PREDICTING SEASONAL INDOOR PCB CONCENTRATIONS BASED ON FUNDAMENTAL EQUATIONS

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Introduction

Aroclor 1254 is a commercial mixture of polychlorinated biphenyls (PCB) congeners which are a well-known hazard to human and ecological health. These chemicals were commonly used in transformers and capacitors, as well as building materials such as caulking and sealants, until further manufacture of PCB was banned in 1977 under TSCA. PCBs in legacy building materials continue to be a source of human exposure to PCBs (Coghlan et al. 2002). Volatilization from building materials and subsequent inhalation is a potentially important exposure pathway. Inhalation exposure concentrations of PCBs in indoor air are expected to be a function of emission rates (mediated by temperature) and dilution (mediated by building ventilation). We utilized fundamental equations and single-compartment box model to estimate PCB emissions from building materials and the resultant predicted indoor air concentrations. The modeling was designed to address questions that have not been previously explored in the peer-reviewed literature to our knowledge; i) Can seasonal variation in levels of PCBs in indoor air of a building known to have PCB-containing caulking be explained by seasonal variation in temperature dependent flux and building ventilation rates?, and ii) What fraction of the PCBs released from the exterior building materials penetrate indoors?

Materials and Methods

Jayjock's back pressure model (1994) was used to predict the flux of Aroclor 1254. Vapor pressure is directly related to flux with an assumption that caulking does not modify the rate of PCB emission with temperature. Temperature dependent vapor pressure of Aroclor 1254 was determined based on findings from Li (2003) and the PCB congener composition of Aroclor 1254 (ATSDR 2000). The calculated flux was used to predict indoor air concentrations in a multi-story building with known PCB-contaminated caulking and where indoor air samples were previously collected and analyzed. PCB concentrations reported as Aroclor 1254 measured in 18 indoor air samples collected over 4 non-consecutive days during 2006 and 2007 served as the reference data to which the model estimates were compared. Approximately 5,200 linear meters of seams between preformed concrete panels that comprise the façade of this building were sealed with PCB-containing caulking at concentrations from 280 – 74,000 ppm. Empirical data on air exchange rates (AER) for commercial buildings are scarce, perhaps because of the difficulties inherent to measuring AER in large buildings. Therefore, we relied upon seasonal AER reported for a large sample of single family homes throughout the US (Murry and Burmaster, 1995) and a recent study of a multi-unit housing in Boston, MA (Krez, 2009). We calculated the indoor PCB concentration using a one-compartment box model and assuming that all of the PCBs emitted from the caulking penetrated directly into the interior of the building.

Results and Discussion

The daily average temperature of the coldest and the warmest day in our study period was 7 and 19 degree Celsius, respectively. The estimated PCB flux was approximately 13 times greater in the warmest than the coldest day. However, AER during the summer is approximately 3 times greater compared to the winter and mitigates the indoor air concentration. Accounting for temperature-dependent flux and seasonal variation in air exchange rates, the predicted indoor concentration of Aroclor 1254 is five times greater during the warmest compared to the coldest day. The simple model results agree reasonably well with seasonal variation in measured indoor air concentrations. The median indoor concentration of Aroclor 1254 on the warmest sampling day (August 21st, 2006) was 0.90 $\mu g/m^3$and 0.31 $\mu g/m^3$ on the coldest day (January 4th, 2007), approximately three times greater in the summer than in the winter.

PCB flux was estimated to be 7 mg/min when the outdoor temperature was 19 degrees Celsius (this corresponds to the warmest day when air samples were collected). Using the estimated amount of caulking collected during the abatement process, the calculated flux, and a conservative air exchange rate of 0.2 h^{-1}, the indoor air concentration of Aroclor 1254 was predicted to be 28 $\mu g/m^3$, assuming all of the PCBs emitted from the caulking on the exterior of the building penetrated directly into the interior of the building. For direct comparison to measured values, the measured indoor air concentration attributable to caulking material was derived by subtracting the post abatement indoor air concentration (0.2 µg/m^3) from the indoor air concentrations recorded during the warmest day prior to abatement. As expected, the predicted concentration (28 µg/m^3) greatly exceeded the measured indoor air concentrations attributable to caulking material (0.46 – 1.2 µg/m^3) due at least in part to the model assumption of all emitted PCBs entering the building. We used this difference to estimate that approximately 1 – 4% of PCBs emitted from caulking materials on the exterior building envelope penetrated the building. This modeling exercise, though limited by small sample size and simplistic model assumptions, demonstrates that seasonal variation in indoor concentrations of PCBs may be explained by temperature-dependent flux and air exchange rates. These findings are consistent with previous reports and data including i) indoor-outdoor ratios of PCB levels in air reported for buildings with PCB-containing construction materials (Coghlan et al., 2002), and ii) inverse relationships between indoor air PCB concentrations and building pressurization observed in this and other buildings. Elements of this approach may be useful in generating first-order estimates of inhalation exposure concentrations associated with PCBs in construction materials.

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References

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