We collected comparative bulk samples in August 2007 from rooms B-240 and A-114-3 for PCB Aroclors targeting the floor tile mastic; window glazing; baseboard (core base) mastic; old, new and steel beam paint; and couch foam (B-240 only).

Results from analyses of the B-240 and A-114-3 classroom bulk samples suggest that a potential trend exists between bulk material PCB concentrations and PCB concentrations present in room air at these same locations. The bulk and air phase PCB results are both significantly higher in B-240 compared to room A-114-3 (see Table 2).

Concluding Remarks

We hypothesized that persistent air concentrations of PCBs in some rooms were associated with numerous low concentration PCB-contaminated building materials serving as reservoir sources for the air phase PCBs. Higher indoor air concentrations may be expected in locations where building material PCB concentrations are higher. Reduced ventilation during the August 2007 monitoring events likely exacerbated this effect, contributing to higher PCB air concentrations in some locations. Outdoor ambient air does not appear to be a significant source of contamination found in indoor air since outdoor air samples collected concurrently were either non-detect for PCBs, or had concentrations an order of magnitude or more lower than concurrent indoor air PCB levels.

Future work planned at NBHS includes conducting further investigation into the potential presence of high concentration PCB-containing building material (source/sink sampling). Since air phase PCB concentrations may be correlated with the concentrations of PCBs in various building materials, detailed characterization and mapping is expected to help target future remedial activities (e.g., source removal). Prior sampling efforts may not have characterized all potential sources of PCBs. High concentration concrete joint sealants, for example, might be present in areas that are relatively inaccessible.

PCB source/sink mapping is expected to take place in the first half of 2008. Data collected from the PCB source/sink mapping will form the basis for plans to further remediate PCB building contamination at NBHS.

References

1) Kohler M., Tremp J., Zennegg M., Seiler C., Minder-Kohler S., Beck M., Lienemann P., Wegmann L., and Schmid P. *Environmental Science & Technology* 2005; 39:1967-1973.

2) *Indoor PCB Sampling Plan, New Bedford High School, Hathaway Boulevard, New Bedford, Massachusetts, Revision 0.* Prepared for: City of New Bedford, New Bedford Public Schools, 133 William Street, New Bedford, Massachusetts. TRC Environmental Corporation, Lowell, Massachusetts. August 21, 2006.
3) Personal communication between Richard Glass, Senior Plant Engineer for New Bedford High School, and David Sullivan, TRC Environmental Corporation, 2007.
4) United States Environmental Protection Agency Method TO-10A, *Determination of Pesticides and Polychlorinated Biphenyls in Ambient Air Using Low Volume Polyurethane Foam (PUF) Sampling Followed by Gas Chromatographic/Multi-Detector Detection (GC/MD),* January 1999.
5) Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling. American Society for Testing and Materials Designation D6661-01. 2001.
6) United States Environmental Protection Agency, SW-846 Method 8082, Polychlorinated Biphenyls (PCBs) by Gas Chromatography, Revision 0, December 1996.
7) Spengler, Samet, and McCarthy, 2001. Indoor Air Quality Handbook. McGraw-Hill, NY, NY
8) Harrad S., Hazrati S., and Ibarra, C. *Environmental Science & Technology* 2006; 40: 4633-4638.

Figure 1: Before/After Photographs - Ventilation System (Duct Work)

Before   After

Figure 2: Graphic Summary - Comparison of TRC NBHS Indoor Air Results August 2006, August 2007, and February 2008

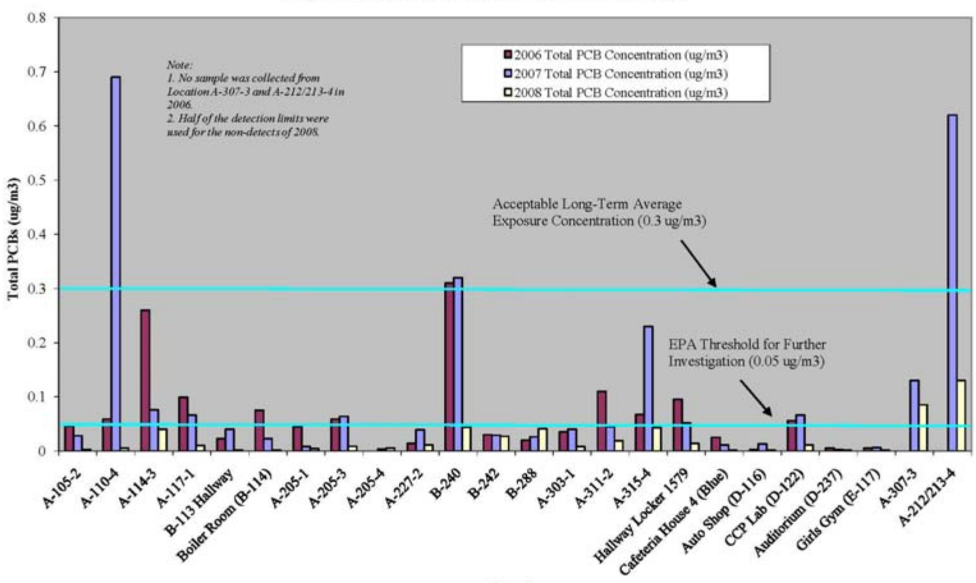

Table 1: Summary of TRC August 2006 Sampling	
PCB Indoor Air Monitoring Results ▪ Concentration Range: ▪ Results In Excess of EPA Action Level (0.05 μg/m^3): ▪ Results At or Above Acceptable Long-Term Average Exposure Concentration (0.3 μg/m^3): – Room B-240 – Room A-114-3	0.0024 μg/m^3 to 0.31 μg/m^3 11 2 0.31 μg/m^3 0.26 μg/m^3
PCB Bulk Sample Results ▪ Concentration Range: ▪ Highest Concentration Materials: – Return Air Duct Dust – Window caulking (classroom) – Floor mastic – Foam padding – Auto Lift Sump Contents (oil/water)	0.20 ppm to 36.5 ppm 36.5 ppm 34.4 ppm 18.1 ppm 10.2 ppm 10.9 ppm (oil fraction)
PCB Wipe Sample Results ▪ Non-Quantitative Results Used to Identify PCB Contaminated Deposition Areas ▪ Items/Areas with Greatest Number of PCB Detections: – Vents – Areas of Dust Accumulation (e.g., locker bottoms, bookcases, light fixtures)	

Table 2: Possible Trend Between Bulk and Air Results

Medium	B-240	A-114-3	High Conc. Association
Floor Tile Mastic	10.1 ppm	0.2 ppm	B-240
Window Glazing	14.9 ppm	2.1 ppm	B-240
Baseboard Mastic	4.5 ppm	2.0 ppm	B-240
Old Paint	0.2 ppm	8.3 ppm	
Recent Paint	2.9 ppm	1.6 ppm	B-240
Steel Beam Paint	6.4 ppm	4.3 ppm	B-240
Couch Foam	4.1 ppm	NA	NA
Air Result 2007	0.32 μg/m^3	0.08 μg/m^3	B-240

NA – Not Applicable
Concentration Units: Bulk results in mg/Kg (ppm), Air Results in μg/m^3