VERMONT

State of Vermont
Department of Health
Environmental Health
108 Cherry Street – PO Box 70
Burlington, VT 05402-0070
HealthVermont.gov

[phone] 802-863-7220
[fax] 802-863-7483
[toll free] 800-439-8550

Agency of Human Services

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PCBs in Indoor Air of Schools, Development of a Screening Value

The Vermont Department of Health developed a screening value for Polychlorinated Biphenyls (PCBs) in school air based on both cancer and noncancer health effects. The screening value is the chemical concentration below which no additional actions are recommended. The screening value is based on a reasonable maximum exposure scenario and can be used as an indicator of when schools may have potential sources of PCBs inside their buildings. Details are provided in the following pages.

The Health Department's screening value for PCBs in school air of 15 ng/m^3 is protective of both cancer and noncancer health effects for children of all ages and staff in Vermont schools. It is recommended that PCB levels in the indoor air of schools be kept as low as possible.

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
ppm = parts per million
µg/m^3 = micrograms per cubic meter

1. Noncancer Screening Values

A. Toxicity Values

The indoor air PCB screening values are derived based upon the level of PCBs known to have toxic effects. The Health Department used the U.S. Environmental Protection Agency (EPA) toxicity values for Aroclor 1254 to calculate the screening levels. 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 2011).

The RfD_O for Aroclor 1254, 20 ng/kg-day, is based on the lowest dose of 0.005 mg/kg-day in a study that resulted in effects such as ocular exudate (pus), fingernail bed malformation and immunological suppression (EPA 1994). The EPA RfD_O was published in 1994. EPA applied uncertainty factors to derive the RfD_O from the Lowest Observed Adverse Effect Level (LOAEL) of 0.005 mg/kg/day based on the qualities of the critical toxicology studies and the database of toxicity information available at the time. The total uncertainty factor was 300. There was no modifying factor or database uncertainty factor (UF_D) to account for identifying a more sensitive point of departure.

B. More Recent Studies

Since 1994, several toxicology studies have been published on sensitive endpoints including neurodevelopmental toxicity at doses lower than the LOAEL selected in the 1994 EPA assessment of Aroclor 1254 (Klocke 2020, Rasinger 2018, NTP 2006, Haave 2011). Epidemiology data published in the last 26 years support the concern for neurodevelopmental outcomes in children exposed in utero (ATSDR 2016, Boucher 2009, Stewart 2008, Schantz 2003, Landrigan 2001, Darvill 2000, Patandin 1999, Jacobsen 1996).

This evidence suggests that the 1994 RfD_O may not adequately protect against sensitive health outcomes. When the underlying toxicological database is found to be deficient to assess sensitive endpoints, EPA applies a UF_D (EPA 2002, Dankovic 2015). For example, a UF_D of 10 was applied for the RfD for benzo(a)pyrene citing in part that "the available neurotoxicity studies did not comprehensively evaluate all potentially vulnerable lifestages of nervous system development" (EPA 2017). If a UF_D of 10 was applied to the RfD_O for Aroclor 1254, the resulting RfD_O would be below the estimated background intake of PCBs. Therefore, for a quantitative comparison, the noncancer screening value was divided by 10 to represent the weakness in the database used for the RfD_O.

C. EPA's PCB Exposure Estimation Tool (PEET)

There are many sources of PCB exposures in the environment. To evaluate the exposures that occur in school buildings, EPA developed the PCB Exposure Estimation Tool (PEET). This tool estimates and combines background exposures and calculates the level of PCBs in school air that keeps the total noncancer dose below the RfD_O for Aroclor 1254 (EPA 2009).

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 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.

The Health Department followed EPA's process to subtract the background contribution of PCBs from the RfD_o to calculate the screening levels for indoor air in schools, as shown below.

2. Cancer Screening Values

To evaluate potential cancer risks, the Health Department used the Inhalation Unit risk for Aroclor 1254 provided by EPA (EPA 2020a). EPA recommends using the high risk/persistence slope factor when exposures include inhalation of a dust or aerosol contaminated with PCBs or early life exposure for all pathways and PCB mixtures (EPA 2020a).

Health used EPA standard risk assessment procedures to derive estimates of cancer risk from potential exposure to indoor air (EPA 2020b). The target incremental increase in lifetime cancer risk is set to 1 excess cancer per million people exposed (1×10^{-6}). This evaluation of cancer risk from PCB exposure in indoor air does not incorporate background exposures to PCBs as the noncancer approach does. Screening values derived with this approach are presented in the table below.

3. Screening Value Exposure Assumptions

Vermont used EPA's PEET model with reasonable maximum exposure (RME) assumptions (exposure time, frequency and duration) to calculate screening values based on noncancer effect assumptions 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). All other central tendency inputs in the EPA PEET were left unchanged, including dietary exposure and PCB concentrations in soil.

	Exposure Estimates and Screening Values					
Parameter	Child care (1 to less than 3 years old)	Preschool (3 to less than 6 years old)	Elementary school (6 to less than 12 years old)	Middle school (12 to less than 15 years old)	High school (15 to less than 19 years old)	Staff adult (19 years and older)
Exposure time (hours per day)	9.75	9.75	9.75	9.75	9.75	9.75
Exposure frequency (days/year)	235	235	235	235	235	235
Exposure duration (years)	2	3	6	3	4	30
Noncancer Screening value (ng/m^3)	4*	6*	15	22	28	30
Cancer Screening value (ng/m^3)	26					16

na = not available on EPA's website

* The reporting level for Aroclor 1254 is 13 ng/m^3 based on 2013-2014 school testing in Vermont.

The screening value of 15 ng/m^3 was chosen as a health-protective value for all age ranges considering both cancer and noncancer outcomes, including sensitive endpoints that were not well documented in 1994, as well as the reporting level.

5. Equations and inputs

Symbol	Definition (Units)	Value	Reference
SVca	Indoor Air Screening Value cancer (ng/m^3)	Calculated	
SVnc	Indoor Air Screening Value noncancer (ng/m^3)	Calculated	
SVnc_adj	Noncancer Screening Value with RfD database UF	Calculated	SVnc/10
RfD	Chronic Oral Reference Dose (ng/kg-day)	20	EPA 1994
URi	Inhalation Unit Risk $(ng/m^3)^{-1}$	$5.71x10^{-1}$	EPA 2020a
THQ	Target Hazard Quotient (unitless)	1.0	
TR	Target Incremental Lifetime Cancer Risk (unitless)	$1x10^{-6}$	
LT	Lifetime (years)	70	EPA 1989
AT_{ca}	Averaging Time, Cancer (days)	365 x LT f=25550	Calculated
EF	Exposure Frequency – Adult (days/year)	235	NCES 2018, EPA PEET
ED	Exposure Duration– Adult (years)	30	VDH 2019
ET	Exposure Time, (hours/day)	9.75	EPA 2011 Table 16-18
InhR	Inhalation Rate -Adult (m3/day)	15.9	Central tendency adult value EPA 2009.
BW	Body Weight -Adult (kg)	71.6	Mean recommended values for adults EPA 1997.
CF1	Conversion Factor 1 (hours/day)	24	
CF2	Conversion Factor 2 (days/year)	365	
CF3	Conversion Factor 3 (kg/mg)	$1x10^{-6}$	
BkgExp	Background exposure to PCBs (ng/kg-day)	2.9	EPA PEET model

A. Cancer Screening Value Equation:

$$\mathrm{SVca}\ (\mathrm{ng/m^3}) = \frac{\mathrm{TR} \times \left(\mathrm{ATca}\ (\mathrm{days}) \times\ \mathrm{CF1}\ \left(\frac{\mathrm{hr}}{\mathrm{day}}\right)\right)}{\left(\mathrm{URi}\ \left({}^{\mathrm{ng}}/_{\mathrm{m^3}}\right)^{-1} \times \mathrm{EF}\ \left(\frac{\mathrm{days}}{\mathrm{year}}\right) \times \mathrm{ED}\ (\mathrm{years}) \times \mathrm{ET}\left(\frac{\mathrm{hr}}{\mathrm{day}}\right) \times \mathrm{CF3}\ \left(\frac{\mathrm{kg}}{\mathrm{mg}}\right)\right)}$$

Example Calculation for Adult 19 years and older:

$$\mathrm{SVca}\ (\mathrm{ng/m^3}) = \frac{0.000001 \times \left(25550\ (\mathrm{days}) \times 24\ \left(\frac{\mathrm{hr}}{\mathrm{day}}\right)\right)}{\left(5.71\mathrm{E}^{-1}\left({}^{\mathrm{ng}}/_{\mathrm{m^3}}\right)^{-1} \times 235\ \left(\frac{\mathrm{days}}{\mathrm{year}}\right) \times\ 30\ (\mathrm{years}) \times 9.75\ \left(\frac{\mathrm{hr}}{\mathrm{day}}\right) \times 0.000001\ \left(\frac{\mathrm{kg}}{\mathrm{mg}}\right)\right)}$$

$$\mathrm{SVca} = 15.6\,\mathrm{ng/m^3}$$

B. Noncancer Screening Value Equation:

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

Example Calculation for Adult 19 years and older:

$$\mathrm{SVnc\ (ng/m^3)} = \frac{\left(20\left(\frac{\mathrm{ng}}{\mathrm{kg\ day}}\right) - 2.9\left(\frac{\mathrm{ng}}{\mathrm{kg\ day}}\right)\right) \mathrm{x\ 71.8\ (kg)\ x\ 30\ (years)\ x\ 24}\left(\frac{\mathrm{hr}}{\mathrm{day}}\right)\ \mathrm{x\ 365}\left(\frac{\mathrm{days}}{\mathrm{year}}\right)}{\left(15.9\left(\frac{\mathrm{m^3}}{\mathrm{day}}\right) \mathrm{x\ 9.75}\left(\frac{\mathrm{hr}}{\mathrm{day}}\right) \mathrm{x\ 235}\left(\frac{\mathrm{days}}{\mathrm{year}}\right) \mathrm{x\ 30\ (years)}\right)}$$

$\mathrm{SVnc} = 295\ \mathrm{ng/m^3}$

$\mathrm{SVnc\_adj} = 29.5\ \mathrm{ng/m^3} = 30\ \mathrm{ng/m^3}$

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