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 Recommended Concentrations

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In recent years, elevated levels of polychlorinated biphenyls (PCBs) have been detected in the indoor air of some buildings, including several schools in the Northeastern United States. Consequently, the Vermont Department of Environmental Conservation (DEC), in conjunction with the Departments of Education (DOE) and Health (VDH), is developing a pilot study to investigate the presence of PCBs in indoor air of schools in Vermont.

PCBs exhibit both cancer and noncancer health effects. In 2009, the United States Environmental Protection Agency (EPA) issued recommendations for PCBs levels in indoor air of schools. These recommendations were derived using average exposure parameter values and based on noncancer health effects. EPA's recommendations for PCB levels in school air range from 70 - 600 ng/m^3 for daycare to high school students.

In Vermont, recommendations are calculated using reasonable maximum exposure parameter values. Our group developed recommendations for PCB levels in school air based on both cancer and noncancer health effects. The most conservative recommendations were associated with an excess lifetime carcinogenic risk of one in one million for hypothetical students and staff members.

Our recommended concentration 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.

Attachment A: Summary of EPA's 2009 Screening Concentrations

1. EPA's exposure assessment tool

Using a workbook of interconnected electronic spreadsheets known as the PCB Exposure Estimation Tool (PEET), EPA developed a set of suggested screening concentrations for PCBs in school indoor air. As noted, seven different age groupings, ranging from hypothetical toddlers of daycare age to adult school staff, were examined. These values are presented below:

EPA 2009 Noncancer Based PCB School Air Screening Concentrations							
Hypothetical exposure scenario	Daycare	Daycare	Preschool	Elementary school	Middle school	High school	School staff
Age range	1- <2 years	2- <3 years	3- <6 years	6- <12 years	12- <15 years	15- <19 years	Adult 19+ years
Screening value (ng/m^3)	70	70	100	300	450	600	450

Overall, the model uses standard point estimate risk assessment procedures to mathematically combine estimates of the concentrations of PCBs in various environmental media with estimates of contact rates to yield estimates of potential exposure dose (dose).

Major sources of PCB exposure, both in and outside (i.e., background) of the school environment, are considered in the model. Exposure in schools is assumed to occur via incidental ingestion of dust and soil, inhalation of indoor and outdoor air and dermal absorption due to contact with indoor dust. Background exposure is assumed to occur via similar routes in the non-school setting with the addition of ingestion exposure via the diet.

For each age grouping, estimates of dose that may be associated with each source and route of exposure, as well as total dose across all sources and routes are derived.

The 2009 screening concentrations are intended to be reflective of average or central tendency estimates of exposure (EPA, 2009). In general, mean or median estimates of age group-specific contact rates and concentrations of PCBs in each source were developed from data in peer-reviewed EPA publications and the scientific literature and used as default model inputs. Estimates of dietary intake were derived from the 1997 Food and Drug Administration total diet study (EPA, 2009). EPA notes that default input values may be changed as needed to address site-specific concerns, other scenarios or conditions of interest. Inputs are easily revised, and updated estimates of exposure dose and school indoor air screening concentrations are automatically derived.

PCBs exhibit both carcinogenic and non-carcinogenic effects. EPA's Integrated Risk Information System (IRIS) database contains oral toxicity values for each. Thus, school indoor air screening concentrations can be derived based on cancer as well noncancer effects. Most typically, values associated with a target excess lifetime carcinogenic risk of one in one million ($1x10^{-6}$) are most restrictive. The EPA's 2009 screening concentrations are based upon concern for the development of noncarcinogenic health effects. A possible reason for this is postulated in Section 3 below.

2. PEET DOSE LIMIT – The Noncancer Oral Reference Dose (RfD_o)

In the PEET, calculated estimates of dose are compared to the noncancer oral toxicity value for a specific commercial mixture of PCBs known as Aroclor 1254. This type of 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).

At 20 nanograms of chemical per kilogram of body weight per day (ng/kg-d), the RfD_O for Aroclor 1254 is the most conservative available for any PCB mixture listed in the EPA's IRIS database. Estimates of chronic average daily dose below this are not expected to result in an increase in the level of concern for development of adverse, noncarcinogenic (threshold type) effects.

IRIS does not contain a noncancer inhalation toxicity value for Aroclor 1254 or any other Aroclor. In order to develop quantitative estimates of dose that may be associated with inhalation exposure, assessment equations were modified to incorporate age group- specific inhalation rates and body weights. This yields estimates of inhalation dose in the same units as oral and dermal dose as well as the RfD_O. Total dose is derived by summing the contribution from each source and route of exposure.

For each age group, the PEET model calculates the maximum concentration of PCBs in school indoor air that would yield an inhalation dose that when combined with the contribution from all other sources would yield a total dose equal to 20 ng/kg-d. This assumes the contribution from all other sources remains unchanged.

3. CONSIDERATION OF CARCINOGENICITY- The Inhalation Unit Risk (IUR)

EPA currently conducts cancer and noncancer assessments in very different ways. For carcinogens, it is generally assumed that no threshold level of exposure exists.

EPA has categorized cancer potency for PCBs using a tiered approach based on risk and persistence (i.e., high risk/persistence, low risk/persistence and lowest risk/persistence). IRIS contains oral cancer potency factors (Slope Factors or CSF_O) for each category. Route-to-route extrapolation to develop estimates of inhalation cancer potency (Inhalation Unit Risk [IUR] in weight of chemical per cubic meter of air e.g., $\mu g/m^3$) is supported. Criteria for use of the high risk/persistence tier includes inhalation of a dust or aerosol contaminated with PCBs as well as

early life exposure for all pathways and PCB mixtures. IRIS details "Because of the potential magnitude of early-life exposures (ATSDR, 1993; Dewailly et al., 1991, 1994), the possibility of greater perinatal sensitivity (Calabrese and Sorenson, 1977; Rao and Banerji, 1988), and the likelihood of interactions among thyroid and hormonal development, it is reasonable to conclude that early-life exposures may be associated with increased risks." An Inhalation Unit Risk of $5.7E^{-4}$ $(\mu g/m^3)^{-1}$ is associated with this tier.

Although verification has not been obtained, it appears that the EPA's 2009 screening concentrations are based on noncancer effects because carcinogenic risk was evaluated using the less restrictive IUR of $1.1E^{-4}$ $(\mu g/m^3)^{-1}$ associated with the low risk/persistence category. Use of this category in the assessment of early life exposures, e.g., a hypothetical school child, appears to be contraindicated as noted above. In addition, as sampling efforts typically do not derive separate particle and gas phase air concentrations, it may not be appropriate to dismiss inhalation of dust or aerosols from consideration. Both incidental ingestion of and dermal exposure to PCBs that may be present in dust are considered in the PEET.

Attachment B: Summary of Vermont-derived Screening Concentrations

Consistent with EPA risk assessment guidance (EPA, 1989) and Vermont Department of Health practice, reasonable maximum exposure (RME) assumptions were developed for the school indoor air inhalation pathway for each age group. The intent of the RME is to estimate a conservative exposure scenario that is still within the range of possible exposures (EPA, 1989). A summary of the RME exposure assumptions employed by VDH and the Central Tendency (CT) values used in the EPA 2009 effort is presented below:

	EPA 2009 Central Tendency Exposure Estimates					
Exposure parameter	Daycare 1-<3 years	Preschool 3-<8 years	Elementary school 6-<12 years	Middle school 12-<16 years	High school 16-<19 years	Staff adult 19+
Exposure time (hours indoors/day	7.5	6	6	6	6	8
Exposure frequency (days/year)	185	180	180	180	180	185
Exposure duration (years)	2	3	6	3	4	25

Note: While EPA does not specify staff exposure duration, 25 years is a standard EPA default value.

	VT Reasonable Maximum Exposure Estimates					
Exposure parameter	Daycare 1-<3 years	Preschool 3-<8 years	Elementary school 6-<12 years	Middle school 12-<16 years	High school 16-<19 years	Staff adult 19+
Exposure time (hours indoors/day	11	11	11	11	11	11
Exposure frequency (days/year)	250	250	250	250	250	250
Exposure duration (years)	2	3	6	3	4	30

Note: Default 70-year lifetime used for cancer assessment

The VDH assessment focused on 1) developing estimates of excess lifetime carcinogenic risk (risk) that may be associated with inhalation exposure to school indoor air at specific concentrations for a hypothetical school child (1-<19 years) and adult staff member using both RME and CT assumptions and 2) deriving screening concentrations that may be associated with a target risk of $1x10^{-6}$ for each scenario based on RME and CT and a noncancer Hazard Index of 1 based on RME (EPA 2009 screening values are based on CT). As is often the case, the most conservative values were associated with a target risk of $1x10^{-6}$ and RME assumptions.

For the VDH investigation, the CSF_O for the high risk/persistence category of 2.0 $(mg/kg\text{-}d)^{-1}$ was converted to an IUR of $5.7E^{-4}$ $(\mu g/m^3)^{-1}$ (assuming a body weight of 70 kg and inhalation rate of 20 m^3/day). As noted in Attachment A, criteria for use of the high risk/persistence tier includes inhalation of a dust or aerosol contaminated with PCBs as well as early life exposure for all pathways and PCB mixtures. In the unlikely event that site-specific sampling indicates that

exposure is only to evaporated congeners, it may be appropriate to re-evaluate only the hypothetical adult receptor with the lesser IUR. Potential childhood exposure would still be assessed using the high risk/persistence IUR.

Due to the way in which estimates of inhalation dose are derived in the noncancer-based PEET (incorporation of inhalation rate and body weight so chronic average daily dose is in units of mg/kg-d), these values are not easily converted to estimates of lifetime average daily dose appropriate for use in carcinogenic assessments (IUR is in $(ug/m^3)^{-1}$). Thus, VDH used standard risk assessment procedures to derive estimates of risk. Screening concentrations derived with this approach are presented below:

	Screening Concentration (ng/m^3) at Target Risk of $1x10^{-6}$	
	Hypothetical school child (daycare- high school)	Hypothetical adult staff member
Central tendency (EPA)	54	29
Reasonable maximum exposure (VDH)	22	13

In terms of noncancer assessment, VDH ran EPA's PEET model replacing default school indoor air inputs with RME assumptions. All other inputs were unchanged. For the youngest age group (Daycare 1-<2 years), the model estimates that a maximum school indoor air concentration of 36 ng/m^3 would result in a total chronic average daily dose equal to the noncancer oral Reference Dose for Aroclor 1254 of 20 ng/kg-d. At the other end of the spectrum, a noncancer based screening value of 247 ng/m^3 was derived for hypothetical adult staff.

Other New England states (EPA Region I) are also being faced with the issue of PCBs in school air. Most states have not set their own screening concentrations for PCBs in school air. TRC Environmental Inc. recently recommended a screening value of 50 ng/m^3 for use at the Keith Middle School in New Bedford, Massachusetts (TRC, 2012). Connecticut, Maine, New Hampshire and Rhode Island Departments of Health have not derived their own screening values with most having limited if any, involvement in this issue. In association with EPA Region II, New York sampled several New York City schools for PCBs in air. Many had PCB levels in air above the EPA's screening concentrations. New York has implemented a plan to remove the sources of PCBs in schools, namely old light ballasts and caulk. The New Jersey Department of Education recommends that school districts survey and inventory all light fixtures in school buildings built before 1979 and develop a plan to replace those fixtures found to contain PCBs in the ballasts.

The EPA and the Agency for Toxic Substances Disease Research report that the bulk of an individual's exposure to PCBs is through the diet. A level of PCBs in school indoor air consistent with the EPA's 2009 screening concentrations would result in the bulk of PCB exposure coming from indoor school air, rather than diet, using RME assumptions. At our recommended screening concentration of 15 ng/m^3, the bulk of PCB exposure will come from diet, rather than from school air.

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