HUMAN HEALTH RISK ASSESSMENT NOTE NUMBER 8: RECOMMENDATIONS FOR EVALUATING POLYCHLORINATED BIPHENYLS (PCBs) AT CONTAMINATED SITES IN CALIFORNIA

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL (DTSC)
HUMAN AND ECOLOGICAL RISK OFFICE (HERO)

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SUMMARY

The Department of Toxic Substances Control (DTSC) Human and Ecological Risk Office (HERO) has developed this Human Health Risk Assessment (HHRA) Note to present common issues that are encountered during data collection/evaluation and risk assessment of polychlorinated biphenyls (PCBs) for protection of human health at contaminated sites in California. The current regulatory framework is also discussed. Additionally, this HHRA Note was prepared to memorialize the risk assessment recommendations provided in time-critical support of PCB releases and HERO's recent interactions with the United States Environmental Protection Agency (USEPA) Region 9 staff during evaluation of PCBs at several sites in California.

Scope and Applicability

This HHRA Note was developed, in part with funding from the DTSC State Response Program (SRP) grant, to be a resource for use by DTSC staff as well as external stakeholders to address key technical issues related to evaluation of exposures and health risks, including regulatory framework, conceptual site model, sample collection and analysis, data evaluation, and human health risk assessment at sites contaminated by leaks or releases of PCBs. However, the guidance is not meant to address site-specific considerations for these topics. It also does not discuss other site characterization and risk management issues such as remediation methods and risk communication. In addition, the USEPA should be consulted on the management and cleanup of products manufactured with PCBs (e.g., transformer oil, fluorescent light ballasts, and caulking) and PCB-contaminated floors/walls that are regulated under the Toxic Substances Control Act (TSCA; see next section).

This guidance is intended to supplement - not replace - other existing DTSC guidance documents. The contents of this HHRA Note are not regulatory requirements and are for informational purposes to assist the user in the risk evaluation process. The project team should define the scope of work in accordance with the conceptual site model (CSM) and corresponding data quality objectives (DQOs) developed for the project. A list of frequently asked questions (FAQ) with short answers is prepared as quick guide with reference to the relevant sections in this Note for additional information. The recommendations in this Note may be revised in the future as new scientific and

regulatory information become available. Besides the methods discussed in this Note, there might be other procedures that are technically acceptable; please discuss such alternative approaches in advance with the HERO toxicologist assigned to the project.

This HHRA Note addresses only human health-related issues; please consult with HERO – Ecological Risk Assessment Section (ERAS) regarding ecological hazards associated with PCB exposure.

Relevance to Federal Laws and Regulations

Depending on the site and the media of concern, management and cleanup of PCBs may be subject to a number of federal and state laws and regulations (see Section 2). In particular, PCB manufacture, use, storage, and disposal are regulated under the USEPA TSCA Program. Thus, this Note also includes some discussion on the TSCA requirements with valuable input provided by Ms. Carmen Santos (PCB Coordinator) and Dr. Patrick Wilson (Senior Toxicologist) of the USEPA Region 9. Because the TSCA regulations are not currently delegated to state or local agencies, this document does not replace or supplant the requirements of the TSCA and other USEPA regulations. Please consult with the USEPA Region 9 PCB Coordinator or project manager regarding additional requirements on management and cleanup of TSCA-regulated PCB materials.

Given different state and federal regulatory authorities and responsibilities, DTSC typically focuses on potential PCB releases to environmental media (which may also be regulated by the federal laws), while USEPA handles PCB contamination in indoor environments as well as management and cleanup of PCBs in articles, containers, and building materials that are regulated under the TSCA Program. While not a routine occurrence, DTSC may provide regulatory oversight or work with USEPA involving sites with indoor releases of PCBs, for instance current or former hazardous waste facilities that handled PCBs. Therefore, while this Note focuses on the measurement and risk assessment of PCB exposure to environmental media, it also includes discussion and recommendations on evaluation of PCB releases in indoor environments.

HERO ISSUE CONTACT PERSONS:

Chawn Y. (CY) Jeng, Ph.D.,	Staff Toxicologist
Phone:	714.484.5359
Email:	Cy.Jeng@dtsc.ca.gov
Efrem Neuwirth, Ph.D. D.A.B.T.,	Staff Toxicologist
Phone:	714.484.5421
Email:	Efrem.Neuwirth@dtsc.ca.gov
Shukla Roy-Semmen, Ph.D.,	Senior Toxicologist
Phone:	714.484.5448
Email:	Shukla.Roy-Semmen@dtsc.ca.gov

WHAT'S NEW (June 2020)

The previous version of this Note (dated April 2018) has been updated to include the following major revisions:

- In Sections 5 and 7, industrial screening levels and some regulatory threshold values for PCBs are updated to be consistent with the latest HHRA Number Note 3 dated April 2019.
- Section 6 is updated to include the requirements of California Code of Regulations (CCR), Title 22, Div. 4.5, Toxicity Criteria Regulation (22 CCR 68400.5 and 69020-69022) effective September 4, 2018 (https://dtsc.ca.gov/regs/toxicity-criteria-for-human-health-risk-assessment/).
- Select references in Section 8 are updated to reflect the latest versions.

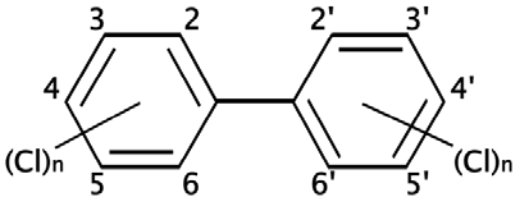
Frequently Asked Questions (FAQs) by DTSC Project Team

Question	Short Answer	Note Section
What are key laws and regulations for addressing sites with PCB impacts?	• California Health & Safety Code (Division 20, Chapters 6.5 & 6.8) • California Code of Regulations (CCR), Title 22, Division 4.5 • 40 CFR (Code of Federal Regulations) Part 761 (TSCA)	2.0
What environmental media should be considered for sampling of PCBs?	• Soil • Other media, based on project-specific data quality objectives (see Table 3.1)	3.0
Which is the recommended analytical method for PCBs?	The best analytical method depends upon the data quality objectives for the project. USEPA Method 8082 for Aroclors is most commonly used. Other methods may be considered for project-specific needs.	4.0
What are the recommended PCB screening levels for soils and surfaces?	• Soil: DTSC-modified Screening Levels (DTSC-SLs) • Surface Wipe: 0.1 µg/100 cm^2	5.0
Should I use the CHHSLs as they are more stringent than the RSLs?	The California Human Health Screening Levels (CHHSLs) are no longer recommended for screening of PCBs in soil, because they were based on toxicity values that have since been updated.	5.0
What toxicity values should be used to evaluate health risks?	As the default procedure, cancer and non-cancer toxicity values should be used for total PCBs based on the "high	6.0

	risk PCB" and Aroclor 1254, respectively. Consult the DTSC toxicologist for use of other toxicity factors.	
What is the recommended health-based goals for PCBs in soil?	For sites where site-specific remediation goals are not developed, HERO recommends using the appropriate screening levels as preliminary remediation goals to guide soil sampling and preliminary evaluation of cleanup, followed by a post-remediation sampling and risk assessment. Consult with USEPA for sites regulated under the TSCA.	7.0
What is the recommended action level for PCBs on surfaces?	HERO recommends using 0.1 µg/100 cm^2 as the preliminary goal to remediate PCB-contaminated surfaces or develop a site-specific remediation goal in consultation with HERO toxicologist.	7.0; App. B
How should air data be evaluated?	If it is necessary to evaluate inhalation exposure, USEPA RSLs and DTSC-modified SLs for air can be used for data screening and estimating the cancer risk and noncancer hazard, respectively.	5.0 & 7.0
What should I do if PCBs are found in buildings?	HERO does not recommend sampling of building materials or surrounding media unless there is evidence of a PCB release that may lead to exposure. Consult with USEPA regarding requirements for addressing products manufactured with PCBs (e.g., caulking, fluorescent light ballasts) and PCB-contaminated floors/walls that are regulated under TSCA.	7.0; App. A
When should I get USEPA's involvement in my PCB sites?	• Evaluation of PCB releases to the environment, especially when PCB levels (in soil or bulk materials) are > 50 mg/kg. • Management and cleanup of PCB-containing articles, containers and liquids and PCB bulk product wastes under TSCA.	2.0 & 7.0

1.0 INTRODUCTION

PCBs belong to a broad family of man-made organic chemicals known as chlorinated hydrocarbons. The number of chlorine atoms and their location in a PCB molecule determine many of its physical and chemical properties.



PCBs were commercially manufactured from 1929 until they were banned as a class of chemicals in 1979, due to their persistent nature and health and environmental hazards. They have a range of toxicity and vary in consistency from thin, light-colored liquids to yellow or black waxy solids. PCBs are usually measured and reported in terms of "Aroclors", "congeners", and "homologs" (see Appendix A for their definitions) by different analytical methods discussed in Section 4.

Due to their non-flammability, chemical stability, high boiling point and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications including:

- Transformers and capacitors
- Electrical equipment including voltage regulators, switches, re-closers, bushings, and electromagnets
- Oil used in motors and hydraulic systems
- Electrical devices or appliances containing PCB capacitors
- Fluorescent light ballasts
- Electrical cable insulation
- Thermal insulation material including fiberglass, felt, foam, and cork
- Adhesives and tapes
- Oil-based paint
- Caulking
- Plastics
- Carbonless copy paper
- Floor finish

Although the production of PCBs in the US has been discontinued since late 1970s, they may still be detected at low levels in the environment due to their broad applications, persistence, and redistribution among various environmental media, including air-borne transport over long distances. Low concentrations may be present

at a site even without historical on-site releases of PCBs (ATSDR 2000). Thus, it is important to consider the ubiquitous nature of PCBs when developing data quality objectives for assessment of PCB contamination (see Section 3).

This HHRA Note presents common issues that may be encountered during sampling, data evaluation, and risk assessment of PCB contamination resulting from releases associated with these historical applications and recommends strategies for addressing these issues under the current regulatory framework. Specifically, this Note is focused on the issues related to evaluation of exposures and health risks associated with soils and surfaces, and also includes some discussions on evaluation of PCB releases in indoor environments.

2.0 REGULATORY FRAMEWORK

The United States Environmental Protection Agency (USEPA) is the primary agency responsible for enforcing federal regulations that affect public health and the environment. Federal regulations pertaining to hazardous materials and wastes are contained in the Code of Federal Regulations (40 CFR). In addition to the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act of 1974 (RCRA), the Toxic Substances Control Act of 1979 (TSCA) is the primary federal law for management and cleanup of PCBs. Specifically, the TSCA regulations governs the manufacture, processing, distribution in commerce, use, cleanup, storage and disposal of PCBs, and provides USEPA with authority to require reporting, record-keeping and testing requirements, and restrictions relating to chemical substances and/or mixtures including PCBs (see Appendix A for a list of TSCA-regulated PCB materials). Specific regulations and legal requirements on PCBs can be found at 40 CFR Part 761.

In California, the Department of Toxic Substances Control (DTSC) is authorized by the USEPA to regulate the management of hazardous waste, including overseeing corrective action at hazardous waste facilities or sites contaminated by hazardous waste. DTSC administers the State's Hazardous Waste Control Law (HWCL) in lieu of RCRA, under Chapter 6.5 of Division 20 of the Health and Safety Code. There is also the Hazardous Substance Account Act (HSSA) under Chapter 6.8 of Division 20 of the Health and Safety Code that authorizes DTSC to take or require cleanup of sites contaminated with hazardous substances which include hazardous waste. Hazardous waste containing PCBs is addressed in Title 22 of Division 4.5 of California Code of Regulations (CCR):

- Characteristics of hazardous waste: 22 CCR 66261.24
- Transporters: 22 CCR 66263.44
- Treatment standards: 22 CCR 66268.45
- Management of fluorescent light ballasts: 22 CCR 67426.1 – 67429.1

For sites located within the jurisdiction of the California Regional Water Quality Control Boards, there may be other requirements for addressing PCBs for protection of water in

California. For example, the San Francisco Regional Water Quality Control Board (SFRWQCB) has provided cleanup guidelines designed to assist attainment of PCB Total Maximum Daily Load for water quality, sediments and fish tissue within San Francisco Bay (SFRWQCB 2017).

Because the TSCA authority is not currently delegated to DTSC, the DTSC project team should consult with the USEPA Region 9 PCB Coordinator or assigned project manager on issues concerning TSCA PCB regulations and issues. USEPA has developed a PCB Facility Approval Streamlining Toolbox (USEPA 2017a), which provides a framework for streamlining PCB site cleanup approvals and encourages responsible parties to initiate contact with USEPA early in the process, preferably prior to site characterization.

3.0 SAMPLE COLLECTION

Characterization of a site contaminated by leaks or releases of PCBs and development of a sampling and analysis plan depend on site history, current and future site uses, site occupants who may come in contact with PCB-contaminated soils and other media (e.g., surfaces), and most importantly, data quality objectives (DQOs). The DQO process is used to establish performance and acceptance criteria, which will guide the design of a plan to collect environmental data of sufficient quality and quantity to support the goals of the study, which may include determining extent of contamination, evaluating potential human health risks and establishing remediation goals protective of human health under different exposure scenarios. The site history, current and future site uses, and the site-specific DQOs are integrated in the Conceptual Site Model (CSM). A CSM serves to conceptualize the relationship between contaminant sources and receptors through consideration of potential or actual migration and exposure pathways. It presents the current understanding of the site, helps to identify data gaps, and helps to focus the data collection efforts.

This section provides an overview of PCB sampling for soil as well as other media including surface (wipe and dust), bulk materials (chips and cores), air, and water to support evaluation of exposures and health risks. Depending on the CSM, collection of multiple sample types can complement each other and should be considered to meet the project DQOs. Table 3.1 presents the exposure pathways which can be evaluated using different sample types discussed in Section 3. The information presented in this section is not intended to nor should be interpreted as requirement to collect these samples at every site, and the scope of site investigation and sampling protocols should be developed by the project team in accordance with the site-specific CSM and corresponding DQOs. For sites where sampling of TSCA-regulated materials and contaminated media may be required, please consult with USEPA when developing the DQOs and sampling plans.

Table 3.1 - Available Sample Types for Evaluating Exposures and Health Risks

SAMPLE TYPE	Ingestion Exposure	Dermal Exposure	Inhalation Exposure
Soil or outdoor dust (a)	X (c)	X (c)	X (c)
Wipes (b)	X (d)	X (d)	(f)
indoor dust (a)	X (c)	X (d)	(f)
Chips and cores (a)	X (e)	X (e)	(f)
Air (a)	na	na	X (c)

Notes: This table includes possible sample types and potentially complete exposure pathways (na: not applicable). For a specific site, the CSM will be used to determine which samples will be collected and which exposure pathways will be evaluated.

(a) Units in milligrams or micrograms of PCBs per kilogram (for soil, bulk dust and chip/core samples) or per cubic meter (for air samples).
(b) Units in micrograms PCBs per unit surface area (typically 100 square centimeters with a wipe).
(c) Standard exposure parameters for residential and commercial/industrial land uses are available.
(d) No standard exposure parameters are available (see Appendix B).
(e) Ingestion and dermal exposure to PCBs inside porous materials is not a complete pathway; however, degradable materials can conservatively be treated as source of future dust (indoor or outdoor) exposure.
(f) These samples may indicate the presence of a potentially complete inhalation exposure pathway but are not used for quantifying inhalation exposure.

3.1 Soil Sampling

The number of samples to be collected, the location of the samples and the depth of the samples will be based on site-specific information and the CSM. If little is known about site history and conditions, systematic sampling may be conducted based on a sampling grid, with additional focused sampling based on the initial results. Focused, discrete sampling may be conducted for specific areas with known or likely PCB releases. If a more representative soil concentration and exposure point concentration is desired, Incremental Sampling Methodology (ISM) can be considered. ISM is a structured composite sampling and processing protocol that reduces data variability and provides an average concentration in soil for a pre-determined decision unit. A combination of these sampling methodologies may be considered, based on the site-specific CSM and DQOs. Please consult with USEPA regarding use of ISM at TSCA-regulated sites.

Guidance documents available for PCB sample collection include:

- DTSC Preliminary Endangerment Guidance Manual, Revised October 2015.
- DTSC Interim Guidance, Evaluation of School Sites with Potential Soil Contamination as a Result of Lead from Lead-Based paint, Organochlorine Pesticides from Termiticides, and Polychlorinated Biphenyls from Electrical Transformers, Revised 06/09/06.
- Interstate Technology and Regulatory Council (ITRC), Incremental Sampling Methodology, February 2012.
- Consult with USEPA on the TSCA and other guidance documents on sampling.

3.2 Potential Sampling of Surfaces

Management and cleanup of products manufactured with PCBs (e.g., caulking and fluorescent light ballasts) and PCB-contaminated floors/walls are regulated under TSCA and should be deferred to the USEPA. Should DTSC, in coordination with USEPA, become involved with sampling of indoor surfaces, the following protocols may be considered. As indicated in Section 3.0 and Table 3.1 of this HHRA Note, collection of surface samples or analysis of building materials is not mandatory for DTSC-lead projects and will only be performed based on the consideration of the CSM and site-specific conditions. (Note that HERO typically does not recommend sampling of building materials or surrounding media unless there is evidence of a PCB release that may lead to exposure).

Spills or leaks from sources containing PCBs may result in contamination of the surface and interior of porous building materials such as concrete which is present indoors and outdoors. Additionally, many buildings that were constructed or renovated between 1950 and 1980 may contain building products manufactured with PCBs, such as caulk, paints and coatings (USEPA 2015). PCBs from these primary sources may also seep into or volatilize and adhere to dust and building materials, such as concrete floors and walls, which become the secondary sources of PCBs (USEPA 2012). These primary and secondary sources of PCBs may also degrade over time via wear and tear, and lead to exposures to PCBs via the ingestion, dermal and/or inhalation pathways. To determine the nature and extent of PCB contamination and the potential for exposures of building occupants, DTSC, in coordination with USEPA, as indicated above, may need to collect samples from surfaces and chips or core samples from porous building materials in some circumstances. In such cases, it may also be necessary to sample outdoor paved surfaces where PCB contamination is of concern.

Surface wipe sampling is a common method for measuring the amount (mass) of PCBs per unit area of surface (mass loading) immediately available for direct contact. Wipe samples can pick up both PCB residues adhered to surface materials and in dust particles. Results of surface wipe sampling may be used during site characterization, for interim evaluation of the progress of the cleanup, and as the final process to verify attainment of remedial goals. Risks to people coming in contact with the PCB-contaminated surfaces may also be estimated using these data. DTSC has developed a risk-based approach for evaluating PCB-contaminated surfaces (see Appendix B.3). Details of common wipe sampling protocol are discussed in Appendix C of DTSC's 2003 PCB Advisory for Schools (DTSC 2003) and several USEPA documents (USEPA 1991; USEPA 2015).

Surfaces may also be evaluated by collecting bulk dust, when enough dust is accumulated on the surface. Bulk dust analysis provides the concentration of PCBs in dust (mass of PCBs per unit mass of total dust). Use of bulk dust data for evaluating exposures and health risks is discussed in Appendix B.2. USEPA (2008) discusses collection of dust samples using vacuum methods for supporting a health risk

assessment for ingestion of lead in dust, which may also be applicable to other dust-bound contaminants including PCBs. Vacuum sampling of surface dust of a defined surface area can also be used to estimate the mass loading of PCBs (i.e., mass PCBs/surface area). Collection of samples via wipes vs. vacuum should be guided by project specific DQOs, and factors to consider for making such decision are discussed in Appendix B.1.

In summary, the conceptual site model for surfaces and building materials containing PCBs can often be very complex due to the multitude of possible sources and following years of migration of PCBs from bulk products, contaminated surfaces, and ambient environmental sources. In such cases, the primary goal of sample collection is not to delineate impacts to a building but to characterize exposure sufficiently in order to manage the risks and hazards that may be present. As shown on Table 3.1, collection of surface wipe samples, bulk dust, chip/core, and indoor air samples (see Section 3.3) can complement one another and should be considered in the DQOs by the project team in consultation with USEPA.

3.3 Sampling of Other Media

Other abiotic (non-biological) environmental media such as air, groundwater, and surface water may be sampled for PCBs if needed for assessing health risks, although vapor-phase and dissolved-phase PCBs are not usually expected to be found at high levels in these media due to low volatility and low solubility for most PCB compounds. Biota and human biomonitoring may also be conducted for PCBs to evaluate dietary exposure and lactation transfer pathways and refine the evaluation of human exposure. The sampling of biota for evaluation of bioaccumulation and food consumption pathway and human biomonitoring are not addressed here as these are atypical for DTSC projects and beyond the scope of this HHRA Note. Below are some examples where collection of air or water samples for PCB analysis may be considered to address PCB releases:

- Fence-line air monitoring during removal of PCB-contaminated soils. Typically, only dust levels are monitored with real time monitors and dust action limits are set based upon protective estimates of the PCB content in soil. Testing of re-suspended PCBs in air may also be appropriate for longer duration projects in sensitive areas to ensure that the dust action levels are protective. In some cases, dust action levels set by the local air quality management district for construction projects may be adequate so no specific PCB action levels or PCB testing will be needed. Guidance on fence-line monitoring and setting dust action limits is in preparation by the DTSC. In the meantime, please consult with the DTSC Project Toxicologist.

- Indoor air sampling to support risk evaluation or to verify health protectiveness of PCB remediation and other mitigation measures inside buildings (see Section 7.0). Inhalation has been identified as a likely exposure pathway for buildings that may contain the primary and secondary indoor PCB sources described in

Section 3.2 (USEPA 2012, 2015; Lehman et al., 2014). Because indoor air may be impacted by both volatile (e.g., mono- and di-chlorinated homologs) and particulate phase PCBs, sampling methods that can collects both vapor and particulate phases (e.g., USEPA Methods TO-4 and TO-10) are recommended for indoor air sampling.

- Sampling of surface water or groundwater if spills in soil have migrated or have the potential to migrate to the water body. This is most likely to occur for fresh spills or spills where PCBs are present in solvents which can mobilize PCBs in soil.

Please consult with the DTSC toxicologist if you are considering sampling these media for PCBs in your project.

Under the TSCA, sampling of PCB articles, containers and liquids (e.g., electrical transformers and hydraulic fluids), porous materials (e.g., concrete), and bulk products (e.g., caulking and fluorescent light ballasts) may be necessary to determine the applicable management and cleanup requirements for PCB-containing materials. In addition, releases of PCBs in indoor environments are typically handled by the USEPA, even though DTSC may get involved in some cases under the regulatory authority discussed in Section 2.0. Please contact the USEPA Region 9 PCB Coordinator or project manager regarding sampling requirements in these situations.

4.0 ANALYTICAL METHODS

A number of laboratory analytical methods are available for quantification of PCBs in soil and other media. PCBs are usually measured and reported in terms of “Aroclors”, “congeners”, and “homologs” (see Appendix A for their definitions). The USEPA SW-846 Method 8082 is the most commonly used method for analyzing Aroclor mixtures. The USEPA Office of Water Method 1668 is used to analyze a complete list of 209 congeners, although Method 8082 can also analyze a limited list of congeners. Several other methods are also available for analyzing PCBs as congeners and homologs. For solid and aqueous samples, the SW-846 Method 3500B provides a list of acceptable extraction methods for sample preparation prior to PCB analysis. Table 4.1 lists the common laboratory methods for PCB analysis, their estimated costs, and typical reporting limits.

Due to cost consideration, Method 8082 has been used to generate PCB data at most sites. For some projects with higher exposure potential or additional QA/QC requirements, HERO recommends performing congener analysis on 5-10% of the samples to verify the total concentration of PCBs and to assess the distribution of specific congeners in the mixture. This information may also be needed to support the selection of alternative toxicity factors for PCBs (see Section 6). Homolog analysis may also serve this purpose but does not provide the concentrations of dioxin-like congeners (see Section 6.3). For this reason, Method 1668 is preferred over the homolog analysis. Method 1668 should also be used for fish and other animal tissue when food chain

exposure is being evaluated due to the selective retention and accumulation of some congeners.

Table 4.1 - Common Laboratory Methods for PCB Analysis

Analysis	Method	Estimated Cost	Typical Reporting Limit
Aroclors	EPA 8082 (GC-ECD*)	Low ($50-150/sample)	~ 33 µg/kg (solid) ~ 1 µg/L (aqueous)
Homologs	EPA 680/8270 (GC-LRMS*)	Medium (~$400/sample)	~ 1 µg/kg (solid) ~0.1 µg/L (aqueous)
Congeners	EPA 1668 (HRGC-HRMS*)	High ($400-1000/sample)	~ 0.002 µg/kg (solid) ~ 0.00002 µg/L (aqueous)

*GC-ECD: gas chromatography - electron capture detector
GC-LRMS: gas chromatography - low resolution mass spectrometry
HRGC-HRMS: high resolution gas chromatography - high resolution mass spectrometry

For projects that are regulated by the TSCA, analysis for PCBs should be performed as Method 8082 or a method validated under Subpart Q (40 CFR 761.320). USEPA Region 9 also recommends using an alternative method, such as EPA Method 1668 or 680, on select samples to provide a more detailed speciation of PCB compounds. In addition, the preferred sample extraction method is the Soxhlet extraction (Method 3540) or a method validated under Subpart Q (40 CFR 761.320). The ultrasonic extraction (Method 3550), although referenced in the TSCA, is not a preferred extraction method according to the USEPA (2017a).

5.0 DATA EVALUATION

After the usability of available data has been validated in accordance with the data quality objectives (DQO) for the project, the reported PCB concentrations should be compared with appropriate risk-based screening levels to determine if further investigation is required. These screening levels are discussed below for evaluation of soil, surface wipe, and air sampling results which are the most common types of data collected for evaluating PCB exposure.

Soil Data

HERO recommends using the DTSC-modified residential and industrial screening levels (DTSC-SLs) in the HHRA Note Number 3 (see Table 7.1; check https://dtsc.ca.gov/human-health-risk-hero/ for the most current version and screening values) for screening soil data, according to current and future site land use. The soil screening levels are available for individual Aroclor mixtures, select congeners, and total PCBs in the "high risk" category.

For screening purposes, individual Aroclor concentrations may be compared with the respective screening levels or summed as total PCBs and compared with the screening levels for “PCBs (high risk)” (see Section 6.0 for additional discussion). Similarly,

individual homolog or congener concentrations may be summed and presented as total PCBs for such comparison.

Note that the USEPA industrial Regional Screening Levels (RSLs) for PCBs are slightly higher than the DTSC-SLs due to different exposure factors (the skin surface area of and soil adherence factor for workers (DTSC 2019a) used to calculate these values. In addition, the California Human Health Screening Levels (CHHSLs; Cal/EPA 2005) for PCBs in soil were based on outdated toxicity values. The OEHHA has since updated the oral slope factor to 2 mg/kg-day (same as the USEPA IRIS value; see Table 6.1), and thus the CHHSLs are no longer recommended for screening of PCB data.

Surface Wipe Data

Below is a summary of the screening levels that have been used for PCBs in surface wipe samples by DTSC and USEPA.

Table 5.1 - Available Screening Levels for PCBs in Surface Wipe Samples

Agency/Source	Screening Level for PCBs in Surface Wipe Samples
DTSC[(a)]	0.1 µg/100 cm^2
USEPA (high frequency contact)[(b)]	1 – 5 µg/100 cm^2
USEPA (low frequency contact)[(b)]	5-10 µg/100 cm^2
World Trade Center[(c)]	0.16 µg/100 cm^2
TSCA	10 µg/cm^2

[(a)] This value corresponds to a cancer risk of approximately 10^{-6} for an indoor worker (e.g., teacher; DTSC 2003); see Appendix B.3 for assumptions and risk calculations.

[(b)] USEPA-recommended values for non-porous surfaces at the CBS Westinghouse site (detailed derivation of these values is not available to the public at this point).

[(c)] This value corresponds to a target cancer risk of 10^{-4} (WTC-IATFWG 2003). Note that the exposure assessment for deriving the risk-based level provided in WTC-IATFWG document is more complex than that used in the DTSC (2003) document; it was developed for a residential receptor with greater hand to mouth contact, skin surface area, among other variables.

HERO recommends using 0.1 µg/100 cm^2 as the screening level. Note that this is comparable to the lowest detection limit typically achieved by laboratories.

Ambient/Indoor Air

If it is necessary to evaluate inhalation exposure using air data (see Section 3.3), HERO recommends use of the USEPA air RSLs (based on cancer effects) for individual Aroclor mixtures or total PCBs (high risk) as in the case for soil. To evaluate non-cancer health effects (e.g., fenceline air monitoring for short-duration soil excavation), HERO recommends use of DTSC-modified screening levels (DTSC-SLs) for Aroclors 1016 and 1254, as appropriate, in the HHRA Note Number 3 (DTSC 2019b).

6.0 EVALUATION OF CANCER RISKS AND NONCANCER HAZARDS

Exposure to PCBs in soil are evaluated similar to any other soil contaminant and the default exposure parameters for residential, commercial/industrial, and construction scenarios are defined in DTSC's HHRA Note Number 1 (DTSC 2019a). Standardized methods for assessing exposure to PCBs on surfaces and in bulk dusts are not available presently. Methods for evaluating exposure include collecting representative surface samples (see Section 3.2) for an exposure point concentration (EPC) as well as exposure parameters including contact rates and frequencies and durations of exposure. Appendix B presents some guidelines on how to evaluate health risks and hazards using PCB data collected on a concentration (bulk dust) and mass loading (surface wipe) basis. The following sections summarizes available cancer and non-cancer toxicity factors for use in PCB risk assessment.

6.1 Cancer Toxicity Factors and Risk Characterization

The USEPA (1996) had developed three tiers of oral cancer slope factors (CSFo) for evaluating cancer risks from PCB exposure that are termed "high risk", "low risk", and "lowest risk", based on the relative congener content and toxicity in mixtures. The USEPA (1996) also recommends performing route-to-route extrapolation for the inhalation route of exposure. Key considerations on which toxicity factor to use include the media, the exposed population, and details on the congener/homolog makeup of the PCB mixture. Table 6.1 provides the upper-bound estimates of these toxicity factors and the criteria for their use.

Table 6.1 - Upper-Bound Cancer Toxicity Values for PCBs

Parameter and Criteria for Use	High Risk PCBs	Low Risk PCBs	Lowest Risk PCBs
CSFo $(mg/kg\text{-}day)^{-1}$	2	0.4	0.07
IUR $(\mu g/m^3)^{-1}$	5.7E-04	1.0E-04	2.0E-05
Criteria for Use	• Food chain exposure • Sediment or soil ingestion • Dust or aerosol inhalation • Dermal exposure if absorption factor applied • Dioxin-like, tumor-promoting, or persistent congeners	• Ingestion of water-soluble congeners • Inhalation of evaporated congeners • Dermal exposure, if no dermal absorption factor has been applied in the risk	• Congener or isomer analyses verify that congeners with more than 4 chlorines comprise less than 0.5% of total PCBs • Aroclor 1016

	in other media (water and vapor) • Early-life[*] exposure to any PCB mixture including those identified as Low and Lowest risk PCBs	assessment (*i.e.,* a factor of 1)	

Source: Adopted with modifications from Table 4-1 from the USEPA (1996). These upper bound cancer toxicity factors are consistent with the requirements of the Toxicity Criteria Regulation (22 CCR 68400.5 and 69020-69022) as described in the HHRA Note Number 10 (DTSC 2019c).
Notes [*]: The USEPA (1996) does not define the ages for early-life exposure. Consult with the Project toxicologist.

When multiple Aroclors, homologs, or congeners are detected in a sample, their concentrations may be summed and presented as total PCBs in the risk assessment. HERO recommends using the "high-risk" toxicity factors as default values to calculate cancer risks for the total PCBs. The HERO toxicologist should be consulted prior to using the low and lowest risk categories to ensure that the criteria for use on receptor age, exposure medium, and chlorine content have been met.

6.2 Non-Cancer Toxicity Factors and Risk Characterization

Table 6.2 lists the oral reference doses (RfD) and inhalation reference concentrations (RfC) calculated by route-to-route extrapolation for Aroclor 1016 and 1254, the only two Aroclors that have the non-cancer toxicity factors published by the USEPA. The DTSC generally recommends route-to-route extrapolation from the oral route of exposure for chemicals with systemic toxicity that lack an inhalation toxicity factor (*e.g.,* DTSC 2019b). The USEPA also utilized route-to-route extrapolation for evaluating non-cancer indoor air risks in school evaluations (USEPA 2015).

Other non-cancer toxicity factors for PCBs have been published or otherwise considered by other agencies including ATSDR (2000) and California EPA (2007). The reference doses (0.02-0.08 µg/kg-day) in these documents are in the same range as those provided by USEPA. Per the requirements of the Toxicity Criteria Regulation (22 CCR 68400.5 and 69020-69022) effective in September 2018, as indicated in the HHRA Note Number 10 (DTSC 2019c), USEPA non-cancer toxicity factors for these Aroclors should be used for human health risk assessments, screening levels, and remediation goals

Table 6.2 - Non-Cancer Toxicity Values for PCBs

Aroclor	**RfD (µg/kg-day)**	**RfC* (µg/m^3)**
1016	0.07	0.28
1254	0.02	0.08

* Alternate age-specific RfC can also be calculated using the route-to-route extrapolation with age-specific breathing rates and body weights (USEPA 2015). For instance, the RfC for Aroclors 1016 and 1254 are 0.11 and 0.03 µg/m^3, respectively using the recommended body weights and breathing rates for children ages 0-6 provided in DTSC HHRA Note 1.

When performing risk assessments, the non-cancer hazards should be calculated for total PCBs (the sum of all Aroclors or congeners present) and not just Aroclor 1016 and 1254. HERO recommends using the RfD and RfC for Aroclor 1254 to calculate the non-cancer hazard for the total PCBs unless the analytical data show Aroclor 1016 is the dominant Aroclor type.

6.3 Considerations for Dioxin-like PCB Congeners

PCBs have multiple mechanisms of carcinogenic and non-carcinogenic toxicity including polychlorinated dibenzodioxin (PCDD or dioxin)-like effects. As described in Section 4.0, PCB congener data may be collected for QA/QC purposes and analysis of dioxin-like congeners for risk assessment purpose is not routinely performed for abiotic environmental media (*i.e.,* soils and sediment, indoor dust, water and air). However, environmental conditions may selectively lead to degradation or volatilization loss of low chlorine PCB fractions while higher chlorine PCB fractions including the dioxin-like congeners may be proportionally concentrated (ATSDR 2000), indicating a need to analyze some samples to ensure that the environmental PCB mixtures do not pose a substantially higher risk than using the toxicity factors discussed above.

An additional consideration to conduct congener analysis is for situations where high levels of exposure is likely, especially contaminated soils and sediments which may contribute significantly to food chain exposure (e.g., releases to sediments in a lake used for fishing or deposition onto pasture used for animal grazing). The DTSC toxicologist should be consulted on the need to sample for the dioxin-like congeners.

If concentrations of the dioxin-like congeners are analyzed for the purpose of evaluating health risks, the cancer risk and non-cancer hazard associated with these congeners should be calculated independently of the remainder of the PCB mixture using the World Health Organization (WHO) toxicity equivalency factors (TEFs) provided in the HHRA Note Number 2 (DTSC 2017). An example of cumulative risk calculations for dioxin-like and non-dioxins-like congeners is provided in Table 5.4 of USEPA (1996).

7.0 THRESHOLD CONCENTRATIONS

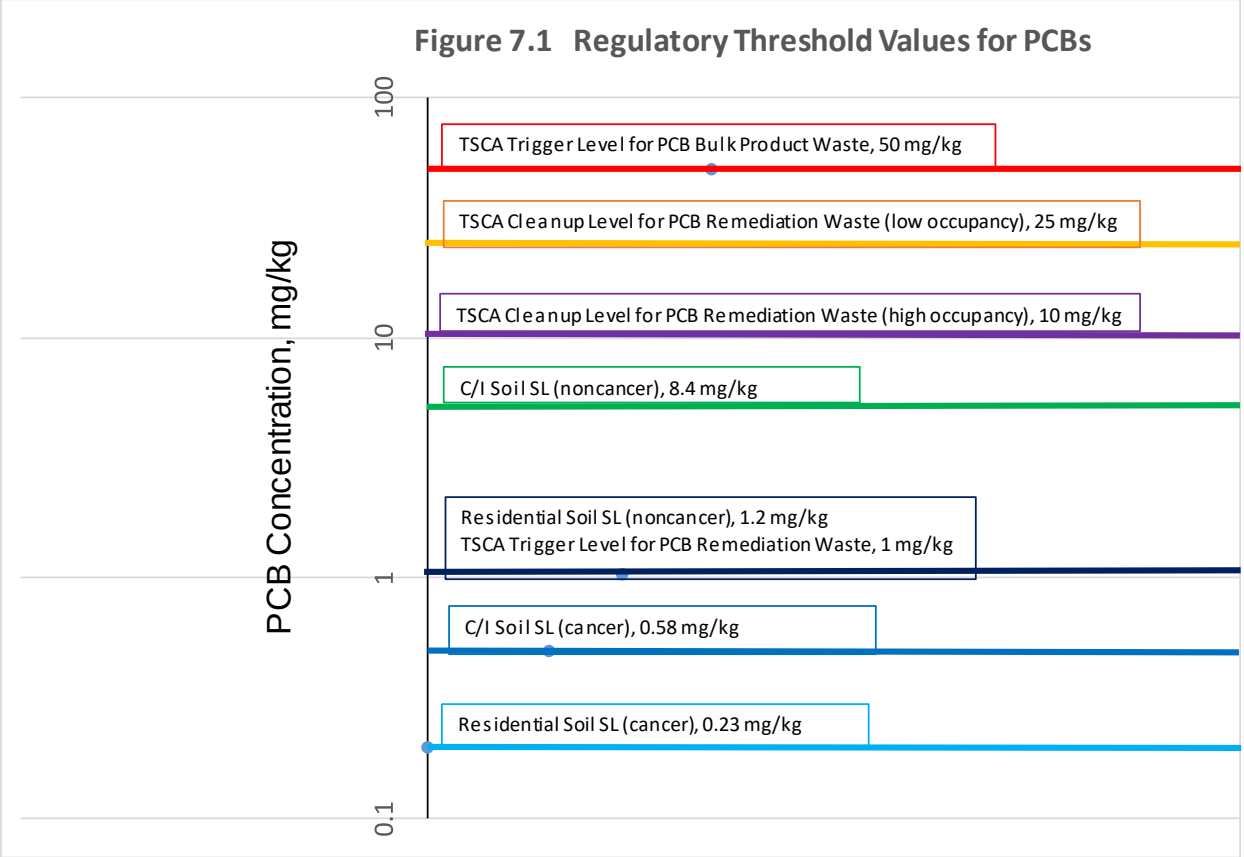
USEPA and California EPA have established screening criteria and action levels for management of PCBs in soil and other wastes as well as materials containing PCBs. Table 7.1 is a summary of common federal and state regulatory threshold values for PCB wastes and TSCA-regulated materials. Figure 7.1 is a graph to illustrate these regulatory threshold values.

Most of the threshold values are intended for management and cleanup of PCB wastes and materials at sites that are regulated under the TSCA. For sites that are not regulated by the TSCA or site-specific cleanup goals are not developed, HERO recommends using the appropriate USEPA RSL as the initial target level for guiding remediation of PCB-contaminated soils, and then conducting a post-remediation risk assessment to demonstrate that the cumulative cancer risk and non-cancer hazard of PCBs and other contaminants of concern remaining at the site following the cleanup meet the project remedial goals. Different remedial goals may be needed for protection of ecological receptors; please consult with HERO – Ecological Risk Assessment Section (ERAS) regarding ecological issues.

Table 7.1 - Federal and State Regulatory Threshold Values

Threshold	mg/kg	Notes
Screening Levels (SL) for Soil* • Residential • Commercial/Industrial (C/I)	0.23 0.58	- Based on a target cancer risk of one in a million (1×10^{-6}) for soil exposure via incidental ingestion, dermal contact, and inhalation of vapor/particulates. - These values may be used as initial target levels for remediating PCB-contaminated soil.
TSCA Trigger Level for PCB Remediation Waste	1	- Typically, TSCA considers as-found concentrations of 1 mg/kg or greater as PCB remediation waste (40 CFR 761.61).
Non-Cancer Screening Levels for Soil* • Residential • C/I	1.2 8.4	- Based on non-cancer DTSC-SLs for Aroclor 1254 (see Section 6.2) at a target hazard quotient of one.
TSCA Cleanup Levels for PCB Remediation Waste	1-25	- TSCA requires removal of all remediation wastes containing ≥ 1 mg/kg PCBs for the self-implementing and performance-based cleanup options. - TSCA (40 CFR 761.61[a]) requires a cleanup level of 10 mg/kg for high occupancy areas (> 6.7 hours/week) with a cap, and 25 mg/kg for low occupancy areas (< 6.7 hours/week).
TSCA Trigger Level for PCB Articles, Containers & Liquids and Bulk Product Waste	50	- TSCA trigger for PCB articles, containers and liquids (e.g., transformers and capacitors; 40 CFR 761.60) - TSCA trigger for PCB bulk product waste (e.g., building materials and fluorescent light ballasts; 40 CFR 761.62). - Total Threshold Limit Concentration (TTLC) as California hazardous waste (22CCR Section 66261.24).

*Based on the DTSC-modified screening levels in Table 1 of the HERO HHRA Note Number 3 (DTSC 2019b); check https://dtsc.ca.gov/human-health-risk-hero/ for the most current values.



Cleanup of PCB releases in indoor environments is typically handled by the USEPA TSCA program. However, DTSC may get involved in some cases under the regulatory authority discussed in Section 2.0. Below are some recommendations to consider for addressing PCB releases in indoor environments:

- Cleanup of smooth surface areas should be confirmed by collecting surface wipe samples. HERO recommends that confirmation sampling be conducted in areas where PCB spills/leaks occurred or were suspected to have occurred in order to ensure the area has been properly remediated. For surface wipe samples, 0.1 µg/100 cm^2 may be used as the initial target level (see Table 5.1 and Appendix B.3) for sites where a site-specific cleanup goal is not developed. Health-based remedial goals for surface wipe samples may be developed by consulting with the HERO toxicologist.
- Remediation of PCB sources such as building materials that are impacting settled dusts typically include verification through demonstrating a reduction in mass loading with surface wipe sampling and/or bulk dust collection. Surface wipe sampling is typically used initially, since removal of settled dusts may leave an insufficient amount of dust for collecting a bulk sample. Further, any residual dust available to sample initially would be expected to have the same PCB concentration as prior to the remediation. As dusts accumulate over time, PCB concentrations in both surface wipe and bulk samples would be reduced due to

remediation of the PCB sources. However, if the mass loading in surface wipe samples or concentrations in bulk samples remain elevated over time, it would suggest some remaining PCB source/reservoir that is contributing to dust concentrations has not been adequately addressed.

- If the inhalation risk needs to be quantified, the air screening levels (USEPA RSLs and DTSC-SLs) discussed in Section 5.0 can be used to estimate the cancer risk and noncancer hazard, respectively for standard residential and commercial/industrial scenarios. USEPA (2015) provides exposure levels for evaluating indoor air at school sites and indicates that these indoor air levels are not to be interpreted or applied as "bright-line" or "not to exceed" criteria"; please consult with USEPA when using these exposure levels to evaluate indoor air levels at school sites. Site-specific risk assessments may also be performed using the toxicity factors present in Section 6.0.
- As discussed in Section 3.3, indoor air sampling may be conducted to verify the success of PCB remediation and other mitigation measures. Specifically, PCB releases may be remediated first followed by testing of indoor air to ensure the protectiveness of the remedy. Alternatively, a practical approach that is often used for managing building materials containing PCBs at USEPA TSCA-regulated sites is to first sample indoor air to determine if further action is needed to reduce exposure.

As stated in Section 2, USEPA is the regulatory lead for management and cleanup of TSCA-regulated PCB materials listed in Appendix A. Please consult with the USEPA Region 9 PCB Coordinator or project manager regarding the cleanup requirements in these situations.

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APPENDIX A - Definitions of Key Terms

1. PCB mixtures are described by the following names, based on the trade name, molecular structure, and analytical method:

    - **Aroclors**: The trade names for the mixtures of PCB compounds that were sold by the North American producer Monsanto Company before 1980. The Aroclor follows a 4-digit number, with the first two digits referring to the number of carbon atoms in the biphenyl skeleton and the second two numbers indicating the percentage of chlorine by mass in the mixture. The common Aroclors include 1221, 1232, 1242, 1248, 1254, 1260, and 1016 (exception to the naming rule).
    - **Congeners**: The family of PCB compounds consists of 209 unique molecular structures, known as congeners, based on the number of chlorine atoms and their location in a PCB molecule. Most PCB congeners are non-coplanar (with chlorine atoms at the ortho positions) and have lower toxicity; the other 12 congeners (PCB-77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 189) are coplanar PCBs, which share similar structure with dioxins and have higher toxicity, and they are often referred as dioxin-like congeners or PCBs.
    - **Homologs**: There are ten homolog groups of PCB congeners with the same chlorine number, varying from one to ten chlorine atoms in PCB molecules. For example, the 2-chlorine homolog group consists of 11 different di-chloro congeners, and the 4-chlorine homolog group consists of 42 different tetra-chloro congeners.
    - **Total PCBs**: The sum of PCB concentrations of Aroclors, congeners, or homologs based on the analytical method listed in Section 4.0.

2. **TSCA-Regulated PCB Materials** are grouped into the following three categories:

    - **PCB-containing articles, containers and liquids** (40 CFR 761.60): including transformers, capacitors, hydraulic systems, switches, voltage regulators, circuit breakers, PCB containers, hydraulic fluids, and cutting oils.
    - **PCB remediation waste** (40 CFR 761.61): including soil, sediment, sludge, building floors and walls that were impacted by PCBs as a result of a spill, release, or other unauthorized disposal.
    - **PCB bulk product waste** (40 CFR 761.62): including fluorescent light ballasts and building products containing PCBs such as caulking and grout, adhesives, sealants, oil-based paint, insulating coatings, and roofing/siding.

APPENDIX B - Evaluation of risks and Hazards associated with PCB-contaminated surfaces

B.1 Introduction

PCB-contamination on frequently contacted surfaces, such as floors, furniture, and play areas, is a major source of exposure and risk through incidental ingestion (hand to mouth transfer), dermal contact (absorption) and inhalation (volatilization and dust resuspension) pathways. Therefore, it is important to estimate potential exposure and risks resulting from contact with PCB contamination on surfaces. The two primary methods for collecting samples from PCB-contaminated surfaces (wipe vs. vacuum) are discussed in Section 3.2, along with recommendations on when it is appropriate to use either one or both of these techniques for sample collection.

Several considerations play into the decision to collect samples via wipes vs. vacuum, for example, surface type/condition, collection efficiency, and physical variability of dust and PCB concentrations. A discussion of the pros and cons of wipe vs. vacuum sampling are provided in the USEPA (1995) document where the dust sampling strategies are presented; however, the discussion was geared towards lead. Considerations that may affect the choice of a vacuum sampling method for PCBs vs. lead include volatile loss of PCBs from the sample and the potential for different collection efficiencies for the PCBs due to the partitioning of PCBs to organic matter with particle size profiles that are not the same as inorganic lead particles.

The equations used to estimate average daily intake (ADI) for PCBs originating from contaminated surfaces depends on the methodology for sample collection, and ultimately influences the cancer risk and non-cancer hazard estimates. If PCB-contaminated dust samples are collected on a bulk basis (e.g., via vacuuming), ADIs can be estimated using the same equations for evaluating exposures to contaminated soils; however, the values for some of the exposure parameters, such as ingestion rate and adherence factor to skin may differ based on the source of dust (strictly indoor, or indoor and outdoor dust) (Section B.2). If PCB contamination on surfaces is evaluated on a mass loading basis (e.g. via wipe sampling), the standard equations for estimating ADIs would be modified with additional parameters integrated into the equations, such as surface to hand and hand to mouth transfer factors (Section B.3).

Inhalation exposure to PCBs is typically estimated using air sampling results when such sampling is warranted (see Section 3.3), so this pathway is not evaluated using surface data. If indoor air is suspected to be affected by PCB-contaminated surfaces, liquids, bulk products or building materials, appropriate sampling protocol should be used, and the data evaluated in a risk assessment using standard equations for assessing inhalation exposures (USEPA RAGS Part F).

B.2 Evaluation of PCBs in Bulk Dust Samples

Calculation of ADIs and subsequent risk estimates using bulk dust samples collected from surfaces (mg PCB/kg dust) is straightforward. The exposure parameters for ingestion of contaminated dusts are treated similarly to contaminated soil with the exception of the ingestion rates. The risk assessment default ingestion rate for indoor dust is 100 mg/day (upper percentile value) for children (ages 6 months to 12 years) and 60 mg/day for older children and adults in the USEPA Exposure Factors Handbook (USEPA 2017b). Because dermal adherence factors (AF) and skin surface areas (SA) for various body parts (hands, forearms, feet, etc.) are not specifically provided for typical indoor environments, default dermal exposure parameters for soil can be used.

For exposure to surface dust in outdoor environments, default ingestion rates and dermal contact rates for soils can be used.

B.3 Evaluation of PCBs in Surface Wipe Samples

Evaluation of exposure to PCB-contaminated surfaces using wipe samples is complicated as there are no standard, widely accepted methodologies or exposure assumptions available for this type of assessment. Therefore, various agencies/entities, including USEPA, DTSC, and the World Trade Center Indoor Air Task Force Working Group (WTC-IATFWG) have developed their own methodologies for calculating risks from exposure to contaminants detected on surfaces using results of wipe samples. Below is an example of using wipe sample data to evaluate the health risks for children and teachers.

Evaluation of PCB-contaminated Surfaces - An Example

DTSC has been involved in evaluating one northern California site with PCB contamination as part of a time-critical response action to protect children and teachers. The sources of PCBs in this case involved light ballasts containing PCBs that leaked in classrooms. The following case study describes DTSC's risk-based approach for determining risks to teachers and students who may potentially come in contact with PCB-contaminated surfaces in these classrooms. This risk-based approach was specific to this site and may need to be adjusted according to project conditions.

In this example, it was assumed that exposure of students/teachers to PCB-contaminated dust on surfaces occurred primarily through surface to hand to mouth contact and through dermal absorption of PCBs from contaminated surfaces. Therefore, only the equations for evaluating the ingestion and dermal contact pathways using the mass loading ($C_{surface}$, µg/cm^2) as measured by surface wipe sampling are described below.

$$Ingestion\ Intake = \frac{C_{surface} \times CA \times CF \times TE \times f_{do} \times f_{gi} \times EF \times ED}{BW \times AT}$$

$$Dermal\ Intake = \frac{C_{surface} \times CA \times CF \times TE \times ABS_{dermal} \times EF \times ED}{BW \times AT}$$

The definitions of the exposure parameters in these intake equations are listed on Table B-1, along with the parameter values used to calculate the intake factors for the ingestion and dermal contact pathways for student and teacher, respectively.

Table B-1 - Exposure Parameters for Surface Dust Evaluation

Exposure Parameter	**Unit**	Student Ingestion Pathway	Teacher Ingestion Pathway	Student Dermal Contact	Teacher Dermal Contact
CA, contact area[(a)]	cm^2/event	372	647	809	1387
CF, contact frequency[(b)]	events/day	6	6	6	6
TE, surface to skin transfer efficiency[(c)]	--	0.1	0.1	0.1	0.1
f_{do}, skin to mouth transfer efficiency[(d)]	--	0.04	0.04	NA	NA
f_{GI}, fractional absorption from GI tract	--	1	1	NA	NA
ABS_d, dermal absorption factor[(e)]	--	NA	NA	0.15	0.15
EF, exposure frequency[(b)]	days/year	230	230	230	230
ED, exposure duration[(b)]	years	6	25	6	25
BW, body weight[(f)]	kg	34	80	34	80
AT, averaging time (cancer)	days	25550	25550	25550	25550
Intake Factor[(g)]	**cm^2/kg-day**	**0.014**	**0.044**	**0.12**	**0.35**

[(a)] It was assumed that only the palms (372 cm^2 for child and 647 cm^2 for adult) would come in contact with surfaces for incidental ingestion; the palms and underside of the forearms (437 cm^2 for child and 740 cm^2 for adult) would come in dermal contact with surfaces. These values are 50% of the recommended surface areas for the hands and forearms on pages 7-40 and 7-41 of the Exposure Factors Handbook (USEPA 2011).

[(b)] It was conservatively assumed that a child (ages 7 to 12) and a teacher could be exposed to the contaminated surfaces for 6 (grades 1 to 6) and 25 years, respectively; classes would be held year-round (230 days/year) with 6 classes per day (i.e., 6 events per day).

[(c)] Source: DiBiasio, et. al. (2003).

[(d)] Source: Michaud, et. al. (1994).

[(e)] Source: DTSC (2015).

[(f)] Based on an average body weight of 34 kg for child (ages 7 to 12) and 80 kg for adult.

[(g)] Intake factor = Intake/$C_{surface}$ (i.e., the right side of the intake equation without the $C_{surface}$ term)

NA = not applicable

Using the calculated intakes listed on Table B-1, the risk-based level for a surface wipe sample that corresponds to a target cancer risk of $1x10^{-6}$ is estimated to be 0.19 and 0.06 µg/100cm^2 for student and teacher, respectively using the following equations:

$$C_{surface} = \frac{TR}{(IngF + DermF) \times SF} \times \frac{1000 \mu g}{1 mg}$$

and

$$C_{wipe} = C_{surface} \times r_{wipe} \times A_{wipe}$$

where:

$C_{surface}$	= PCB mass loading on surface (µg/cm^2)
C_{wipe}	= PCB mass loading measured in wipe sample (µg/100 cm^2)
TR	= Target cancer risk (1 x 10^{-6})
IngF	= Ingestion intake factor (cm^2/kg-day, see Table B-1)
DermF	= Dermal intake factor (cm^2/kg-day, see Table B-1)
SF	= PCB cancer slope factor, 2 (mg/kg-day)$^{-1}$ (see Section 6.1)
r_{wipe}	= Sample collection removal efficiency (default = 0.5)
A_{wipe}	= Wipe Area (= 100 cm^2)

The derivation includes an assumed sample collection removal efficiency of 50% (DiBiasio, et. al., 2003) to reflect that approximately half of the dust would typically be removed by surface wipe, and thus the measured PCB mass loading in wipe sample is adjusted accordingly. It should be noted that the removal efficiency from smooth surfaces (80-90% for Formica laminate) is generally higher than rough surfaces (50-91% for plywood) (USEPA 2007).

Because the risk-based level for teachers is more conservative, this value (0.06 µg/100 cm^2 rounded to 0.1 µg/ cm^2) has been selected as the screening level for PCBs in surface dust (DTSC 2003). It should be noted that the body weight and skin surface area values have increased since the screening level was developed in 2003, as reflected in the body weight and skin surface area estimates listed on Table B.1 in accordance with USEPA's 2011 Exposure Factors Handbook. The exposure parameters listed on Table B-1 may also be adjusted according to the receptor type, surface conditions, etc. (USEPA 2011; WTC-IATFWG 2003) to derive site-specific risk-based levels.