Current Approaches for Evaluating Potential Health Risks from Polychlorinated Biphenyls in Indoor School Air

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Introduction

Elevated indoor air concentrations of polychlorinated biphenyls (PCBs) have been found in some school buildings in the United States (U.S.) [1]. The U.S. Environmental Protection Agency (EPA) has been engaged in efforts to assess the risk that elevated PCB levels in air may pose to the health of students, teachers, and other occupants of these buildings. In some indoor settings and for some age groups, inhalation may contribute more to total PCB exposure than any other exposure route [2]; and, while PCB exposure has been associated with human health effects, data specific for the inhalation route are limited for supporting exposure-response assessment. Given this limitation, EPA has calculated and recommended "Exposure Levels for Evaluation of PCBs in Indoor School Air" (ELEs) that are intended to maintain overall PCB exposures below the Integrated Risk Information System (IRIS) oral reference dose (RfD). The RfD is an estimate of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of harmful effects during a lifetime [3].

Materials and methods

When calculating the ELEs, EPA considered indoor and outdoor air, indoor dust, outside soils and diet as potential sources of PCB exposure. PCB concentration data for these environmental media [4,5] were used together with average inhalation, ingestion, and dermal contact rates [6,7,8] to estimate average background levels of exposure from each potential source both inside and outside the school environment. The ELEs were calculated as the school indoor air PCB concentrations that would result in an estimated total exposure equal to the RfD when exposures from all other school and non-school PCB exposure sources were assumed to be at background levels. Tables 1 and 2 summarize the exposure factors and equations used and the assumptions made when estimating PCB exposure levels from various sources.

Table 1. Exposure factors used in ELE calculations

Exposure factor	Range of values used, varies by age group
Dust ingestion rate ($IngR_{dust}$) (mg/day) [6,7]	27.5 (≥19 year) – 60 (1-<19 year)
Soil ingestion rate ($IngR_{soil}$) (mg/day) [6,7]	22.5 (≥19 year) – 50 (1-<19 year)
Inhalation rate (IR) m^3/day) [7,8]	8.0 (1-<2 year) – 16.5 (15-<19 year)
Dermal adherence factor (Ad) (mg/cm^2-day) [7]	0.003 (≥19 year) – 0.006 (1-<6 year)
Dermal surface area exposed (SA) (cm^2) [6,7]	1,155 (1-<2 year) – 5,000 (≥19 year)
Relative absorption factor for indoor and outdoor air inhalation (Abs_{air}) [9]	1.0 (≥1 year)
Relative absorption factor for dust and soil ingestion ($Abs_{dust-soil}$) [9]	0.6 (≥1 year)

Relative absorption factor for dermal contact (Abs_{dermal}) [9]	0.09 (≥1 year)
Body weight (BW) (kg) [6,7]	11.4 (1-<2 year) – 71.8 (≥19 year)
Sleep time (ST) (hours/day) [6,7]	8.3 (≥19 year) – 12.9 (1-<2 year)
Outdoor time (OT) (hours/day) [6,7]	0.6 (1-<2 year) – 4.7 (≥19 year)
Indoor time at school (ETsi) (hours/day)	6.0 (3-<19 year) – 8.0 (≥19 year)
Outdoor time at school (ETso) (hours/day)	0 (≥19 year) – 0.5 (1-<3 year)
Total exposure time in school (hours/day) (ETst)	6.5 (3-<19 year) – 8 (1-<3 year and ≥19 year)
Exposure frequency in school (days/year) (EFs)	180 (3-<19 year) – 185 (1-<3 year and ≥19 year)

Table 2. Equations used in ELE calculations

Indoor Air	**Average daily dose from inhalation ($ADD_{inhalation}$) (µg/kg-day):** Non-school (e.g., residential): IR × Abs_{air} × fraction of time spent indoors at locations other than schools × [PCB] in indoor (non-school) air (6.9 ng/m^3 [4]) × (1/BW) School: IR × Abs_{air} × fraction of time spent indoors at school × [PCB] in indoor (school) air (equal to the ELEs when total exposure is equal to the RfD) × (1/BW)
Outdoor Air	**$ADD_{inhalation}$ (µg/kg-day):** Non-school: IR × Abs_{air} × fraction of time spent outside away from school × [PCB] in outdoor air (0.5 ng/m^3 [4]) × (1/BW) School: IR × Abs_{air} × fraction of time spent outside at school × [PCB] in outdoor air* × (1/BW)
Indoor Dust	**Average daily dose from ingestion of dust and soil ($ADD_{dust\text{-}soil}$) (µg/kg-day):** Non-school: $IngR_{dust}$ × $Abs_{dust\text{-}soil}$ × fraction of indoor awake time spent in locations other than schools × [PCB] in background dust (0.22 µg/g [4]) × (1/BW) School: $IngR_{dust}$ × $Abs_{dust\text{-}soil}$ × fraction of indoor awake time spent in school × [PCB] in school dust* × (1/BW) **Average daily dose from dermal contact with dust (ADD_{dermal}) (µg/kg-day):** Non-school: Ad × SA × Abs_{dermal} × [PCB] in background dust School: Ad × SA × Abs_{dermal} × fraction of year spent in school × [PCB] in school dust* × (1/BW)
Outside Soils	**$ADD_{dust\text{-}soil}$ (µg/kg-day):** Non-school: $IngR_{soil}$ × $Abs_{dust\text{-}soil}$ × fraction of outdoor time spent in locations other than schools × [PCB] in background soil (0.05 µg/g [5]) × (1/BW) School: $IngR_{soil}$ × $Abs_{dust\text{-}soil}$ × fraction of outdoor time spent at school × [PCB] in school soil* × (1/BW)
Diet	**Average daily dose from ingestion of food ($ADD_{dietary}$) (µg/kg-day):** varies by age group [10] 1 to <6 years old: 0.002 µg/kg-day 6 years old to adult: 0.001 µg/kg-day
*PCB concentrations in school outdoor air, dust, and soil assumed to be the same as those of average homes or other buildings without elevated PCBs	

Results and discussion

The exposure factors, equations, and assumptions summarized in Tables 1 and 2 were used to calculate the ELEs as provided in Table 3 [3]. These values are intended to be health protective and to be used solely for evaluation purposes. As noted by U.S. EPA [3]: *They should not be interpreted nor applied as "bright line" or "not-to-exceed" criteria, but may be used to guide thoughtful evaluation of indoor air quality in schools*.

Table 3. Exposure Levels for Evaluating PCBs in School Indoor Air (ng/m^3)

Age: 1-<2 yr	Age: 2-<3 yr	Age: 3-<6 yr	Age: 6-<12 yr elementary school	Age: 12-<15 yr middle school	Age: 15-<19 yr high school	Age: ≥19 yr adult
100	100	200	300	500	600	500

*Exposure levels were rounded to the nearest hundred ng/m^3.

The information provided in Tables 1 and 2 can also be used to evaluate the contributions of various PCB sources to total exposure at background exposure levels and in contaminated schools. Results of an example analysis are shown in Fig. 1, where we estimated (A) potential total and route-specific background PCB indoor and outdoor exposures from ingestion of soils and dusts, ingestion of food, dermal contact, and inhalation for children ages 6 to <12 years, (B) analogous exposures assuming background exposure levels except for an exposure from indoor air at a contaminated school ([PCB] in indoor (school) air = 300 ng/m^3), and (C) analogous exposures assuming the same exposure levels as in (B), but in this case, the PCB levels in dust and soil at the contaminated school are also known to be elevated above background ([PCB] in dust = 10 µg/g and [PCB] in background soil = 2.5 µg/g). Although the school exposure levels used in these examples are purely hypothetical, they illustrate the potential for PCB exposures in the school setting to impact overall exposure levels. When all PCB exposures are set to background levels, total exposure is well below the IRIS RfD (20 ng/kg-day), and inhalation of indoor air and dietary intake account for the largest portions of total PCB exposure. When children in this age group are exposed to a school indoor air concentration of 300 ng/m^3 (with all other included exposure sources set to background levels), total PCB exposure remains lower than the RfD and, as expected, the contribution of indoor air inhalation to that exposure is increased. And, when school dust and soil PCB concentrations are increased to 10 µg/g and 2.5 µg/g from background levels of 0.22 µg/g and 0.05 µg/g, respectively, total PCB exposure would slightly exceed the RfD in children ages 6 to <12 years.

Uncertainties in this approach to assessing potential health risk from inhalation exposure to PCBs in school air result from (1) the use of a reference value based on the results of oral (rather than inhalation) exposure studies, (2) limitations of the PCB concentration data available for estimating background exposure levels, and (3) assumptions about PCB concentrations in dusts, soils, and outdoor air in and around schools with elevated indoor air PCB levels. When site-specific data are available, building owners and school administrators may work with EPA regional PCB coordinators to address this third uncertainty by calculating school-specific exposure levels using a method like that described above and illustrated in Fig. 1. School-specific exposure levels may also be useful for schools that operate under conditions that differ from those assumed in the ELE calculation (Table 1) (e.g., longer/shorter school days or more/fewer days of school per year).

The intent of the ELEs is to provide a useful metric for evaluating air quality in schools. However, these values are but one component of a comprehensive strategy developed by U.S. EPA to support the efforts of school administrators, building owners, and building managers to reduce PCB exposures. More information on the types of building materials that may contain PCBs, the potential for building occupants to be exposed to PCBs, and PCB exposure assessment and reduction can be found at https://www.epa.gov/pcbs/polychlorinated-biphenyls-pcbs-building-materials.

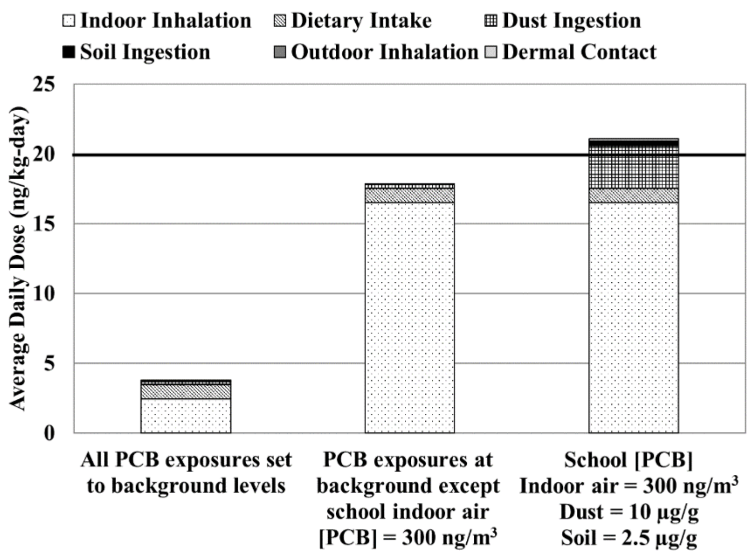

Figure 1. Contributions of various PCB sources to total exposure in children ages 6 to <12 years under three hypothetical example exposure scenarios. A bold line is drawn at the IRIS RfD (20 ng/kg-day). In each scenario, the relative contributions of each exposure source to total PCB exposure follow a similar pattern: indoor inhalation > dietary intake, dust ingestion > soil ingestion > outdoor inhalation, dermal contact with indoor dust. In the first two scenarios, the contribution of dietary intake is greater than dust ingestion, and the contribution of outdoor inhalation is greater than dermal contact. But, these relationships are reversed in the third scenario.

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