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PCBs in Indoor Air of Schools, Development of School Action Levels

1. Summary

In 2021, the Vermont legislature required that by 2024 all schools built or renovated prior to 1980 be tested for polychlorinated biphenyls (PCBs) in the indoor air. Also in 2021, the Vermont Department of Environmental Conservation (DEC) was given authority to regulate releases of PCBs from building materials into indoor air.

For evaluation of PCBs in school indoor air, the Vermont Department of Health (Health) has derived a Screening Level of 15 ng/m^3. Because the Screening Level is close to the background PCB concentrations in air (Bräuner et al., 2016, Brown et al., 2016, Marek et al., 2017, Andersen et al., 2020), the testing of several hundred schools in Vermont may result in frequent exceedances due to the prevalence of low levels of PCBs in the indoor environment. Based on our literature review, when indoor air levels of PCBs are only slightly greater than the screening level it may be difficult to identify and abate sources. This is because sources of PCBs inside schools may constantly absorb and emit PCBs into the air, without exceeding bulk material standards (Brown et al., 2016).

To help prioritize the need for action if the Screening Values are exceeded, School Action Levels (SALs, Table 1) have been derived. The State recognized that acceptable SALs need to protect against noncancer health effects of PCBs while considering their widespread presence in our environment and the challenges of removing them. The fact that the SALs are higher than the screening level increases the likelihood that point sources will be identified and remediated to lower indoor air.

The derivation of the SAL differs from that used for the Screening Level. The Screening Level is based on the lowest of the cancer and noncancer values, with the target cancer risk set to one extra case in a million people exposed. The SALs accept a slightly greater cancer risk to adults who work at the school for 30 years than the Vermont screening level. Specifically, the Vermont high school SAL of 100 ng/m^3 may present an increased lifetime cancer risk to adults of approximately 6 extra cases of cancer per million people exposed (based on 30-year exposure duration, 9.75 hours per day and 235 days per year).

The U.S. Environmental Protection Agency (EPA) has developed Exposure Levels for Evaluating PCBs in Indoor Air (ELEs) which protect against noncancer health effects. The ELEs were derived using exposure parameters that estimate average or "central tendency" exposures. Health deviated from EPA's approach by using "reasonable maximum exposure" inputs instead of average exposure inputs for hours per day, days per year, and years worked. The reasonable maximum exposure is the highest exposure that is reasonably expected to occur at a site (EPA 1996). Health also accounted for exposure to non-school air differently than EPA.

The SALs can be used as an indicator of when schools need to identify and abate potential sources of PCBs inside their buildings. PCB levels in the indoor air of schools should be kept as low as possible.

Table 1. PCB School Indoor Air Action Levels ng/m^3

	Pre-Kindergarten	Kindergarten to Grade 6	Grade 7 to Adult
School Action Level	30	60	100

Unit Abbreviations

kg = kilograms
m^3/day = cubic meters per day
mg/kg-day = milligrams per kilogram of body weight per day
ng/kg-day = nanograms per kilogram of body weight per day
ng/m^3 = nanograms per cubic meter

2. Derivation of PCB Indoor Air School Action Levels (SALs)

EPA maintains a list of screening levels for both residential and worker scenarios, that includes screening values for PCBs in residential and worker air. EPA also provides ELEs which are risk management levels. EPA screening levels for PCBs are set to a target cancer risk of one in a million excess lifetime cancer risk, while the ELEs are calculated to protect against noncancer effects. EPA's ELE of 500 ng/m^3 may present an increased lifetime cancer risk to adults who work at the school for 30 years of approximately 32 extra cases of cancer per million people. Like EPA, Health provides both a screening level and SALs (risk management levels) for evaluating PCBs in school indoor air. Health derived SALs for PCBs in indoor air at schools using the EPA ELE methods, as described below. Deviations from the EPA methods are discussed, and formulas and example calculations are provided.

2.1 Toxicity Values

In the derivation of EPA ELEs and Health SALs, EPA toxicity values for Aroclor 1254 (a trade name for common mixtures of PCBs) were used. The noncancer oral toxicity value, termed an oral Reference Dose or RfD$_o$, is defined as "[a]n estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime" (EPA 2011a). The RfD$_o$ for Aroclor 1254, 20 ng/kg-day, is based on the administered lowest dose of 0.005 mg/kg-day, from a study that resulted in effects that included ocular exudate, fingernail bed malformation and immunological suppression (EPA IRIS 1994).

2.2 EPA's PCB Exposure Estimation Tool (PEET)

To evaluate the exposures that occur in school buildings, EPA developed the PCB Exposure Estimation Tool (PEET). This model combines estimates of background exposures and calculates the level of PCBs in school air that will keep the total noncancer dose below the RfD$_o$ for Aroclor 1254 (EPA 2020).

The model incorporates major sources of background PCB exposures, both within and outside of the school environment for several age groups. Exposure in schools is assumed to occur via incidental ingestion of dust and soil, inhalation of indoor and outdoor air and dermal (skin) absorption due to contact with indoor dust. The EPA default model inputs for these parameters are based on average exposures in a non-contaminated environment. Background exposure in the non-school setting is assumed to occur via similar routes with the addition of ingestion exposure via the diet. Using the total background dose for each age group (the sum of the contribution from each source and route of exposure), the PEET model calculates the maximum concentration of PCBs in school indoor air that would not exceed the Aroclor 1254 RfD$_o$ for each age group.

EPA used the PEET to incorporate background PCB exposures to the ELEs for indoor air in schools. Health used the PEET to incorporate background PCB exposures to the SALs for indoor air in schools. The default inputs in the PEET may underestimate exposure in some situations. Health also accounted for sources of PCBs for which the default EPA PEET inputs may not adequately protect students and staff. These sources are discussed below.

2.2.1 PCBs in Foods

A listed limitation of the EPA's PEET is uncertainty in total PCB exposures because of the lack of robust data for background exposures from dietary and other non-school sources (EPA 2012). PCBs are ubiquitous and bioaccumulate in animals, foods with the highest PCB levels are typically fish, meat, and dairy products (ATSDR 2000). While dietary sources are thought to be decreasing since the commercial ban on PCBs, in the absence of a contamination source, the diet is the exposure route of primary importance (Ampleman et al., 2015). After subtracting diet and background from the RfD$_o$, the PEET allows the remaining balance of the RfD$_o$ to be filled by PCBs in school air. If the population in Vermont eats a different diet than the national average or eats more of one specific food group such as dairy, then the PEET would underestimate the contribution from diet. This could result in exposure to school air that exceeds the RfD$_o$.

2.2.2 PCBs in Indoor Dust at Contaminated Schools

Current knowledge about the relationship between air PCB levels in schools and indoor dust levels indicates that elevated PCB dust levels are very likely when air levels above background are present (EPA 2012). EPA's PEET incorporates average background inputs for PCB concentrations in soil and dust at school. The model does not increase the soil and dust PCB levels proportionately to the indoor air PCB levels. If indoor air PCBs are elevated at a school, soil and dust PCB concentrations may also be elevated, therefore a SAL modelled using average (non-contaminated) background inputs may not be protective at a school with PCBs in the indoor air.

2.2.3 PCBs in the Residential Environment

The residential environment may present a source of PCB exposure. An investigative study in Wisconsin found PCBs in household dust with the highest levels from homes built between 1959 and 1970. Suspected sources of this residential PCB contamination include varnishes, paints, caulks, fluorescent light ballasts, and older appliances (Knobeloch, 2012). While the diet is the major source for background PCB exposure in an uncontaminated environment, indoor air in contaminated buildings has been shown to have a greater impact on PCB body-burdens than dietary exposure (Weitekamp et al., 2021, Saktrakulkla et al., 2020). In some situations, PCB levels in residential indoor air and dust may be above the average default inputs in the EPA PEET. Indoor air levels of PCBs were as high as 233 ng/m^3 in New York homes (Wilson, 2011) and as high as ~1,300 and 3,843 ng/m^3 in two separate Denmark apartment buildings (Anderson, 2021; Frederiksen, 2012). In Vermont, approximately 60% of houses were built before 1980 when PCBs were still being manufactured (Vermont Housing Finance Agency, 2020), making residential indoor air a possible source of exposure. In addition to legacy sources of PCBs in buildings, there are ongoing consumer exposures to some PCBs found as contaminants in pigments in currently produced commercial goods such as newspapers, magazines, and cardboard boxes (Hu and Hornbuckle 2010). Therefore, a SAL modeled using average indoor non-school air may result in exposure that exceeds the RfD$_o$ when residential air exceeds EPA's average input for non-school air.

2.3 Source Allocation Factor

In calculating the risk management levels, Vermont differed from EPA in that Health incorporated a Source Allocation Factor (SAF) in the derivation of SALs. The SAF is used to ensure that the concentration of a chemical allowed, when combined with other identified sources of exposure common to the population of concern, will not result in unacceptable exposures (Krishnan and Carrier 2013, Azuma et al., 2020). The EPA PEET incorporates estimates of PCB exposures through soil, dust, diet, and air at average background levels, however at PCB contaminated sites, sources other than the diet make a greater contribution to risk. Average default inputs into the PEET may not adequately protect students and staff from PCB exposure at school. Therefore, the SAF allows for a level of confidence that an individual's total exposure is not underestimated.

The SAF is used to account for the time of exposure to PCBs both at school and while not in school. If a SAF is not applied, then a person exposed in school at the SAL could have no other sources of PCB exposures above the default average background values incorporated in the EPA PEET model. Because not all of one's possible exposure to PCBs may come from the indoor air at school, Health allocated the total exposure by the percentage method (EPA 2000), using the time at school as a relative exposure metric. To allocate for exposures other than during the school day, Health used the percent of time at school: 9.75 hours per 24-hour day, equal to 0.41.

2.4 Vermont SAL Exposure Assumptions

To calculate SALs based on noncancer effects in Vermont schools, Health modified EPA's PEET model to use reasonable maximum exposure (RME) assumptions for exposure time, frequency, and duration, as suggested in EPA's Risk Assessment Guidance for Superfund (EPA 1989). The intent of the RME is to estimate a conservative exposure scenario that is still within the range of possible exposures (EPA, 1989). Exposure time is 9.75 hours, taken from the EPA Exposure Factors Handbook, time spent indoors at school (EPA 2011b). Exposure frequency is 235 days, based on the required 175 days of school plus EPA's high-end estimate of 60 days spent at summer camp at school (EPA 2020). Exposure duration for adults is 30 years, which represents typical retirement age in Vermont. Inputs for background air PCBs were set to zero since the non-school air exposures were accounted for based on time (section 2.3). All other central tendency inputs (e.g., soil, dust, and diet) in the EPA PEET were left unchanged.

Table 2. Inputs Used to Calculate the VT SALs

Symbol	Definition (Units)	Value	Reference
SAL	School Action Level (ng/m^3)	Calculated	
RfD	Chronic Oral Reference Dose (ng/kg-day)	20	EPA 1994
THQ	Target Hazard Quotient (unitless)	1.0	
SAF	Source Allocation Factor	0.41	Fraction of day at school
LT	Lifetime (years)	70	EPA 1989
EF	Exposure Frequency – (days/year)	235	NCES 2018, EPA PEET
ED	Exposure Duration– Adult (years)	30	Health 2019
ET	Exposure Time, (hours/day)	9.75	EPA 2011b Table 16-18
InhR	Inhalation Rate - (m^3/day)	8-16.3	Central tendency age-based ranges EPA 2020
BW	Body Weight - (kg)	11.4-80	Mean recommended age-based values EPA 2020
CF1	Conversion Factor 1 (hours/day)	24	
CF2	Conversion Factor 2 (days/year)	365	
CF3	Conversion Factor 3 (kg/mg)	1×10^{-6}	

2.5 Equations used for the School Action Level

School Action Level Equation

$$\text{SAL (ng/m}^3) = \text{SAF x} \frac{1\left(\text{RfD}\left(\frac{\text{ng}}{\text{kg day}}\right) - \text{BkgExp}\left(\frac{\text{ng}}{\text{kg day}}\right)\right) \text{x BW (kg) x ED (years) x CF1}\left(\frac{\text{hr}}{\text{day}}\right) \text{ x CF2}\left(\frac{\text{days}}{\text{year}}\right)}{\left(\text{InhR}\left(\frac{\text{m3}}{\text{day}}\right)\text{x ET}\left(\frac{\text{hr}}{\text{day}}\right)\text{x EF}\left(\frac{\text{days}}{\text{year}}\right)\text{ x ED (years)}\right)}$$

Example Calculation for Adult 19 years and older

$$\text{SAL (ng/m}^3) = 0.41 \text{ x} \frac{\left(20\left(\frac{\text{ng}}{\text{kg day}}\right) - 4.9\left(\frac{\text{ng}}{\text{kg day}}\right)\right) \text{x 71.8 (kg) x 30 (years) x 24}\left(\frac{\text{hr}}{\text{day}}\right) \text{ x 365}\left(\frac{\text{days}}{\text{year}}\right)}{\left(15.9\left(\frac{\text{m}^3}{\text{day}}\right)\text{x 9.75}\left(\frac{\text{hr}}{\text{day}}\right)\text{x 235}\left(\frac{\text{days}}{\text{year}}\right)\text{ x 30 (years)}\right)}$$

$$\text{SAL} \approx 100 \text{ ng/m}^3$$

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