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

1. Summary

In 2021, the Vermont legislature required that 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.

In 2020, the Vermont Department of Health (Health) derived a Screening Value of 15 ng/m^3 for PCBs in indoor air of schools. The school air PCB Screening Value 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), therefore 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 prioritize the need for action if the Screening Value is 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 Value increases the likelihood that significant point sources will be identified and remediated to lower indoor air PCBs.

The derivation of the SALs differs from what was used for the Screening Value. The Screening Value is based on the lower of the cancer and noncancer risk-based air concentration, with the target cancer risk set to one extra case in a million people exposed. The PCB air concentrations used as SALs accept a slightly greater cancer risk to adults who work at the school for 30 years than the Vermont Screening Value. Specifically, the Vermont high school SAL of 100 ng/m^3 (Grade 7 and above) equates to an increased lifetime cancer risk 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).

Vermont used the U.S. Environmental Protection Agency (EPA) recommended approach to derive both the school indoor air PCB Screening Value and the SALs. EPA has developed Exposure Levels for Evaluating PCBs in Indoor School Air (ELEs) which protect against noncancer health effects (EPA 2022). The EPA ELEs were derived using average or "central tendency" exposure estimates. 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 from routes other than school air by incorporation of a Source Allocation Factor (SAF), as described below.

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/m3

	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)

Environmental screening values help expedite the identification and evaluation of potential environmental concerns at contaminated sites. Health risk assessment determines the environmental chemical levels that are unlikely to produce adverse health effects from a specific exposure. Risk management is used to determine acceptable risk in consideration of scientific uncertainty, management options, economic benefits and costs, relevant laws and social norms (WHO 2021). For risk evaluation of PCBs in indoor air, EPA has established both Regional Screening Levels (RSLs) for residential and worker scenarios, and ELEs for PCBs in school air which are risk management levels (EPA 2023). The RSLs 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 a school for 30 years, of approximately 32 extra cases of cancer per million people. Like EPA, Health provides both a Screening Value and SALs (risk management levels) for evaluating PCBs in school indoor air. Health derived SALs for PCBs in indoor air of schools using the EPA ELE methods. Vermont modifications to the EPA methods are discussed and the formulas and example calculations are provided below.

2.1 Toxicity Values

EPA toxicity values for Aroclor 1254 (a trade name for common mixtures of PCBs) were used for derivation of EPA's ELEs and Health's SALs. 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 an animal study where the administered lowest dose of 0.005 mg/kg-day resulted in adverse 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). The PEET combines estimates of total PCB exposure from diet and home environments 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 PEET 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 accounted for sources of PCBs for which the default EPA PEET inputs may not adequately protect students and staff. These sources are discussed below.

2.3 Source Allocation Factor (SAF)

Vermont differed from EPA in calculation of risk management levels by incorporating a SAF in the derivation of SALs. The SAF is used to ensure that the concentration of a chemical at the SAL, when combined with other sources of environmental exposure to the chemical, will not result in a cumulative unacceptable exposure (Krishnan and Carrier 2013, Azuma et al., 2020). The EPA PEET incorporates estimates of average background PCB exposure through soil, dust, diet and air from a non-contaminated environment. However, at PCB contaminated sites, soil, dust and air may make a greater contribution to risk (Montano et al., 2022). EPA states that

"PCB concentrations in a school's outdoor soils or indoor dusts greater than those in non-school environments would indicate a potential for increased exposure from these pathways. Thus, school indoor air concentrations would need to be decreased to maintain overall exposure below the RfD." Health used a SAF to account for sources of PCBs for which the default EPA PEET inputs may not accurately reflect potentially elevated PCB exposures to students and staff at PCB-contaminated schools. Other potential sources of environmental PCB exposure are discussed below.

2.3.1 PCBs in Foods

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). The PEET model uses the best available average estimate of PCBs in the US diet, however average data represent exposure in the general population and may underestimate people with higher PCB intake (EPA 2020). After subtracting average diet, soil and dust intake from the RfDo, the PEET allows the remaining balance of the RfDo 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. Without a SAF, an increase in dietary exposure above the average could result in a cumulative exposure that exceeds the RfDo.

2.3.2 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. Use of a SAF allows for potentially increased exposures from sources other than school air, such as dust at contaminated schools.

2.3.3 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). Use of a SAF allows for potentially increased exposures from sources other than school air, such as residential air.

2.3.4 SAF Determination

The SAF is used to account for exposure to PCBs both at school and while not in school. If a SAF was 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 (Carlson et al., 2023). 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 Exposure Assumptions for SALs

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). The exposure time of 9.75 hours is taken from the EPA Exposure Factors Handbook, for time spent indoors at school (EPA 2011b). The 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). The exposure duration for adults is 30 years, which represents typical length of employment for school staff in Vermont. The exposure durations for school age groups were left at EPA defaults. Within the PEET, the background air PCB concentrations 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 Vermont SALs

Definition (Units)	Symbol	Value	Reference
School Action Level (ng/m^3)	SAL	Calculated	
Chronic Oral Reference Dose (ng/kg-day)	RfD	20	EPA 1994
Target Hazard Quotient (unitless)	THQ	1	
Source Allocation Factor	SAF	0.41	Fraction of day at school
Lifetime (years)	LT	70	EPA 1989
Exposure Frequency (days/year)	EF	235	NCES 2018, EPA 2020
Exposure Time (hours/day)	ET	9.75	EPA 2011b Table 16-18
Exposure Duration (years)	ED		
Age Group	1<3	2	EPA 2020
	3 to <6	3	EPA 2020
	6 to <12	6	EPA 2020
	12 to <15	3	EPA 2020
	Adult	30	Health 2021
Inhalation Rate (m^3/day)	InhR		Central tendency age-based ranges
Age Group	1<3	12.6	EPA 2020
	3 to <6	10.9	EPA 2020
	6 to <12	12.4	EPA 2020
	12 to <15	15.1	EPA 2020
	Adult	15.9	EPA 2020
Body Weight - (kg)	BW		Mean recommended age-based values
Age Group	1<3	12.6	EPA 2020
	3 to <6	18.6	EPA 2020
	6 to <12	31.8	EPA 2020
	12 to <15	56.8	EPA 2020
	Adult	71.8	EPA 2020
Background Exposure (ng/kg-day)	BkgExp		
Age Group	1<3	5.8	EPA 2020
	3 to <6	4.5	EPA 2020
	6 to <12	3.2	EPA 2020
	12 to <15	2.1	EPA 2020
	Adult	2.1	EPA 2020
Conversion Factor 1 (hours/day)	CF1	24	
Conversion Factor 2 (days/year)	CF2	365	
Conversion Factor 3 (kg/mg)	CF3	$1\text{x}10^{-6}$	

2.5 Example Equations for School Action Level Derivation

School Action Level Equation

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

Example Calculation for Grades 7 and Older

$$\text{SAL }(\text{ng/m}^3) = 0.41 \text{ x } \frac{\left(20\left(\frac{\text{ng}}{\text{kg day}}\right) - 2.1\left(\frac{\text{ng}}{\text{kg day}}\right)\right) \text{ x } 56.8 \text{ (kg) x } 30 \text{ (years) x } 24 \left(\frac{\text{hr}}{\text{day}}\right) \text{ x } 365 \left(\frac{\text{days}}{\text{year}}\right)}{\left(15.1 \left(\frac{\text{m}^3}{\text{day}}\right) \text{ x } 9.75 \left(\frac{\text{hr}}{\text{day}}\right) \text{ x } 235 \left(\frac{\text{days}}{\text{year}}\right) \text{ x } 30 \text{ (years)}\right)}$$

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

Example Calculation for Grades K-6

$$\text{SAL }(\text{ng/m}^3) = 0.41 \text{ x } \frac{\left(20\left(\frac{\text{ng}}{\text{kg day}}\right) - 3.2\left(\frac{\text{ng}}{\text{kg day}}\right)\right) \text{ x } 31.8 \text{ (kg) x } 6 \text{ (years) x } 24 \left(\frac{\text{hr}}{\text{day}}\right) \text{ x } 365 \left(\frac{\text{days}}{\text{year}}\right)}{\left(12.4 \left(\frac{\text{m}^3}{\text{day}}\right) \text{ x } 9.75 \left(\frac{\text{hr}}{\text{day}}\right) \text{ x } 235 \left(\frac{\text{days}}{\text{year}}\right) \text{ x } 6 \text{ (years)}\right)}$$

$$\text{SAL} \approx 60 \text{ ng/m}^3$$

3. References

ATSDR 2000. Toxicological profile for polychlorinated biphenyls (PCBs). Agency for Toxic Substances and Disease Registry (ATSDR). 2000. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Ampleman MD, Martinez A, DeWall J, Rawn DF, Hornbuckle KC, Thorne PS. Inhalation and dietary exposure to PCBs in urban and rural cohorts via congener-specific measurements. Environ Sci Technol. 2015;49(2):1156-1164. doi:10.1021/es5048039

Andersen, H. V., Gunnarsen, L., Knudsen, L. E., & Frederiksen, M. (2020). PCB in air, dust and surface wipes in 73 Danish homes. International Journal of Hygiene and Environmental Health, 229, [113429]. https://doi.org/10.1016/j.ijheh.2019.113429

Azuma K, Jinno H, Tanaka-Kagawa T, Sakai S. Risk assessment concepts and approaches for indoor air chemicals in Japan. Int J Hyg Environ Health. 2020;225:113470. doi:10.1016/j.ijheh.2020.113470

Bräuner, E., Andersen, Z., Frederiksen, M. et al. Health Effects of PCBs in Residences and Schools (HESPERUS): PCB – health Cohort Profile. Sci Rep 6, 24571 (2016). https://doi.org/10.1038/srep24571

Brown KW, Minegishi T, Cummiskey CC, Fragala MA, Hartman R, MacIntosh DL. PCB remediation in schools: a review. Environ Sci Pollut Res Int. 2016;23(3):1986-1997. doi:10.1007/s11356-015-4689-y

Carlson 2023. Laura M. Carlson, Kramek N., Lehmann D.M., Thomas K., Owen S., Maddaloni M., Ginsberg G., Poulsen M., Rajan P., Kapraun D.F., Foster S., Lehmann G.M., Risk assessment, risk management, and regulation of halogenated organic chemicals: Current practice and future directions. Advances in Neurotoxicology. Academic Press,2023.

EPA 1989. U.S. Environmental Protection Agency. Risk assessment guidance for superfund. Volume I. human health evaluation manual (Part A). Interim Final. Office of Emergency and Remedial Response U.S. Environmental Protection Agency Washington, D.C. 20450 EPA/540/1-89/002 December 1989.

EPA 1994. U.S. Environmental Protection Agency. Integrated Risk Information System (IRIS) assessment of Aroclor 1254. U.S. Environmental Protection Agency https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=389. Accessed 10/15/2020.

EPA 2000. U.S. Environmental Protection Agency. Methodology for deriving ambient water quality criteria for the protection of human health. U.S. Environmental Protection Agency Office of Water, EPA-822-B-00-004, Oct., 2000. https://www.epa.gov/wqc/fact-sheet-methodology-deriving-ambient-water-quality-criteria-protection-human-health-revised

EPA 2011a. U.S. Environmental Protection Agency. IRIS glossary. https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&vocabName=IRIS%20Glossary&filterTerm=reference&checkedAcronym=false&checkedTerm=false&hasDefinitions=false&filterTerm=reference&filterMatchCriteria=Contains Accessed October 2021.

EPA 2011b. U.S. Environmental Protection Agency. Exposure factors handbook. Office of Research and Development, National Center for Environmental Assessment, Washington, D.C. 20460. https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=522996. Accessed October 2021.

EPA 2012. U.S. Environmental Protection Agency. "Polychlorinated biphenyls (PCBs) in school buildings: Sources, environmental levels, and exposures" Au: Kent Thomas, Jianping Xue, Ronald Williams, Paul Jones, Donald Whitaker; EPA/600/R-12/051. 2012 Sep 30. https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/1597570

EPA 2020. U.S. Environmental Protection Agency. PCB Exposure Estimation Tool, Version 2.1, January 16, 2020. Obtained from EPA Region 1 PCB Coordinator, September 2021, not available online.

EPA 2022. U.S. Environmental Protection Agency. Exposure Levels for Evaluating Polychlorinated Biphenyls (PCBs) in Indoor School Air. Available at: epa.gov/pcbs/exposure-levels-evaluating-polychlorinated-biphenyls-pcbs-indoor-school-air

EPA 2023. U.S. Environmental Protection Agency. Regional Screening Levels (RSLs) - Generic Tables May 2023. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

Frederiksen M, Meyer H, Ebbehøj NE, Gunnarsen L. Polychlorinated biphenyls (PCBs) in indoor air originating from sealants in contaminated and uncontaminated apartments within the same housing estate. Chemosphere 2012, 89, 473-479. http://dx.doi.org/10.1016/j.chemosphere.2012.05.103

Health 2021. Vermont Department of Health, Indoor air screening value guidance 2021. https://www.healthvermont.gov/sites/default/files/documents/pdf/ENV_ECP_GeneralScreeningValues_Air.pdf

Hu, D and Hornbuckle, KC. Inadvertent polychlorinated biphenyls in commercial paint pigments. Environ Sci Technol. 2010 Apr 15; 44(8): 2822–2827. Published online 2009 Dec 3. doi: 10.1021/es902413k

Knobeloch L, Turyk M, Imm P, Anderson H. Polychlorinated biphenyls in vacuum dust and blood of residents in 20 Wisconsin households. Chemosphere. 2012;86(7):735-740. doi:10.1016/j.chemosphere.2011.10.048

Krishnan K. and Carrier R. (2013) The use of exposure source allocation factor in the risk assessment of drinking-water contaminants, Journal of Toxicology and Environmental Health, Part B, 16:1, 39-51, doi: 10.1080/10937404.2013.769419

Montano L, Pironti C, Pinto G, Ricciardi M, Buono A, Brogna C, Venier M, Piscopo M, Amoresano A, Motta O. Polychlorinated Biphenyls (PCBs) in the Environment: Occupational and Exposure Events, Effects on Human Health and Fertility. Toxics. 2022 Jul 1;10(7):365. doi: 10.3390/toxics10070365

NCES 2018. National Center for Education Statistics (NCES) Table 5.14. Number of instructional days and hours in the school year, by state: 2018 https://nces.ed.gov/programs/statereform/tab5_14.asp (accessed 10/2020).

Saktrakulkla P, Lan T, Hua J, Marek RF, Thorne PS, Hornbuckle KC. Polychlorinated biphenyls in food. Environ Sci Technol. 2020;54(18):11443-11452. doi: 10.1021/acs.est.0c03632

Vermont Housing Finance Agency. February 2020. Vermont housing needs assessment: housing stock. Accessed October 2021. https://accd.vermont.gov/sites/accdnew/files/documents/Housing/Fact%20sheet%203%20Housing%20stock.pdf

Wilson LR, Palmer PM, Belanger EE, Cayo MR, Durocher LA, Hwang SA, Fitzgerald EF. Indoor air polychlorinated biphenyl concentrations in three communities along the Upper Hudson River, New York. Arch Environ Contam Toxicol. 2011 Oct;61(3):530-8. https://doi.org/10.1007/s00244-010-9627-x

Weitekamp CA, Phillips LJ, Carlson LM, DeLuca NM, Cohen Hubal EA, Lehmann GM. A state-of-the-science review of polychlorinated biphenyl exposures at background levels: Relative contributions of exposure routes. Science of The Total Environment, Volume 776, 2021, 145912, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2021.145912

WHO 2021. WHO human health risk assessment toolkit: chemical hazards, second edition. Geneva: World Health Organization; 2021 (IPCS harmonization project document, no. 8). https://www.who.int/publications/i/item/9789240035720