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A Research Study to Investigate PCBs in School Buildings

Final Research Plan

Office of Research and Development
National Exposure Research Laboratory

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June 16, 2010

National Exposure Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Research Triangle Park, NC

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1. Background

Polychlorinated biphenyls (PCBs) are synthetic chemicals that were manufactured in the United States between about 1930 and 1977 for use in various industrial and commercial applications because of their nonflammability, chemical stability, high boiling point, and electrical insulation properties (ATSDR, 2000). PCBs were used in numerous products and processes, including electrical, heat transfer, and hydraulic equipment; as plasticizers in various products; in paints and finishes; in pigments, dyes, and carbonless copy paper; and in other industrial and commercial applications. There are no known natural sources of PCBs. PCBs are either oily liquids or solids that are colorless to light yellow. PCBs are mixtures of up to 209 individual chlorinated compounds (known as congeners).

Most of the PCB mixtures manufactured for commercial use in the United States are known by the trade name Aroclor. Each specific Aroclor contained mixtures of some of the 209 congeners, with chlorine contents of the different Aroclors ranging from 21% to 68%. Between 1957 and 1971, 12 types of Aroclors were produced (ATSDR, 2000). During this time, PCBs were used in completely closed systems (such as transformers and capacitors), nominally closed systems (such as hydraulic systems and vacuum pumps), and open systems (such as plasticizers and paints). In 1970, the manufacturer discontinued use of Aroclors in open products and uses that could lead to direct transfer into the environment (Erickson, 1997).

Manufacture of PCBs was banned in the United States by Congress, and their use was phased out, except for certain limited uses, by 1978 because of evidence they are persistent in the environment and can cause harmful health effects. PCBs have been shown to cause cancer in animals, and, in chronic animal studies, PCBs have been shown to cause effects on the immune, reproductive, nervous, and endocrine systems. In some studies, exposure to PCBs has been associated with adverse health effects in humans. Because of potential neurotoxic and endocrine effects, there is concern regarding children's exposures to PCBs.

PCBs are highly persistent in the environment. As such, they are still present in soils and sediments in many locations and may be found at low levels in ambient air and water. PCBs can be released into the environment from hazardous waste sites, illegal or improper disposal of industrial wastes and consumer products, leaks from old electrical transformers and capacitors containing PCBs, and burning of some wastes in incinerators. PCBs undergo bioaccumulation and may eventually enter foods that people consume. Foods with the highest PCB levels are typically fish, meat, and dairy products. Dietary consumption of contaminated foods is believed to be a primary route of exposure to PCBs for people in the United States.

Additional exposure to PCBs may occur for people who spend time in buildings where PCB-containing materials are present. A number of products manufactured before the mid-1970s contained PCBs. Products that may contain PCBs include

- dielectric fluid in transformers and capacitors;
- other electrical equipment, including voltage regulators, switches, circuit breakers, reclosers, bushings, and electromagnets;
- oil used in motors and hydraulic systems;
- old electrical devices or appliances containing capacitors with PCBs;
- fluorescent light ballasts;
- cable insulation;
- thermal insulation material, including fiberglass, felt, foam, and cork;
- adhesives and tapes;
- oil-based paints;
- caulk and window glazing;
- plastics;
- carbonless copy paper; and
- floor finish.

Some of these materials can still be found in buildings, particularly those constructed between 1950 and 1978.

Production of PCBs used as plasticizers by the Monsanto Industrial Chemicals Company ranged from approximately 3 million lbs in 1957 to 19 million lbs in 1969, decreasing to zero by 1971 (McCarthy, 2009). Caulk and similar materials that incorporated PCBs as plasticizers have been examined as a potential source of exposure to building occupants. Kohler et al. (2005) reported on concentrations of PCBs in more than 1300 samples of joint sealants collected from buildings in Switzerland built between 1950 and 1980. Nearly half (48%) contained PCBs, and levels exceeding 50 ppm were found in 42% of the samples. Concentrations exceeding 10,000 ppm were found in 21% of the samples, whereas concentrations exceeding 100,000 ppm were found in 9.6% of the samples. Chlorine content was examined in a subset of Swiss samples, and more than 90% had results consistent with mixtures of Aroclors 1248, 1254, 1260, and 1262.

PCBs from caulk and other materials containing PCBs may disperse into the air and dust indoors and into the soil around older buildings, leading to the potential for exposures to people using the buildings and grounds (Hazrati and Harrad, 2006; Herrick et al., 2004; Kohler et al., 2002, 2005). The different vapor pressures of the 209 PCB congeners and the effects of weathering over 30 or more years may affect which congeners are present and available for exposure from different environmental media (Harrad et al., 2009). The extent of exposure to PCBs in indoor environments may depend on their vaporization into indoor air in combination with degradation of materials resulting in contaminated particles available for contact. Many researchers have measured or estimated vapor pressures of PCB congeners and mixtures, and results vary considerably depending on the method (Erickson, 1997). In general, congener vapor pressures decrease with increasing levels of chlorination (see Table 1). Within chlorine-number homolog groups, vapor pressures increase with increasing levels of chlorination in ortho positions (Facloner and Bidleman, 1994). Based on these results, it might be anticipated that inhalation exposures to PCB vapors will be weighted to congeners with lower chlorine numbers unless PCB-contaminated particulate matter becomes available for airborne dispersal. It also may mean that PCB congeners measured in indoor air may not match patterns found in the Aroclor mixtures used in materials in a building.

Table 1. PCB Vapor Pressure Ranges: Examples from Three Reports

Homolog Series	**Delle Site, 1997[a]**	**Falconer and Bidleman, 1994[b]**	**Holmes et al., 1993[c]**
	Pa at 25º C (Number of Congeners)	**Pa at 20º C or 25º C**	**Pa at 25º C (Number of Congeners)**
Monochlorobiphenyls	7.9E-2 to 2.1E (3)	Not reported	3.2E-1 to 9.3E-1 (3)
Dichlorobiphenyls	7.4E-4 to 3.2E-1 (5)	1.0E-1 to 2.5E-1	5.1E-2 to 4.2E-1 (12)
Trichlorobiphenyls	4.8E-3 to 7.6E-2 (5)	6.3E-3 to 4.0E-2	8.4E-3 to 1.7E-1 (24)
Tetrachlorobiphenyls	1.8 E-5 to 2.2E-2 (5)	3.2E-3 to 1.6E-2	1.4E-3 to 6.6E-2 (42)
Pentachlorobiphenyls	4.0E-4 to 2.2E-3 (1)	5.0E-4 to 2.5E-3	2.7E-4 to 1.7E-2 (46)
Hexachlorobiphenyls	2.9E-6 to 1.6E-3 (3)	2.5E-4 to 7.9E-4	5.4E-5 to 6.4E-3 (35)
Heptachlorobiphenyls	None reported	5.0E-5 to 2.5E-4	1.4E-4 to 1.6E-3 (24)
Octachlorobiphenyls	2.4E-6 to 3.0E-5 (1)	Not reported	3.8E-5 to 6.2E-4 (12)
Nonachlorobiphenyls	None reported	Not reported	1.0E-4 to 1.3E-4 (3)
Decachlorobiphenyl	2.9E-9 to 1.4E-5 (1)	Not reported	2.8E-5 (1)

[a]Delle Site, 1997: Compiled vapor pressures for selected congeners from multiple references using direct, indirect, and prediction methods
[b]Falconer and Bidleman, 1994: Liquid saturation vapor pressures; range across average vapor pressures of different levels of othro-substituted chlorines within homolog (estimated from Figure 2)
[c]Holmes et al., 1993: Originally from Buckhard et al., 1985, *ES&T,* 22:503-509. Based on liquid or sub-cooled liquid values rather than from solid phase

Harrad et al. (2009) noted that the combination of residential indoor air inhalation and dust ingestion could exceed dietary intake of PCBs in some scenarios. Exposures to PCBs in air and dust from contaminated nonresidential buildings could increase exposures for some people. For example, levels of PCBs in the indoor air of some office buildings with PCB-contaminated sealants (up to 6000 ng/m^3 [Kohler et al., 2005]) exceed the levels reported in residential indoor air (maximum of 14 ng/m^3 total PCBs [Harrad et al., 2009] and 35 ng/m^3 for congeners 52, 105, and 153 in a contaminated home [Rudel et al., 2008]).

Of particular concern is the potential for school children's exposures to PCBs in older schools. Schools constructed between 1950 and 1978 may contain caulk that incorporated PCBs as a plasticizer. Caulk containing PCBs may have been used around exterior windows and doors, exterior building joints, and in interior locations. PCBs may vaporize from the caulk and become airborne. PCBs may be absorbed onto (or into) other surfaces, materials, or dust. Caulk may degrade or suffer abrasion wear that can create PCB-containing dust that is then available for transport in indoor areas. PCBs from exterior caulk may be deposited into soils near the school building.

There has been no systematic effort to characterize PCB sources and environmental levels at schools across the United States. Measurements of PCBs in caulk have been made for several college buildings and a number of primary and secondary schools. Environmental samples, including air, dust, wipe, and soil samples, also have been collected at a number of school buildings. Measurement results for PCBs in schools in the United States have not been widely published in the scientific literature, although Herrick et al. (2007) reported on PCBs in soil collected near buildings with PCB-contaminated caulk or joint material. Measurement results have been reported in presentation and report formats (e.g., Coghlan et al., 2002; Sullivan, 2008; TRC, 2006, 2008, 2009), and results from individual schools have been compiled on the internet (pcbsinschools.org). Total PCBs in caulk in U.S. college and school buildings have ranged from not detected to over 200,000 ppm. Concentrations in school indoor air have ranged up to approximately 1000 ng/m^3. Total PCB levels in dust have ranged up to approximately 80 ppm. Wipe samples have ranged up to approximately 1 µg/cm^2 total PCBs. Soil concentrations in samples collected next to buildings have ranged up to approximately 80 ppm of total PCBs.

Although caulk is believed to be a primary source of PCBs in some older schools, there is still considerable uncertainty regarding the extent to which PCBs in other materials used in schools might contribute to exposures (Coghlan et al., 2002). Other primary sources (materials manufactured with and containing PCBs) or secondary sources may be present in some schools. For example, window glazing has been found in several locations to contain levels of PCBs greater than 50 ppm. Secondary sources might include surfaces, materials, and dust that have been contaminated through transport of PCBs from caulk. An in-depth investigation in a high school found PCBs in numerous materials, including but not limited to laminate adhesive, mastics, paint, gasket, carpet, foam padding, and bulk dust (TRC, 2008; Sullivan, 2008; TRC, 2009). Some of these materials had concentrations exceeding 10 ppm, ranging up to more than 250 ppm. If other primary and secondary PCB sources are present in schools, they could contribute to exposures to children. To make sound decisions regarding reducing exposures to PCBs in schools, it is important to understand the range of potential sources of PCBs in schools; their contributions to PCBs in air, dust, and soil; and the magnitude of potential exposures to children, teachers, and staff in school environments.

There is very limited information on PCBs in schools in the United States. Neither the sources, including PCB-contaminated caulk, nor the routes of exposure have been well characterized in schools. Indoor models describing the emission, transport, accumulation, and disappearance of PCBs in buildings are lacking. As such, there remains considerable uncertainty regarding the extent to which children and staff members may exposed to PCBs in school environments. Research is needed to help fill these information gaps to improve our understanding of exposure to PCBs in schools.

2. Research Objectives

Research on sources of PCBs and levels in school environments is needed to improve risk management decisions. To better understand the significance of PCB-contaminated caulk as a source of exposures to children, teachers, and staff in school buildings, the U.S. Environment Protection Agency's (EPA's) Office of Research and Development (ORD) plans to

- characterize PCB-contaminated caulk and other potential sources of PCBs in schools;
- investigate relationships between PCB concentrations in air, on surfaces, and in dust and soil with potential sources in school buildings;
- evaluate which routes of exposure (e.g., inhalation, contact with surfaces or dust) are likely to be most important;
- improve exposure assessment models for school-related exposures and examine the feasibility for development of an indoor model for PCBs; and
- provide samples, data, and other information to assist in developing risk management practices for reducing exposure to PCBs in schools.

To meet these research objectives, the ORD National Exposure Research Laboratory (NERL) plans to conduct a measurement study in up to nine schools in the United States. The research described in this study design is being coordinated with research efforts in the ORD National Risk Management Research Laboratory (NRMRL) that are aimed at evaluating PCB emission rates, transport, and exposure mitigation methods.

3. Study Summary

3.1 Study Overview

A brief overview of the research study is outlined below. Details regarding each element are provided in subsequent sections of this research plan.

ORD research will consist of both field and laboratory components. This study design addresses the school measurement field study and also includes the collection of materials from schools that will be used in NRMRL laboratory investigations of PCB emissions and transport. The field measurement study will involve recruitment of a limited number of schools (up to nine) with PCB-contaminated caulk to participate in the study. Limiting the number of schools will allow a more intensive characterization of PCB sources and environmental measurements that can be used to better understand the relationships between sources, environmental concentrations in selected media (dust and air), and potential exposure. At each school, PCBs will be measured in indoor and outdoor air, soil adjacent to the building, and on surfaces or in dust at multiple locations within the school building. Caulk and other materials that may be primary or secondary PCB sources will be collected for PCB analysis. Some materials also will be collected for subsequent chamber tests to characterize PCB emissions and transport. Information will be collected at each school regarding building characteristics, building materials, ventilation systems, school operations, and other factors that may affect the distribution of PCBs in the school building and the potential for exposure. All samples will be analyzed for selected Aroclors or homologs to determine total PCB levels, and a subset of samples will be analyzed for specific PCB congeners. The measurements and other study information will be used as input data into ORD's Stochastic Human Exposure and Dose Simulation (SHEDS) model to improve the model's ability to predict exposure distributions for school-age children, teachers, and other workers under selected scenarios. In combination with laboratory test results, the measurement of source materials and environmental media also may lead to the development of indoor PCB models. Study results will be provided to the schools and to Agency Offices and Regions for use in improving tools for exposure assessment, risk assessment, and risk management.

3.2 Investigators

Researchers and staff members for this research study include the following individuals.

- Kent Thomas, NERL, Principal Investigator and Study Manager
- Ron Williams, NERL, Co-principal Investigator
- Roy Fortmann, NERL, HEASD Division Director and Co-investigator
- Don Whitaker, NERL, EMAB Branch Chief and Co-investigator
- Paul Jones, NERL, Co-investigator (statistician)
- Jiaping Xue, NERL, Co-investigator (SHEDS modeling)
- Carry Croghan, NERL, Co-investigator (data management)
- Zhishi Guo, NRMRL, Collaborating Investigator
- Contractor, TBD, Sample Collection
- Contractor, TBD, Sample Analysis

3.3 Study Limitations

A primary objective of the school PCB measurement research study is to characterize potential PCB sources and environmental levels of PCBs in multiple locations in schools. These types of data are needed to understand sources and relationships between sources and environmental levels of PCBs to make the most informed risk reduction decisions. Because of the intensive nature of this research requiring a large number of measurements within schools, it will not be feasible to select and enroll a representative sample of schools for making inferences about the presence and levels of PCBs in schools either nationally or within a region. A simple survey based on only one or two measurements in a large number of schools would not address the primary study goal of providing information to inform risk management decisions in schools. It is also not clear, at this time, how many and what type of samples, would need to be collected at each school in a larger prevalence survey. Results from this study can be used to help address that question.

Although the study is designed to collect samples of numerous materials in school buildings, including those thought likely to contain PCBs, it will not be possible to collect and analyze all materials present inside and outside of the buildings. It is possible that some potentially important primary or secondary PCB sources will be missed.

The proposed research will not collect or analyze blood samples from students, teachers, or school staff. Therefore, it will not be possible to examine the associations or relationships between environmental concentrations in schools and PCB body burden. Although this would be important information, it would require additional resources to develop control groups and assess non-school-related sources of PCB exposures that would limit the primary research goal of this study.

4. School Recruitment and Engagement

4.1 Number and Types of Schools

It is beyond the scope of the current research and available resources to understand the extent of what is likely to be a nationwide issue. Also, at this time, it is not clear exactly which types of measures and how many measures per school would be required to implement a large-scale prevalence survey. The primary goal of this research effort is to collect a large number of measurements in schools to help understand within-school variability and, most importantly, relationships between PCBs in materials and levels in air, on surfaces, and in dust and soil. This information is important for better understanding potential exposures, informing risk management decisionmaking and mitigation approaches, and how to better evaluate schools for PCBs in the future. The research study will be an intensive monitoring effort performed in up to nine schools. Elementary, middle, and high schools are of most interest for this research study. In the event that insufficient schools agree to participate, college buildings may be considered for selection. Schools that were constructed between 1950 and 1978 are most likely to have PCB-containing caulk, so schools that were constructed or significantly renovated during that period will be monitored. Because the study focuses on PCB source assessment and environmental levels associated with PCB-containing materials, no control school buildings constructed after 1978 will be monitored. In the absence of control school buildings, appropriate quality control (QC) materials and procedures will be used to ensure that PCBs measured in school environments and materials are not the result of background contamination of materials used for sample collection and analysis.

4.2 Identifying and Recruiting Schools

NERL will work with EPA regions and State and local governments as needed to locate schools interested in having monitoring performed. An information sheet that provides a summary of the research goals and study approach has been prepared as a communication tool and is included in the appendix. We anticipate that schools that already have found elevated PCBs in caulk or those that are planning renovations are most likely to be monitored. In the event that work is considered in a school where it is not known whether PCBs are present in the caulk, it may be necessary to perform a screening sample collection to determine whether the school is eligible for participation in the full measurement study.

4.3 Development of Individual School Sampling Plans

The general approach for the proposed sampling is described in later sections. However, each school will have unique characteristics, operations, and requirements that will necessitate development of school-specific plans. We will work collaboratively with the school administration to develop a plan for each school that identifies access times and procedures, sampling locations, the specific materials to be collected, and the appropriate school contacts. Part of this collaborative effort will be an on-site scouting visit to examine the school space and discuss logistical, sample collection, and scheduling issues. Research staff will work with school administrators and staff to minimize the disruption of school activities and operations. The school plans also may identify procedures for reporting study results to the school.

4.4 Information about the School

Some selected information about the school is needed for two reasons. First, information regarding the layout, history, and operations is needed to plan the sample collection locations and to identify materials for sample collection. Second, selected information also is needed as inputs for the SHEDS PCB modeling effort. Two structured forms for recording information about the school will be developed. The first will be used during a premonitoring scouting visit to the school to plan monitoring activities with regard to sampling dates and times, sampling locations, and identification of the materials that are both available for sampling and for which the school provides approval to collect at each location. This information also will be used later during data analysis to facilitate examination of correlations and source relationships for environmental samples. A detailed walk-through of the school with appropriate school staff will be needed during this scouting visit. Results from this scouting visit will be incorporated in the school-specific study plan. Information of interest includes

- general school layout (copies of floor plans would be helpful if available);
- heating, ventilation, and air conditioning (HVAC) systems information (type of HVAC, areas served, and use during the year and during the sample collection period);
- identifying specific locations inside and outside the school for sample collection;
- materials present in the building at locations to be monitored;

- materials that the school will allow to be collected for PCB measurements;
- condition of materials (i.e., caulk that is intact or has visible signs of deterioration); and
- scheduling information regarding access to the school for sample collection.

The second form will be used to collect additional information to be used as input to the SHEDS model. This form can be provided to the appropriate school staff for completion and return to the research team either prior to or following the sampling visit. In general, the types of information of interest include

- school construction and renovation dates and history,
- school operation (start and end dates and times, class period times, and other uses),
- general enrollment information (total students, total number in each grade, and general class sizes),
- information on locations monitored (number of classes per day by grade level), and
- cleaning information (cleaning methods and frequency of cleaning for each method, including monitored areas).

Study staff will need access to school staff who can provide this SHEDS model input information. It will be preferable to collect this information during the scouting visit.

The research described in this study plan is not human subjects research. No personal information will be collected from or about any student, teacher, or staff member. The study will not involve any measurements of PCBs in the children or school staff, nor do we anticipate that changes to school activities will be needed. The research study will not alter the school environment or any individual's activities.

4.5 Time Needed at Each School

If a school is being considered for participation in the research study, and it is not known if caulk in the school contains PCBs, it may be necessary to perform a screening sample collection visit. At this visit, a small sample of caulk would be collected from several locations at the building. The samples would be analyzed to determine whether PCBs are present, and their approximate concentrations. If elevated PCB levels are found, then the school would be eligible to participate in the full study, with visits as described below. At this time, there is no predetermined concentration that would determine potential eligibility; this likely will be based on a relative basis that would consider PCB concentrations, the extent of the caulk in the building, and levels found in other schools.

We anticipate that 3 days will be required to complete monitoring activities at each school, including a day for a scouting visit by study staff and a 2-day period for sample collection. A scouting visit by the study staff will be performed on 1 day several days or weeks prior to collecting samples. Study staff will meet with school administrators and staff to collect the types of information described above. Part of this visit will be a walk-through of the school to identify sample collection locations and the materials of interest to be collected as part of the PCB source assessment. Study staff also will discuss logistical planning issues at this time, including sample collection dates and times, access and school staff assistance for access, and any sampling safety and security issues. This initial scouting visit will take several hours to complete. Information from this scouting visit and from any other discussions with school administrators will be used to develop a brief written sampling plan for the school. The plan will be provided to the school administrators and EPA managers for approval prior to the sample collection visit.

Sample collection will be conducted over a 2-day period. This length of time is needed to allow collection of air samples with acceptable detection limits for PCBs. Air sample collection will be initiated on 1 day and completed approximately 24 h later on the following day. The remainder of the wipe, dust, caulk, soil, and material samples also will be collected during these 2 days. It is preferable to collect the air samples over a period in which any HVAC system is running under normal conditions and when students are present at the school because these activities may affect the level of dust and PCBs in the air. However, research study staff will work with school administrators to determine the most suitable sample collection times and dates. It is acceptable to collect air samples during periods when students are not present. The remainder of the environmental and material samples should be collected during times when students are not present.

5. Sample Collection

5.1 Types of Samples

Screening samples of caulk (interior and exterior) and window glazing may be collected at candidate schools to assess whether elevated levels of PCBs are present. The collection of screening samples is intended to identify buildings in which PCB-containing caulk is present to make decisions regarding the inclusion of a school in the full PCBs in Schools research study. Screening assessments will be performed to determine whether PCBs are present in the caulk and window glazing materials used most widely in a building because reports to date suggest that these materials are likely to have the potential for the highest PCB concentrations. A research operating procedure, “Screening Collection of Caulk and Window Glazing from Buildings for PCB Analysis” has been developed for collection of screening samples (U.S. EPA, 2010). Sample collection will focus on locations where students are most likely to spend time, including classrooms, libraries, multipurpose rooms, gymnasiums, cafeterias, hallways, and outdoors. It may not be possible to identify and collect every different kind of caulk and window glazing in a building during the screening process. The screening approach may not rule out the presence of PCB-containing caulk in every location in a building, nor will it determine whether there may be other primary or secondary sources of PCBs in a building. We have not developed any specific inclusion or exclusion selection criteria based on screening results. A decision to include or not include a school may depend on several factors, including the concentration of PCBs in caulk, how widespread PCB-containing caulk is in the school, and the overall availability of schools for recruitment and selection. It is not known how many schools might need to be screened to identify up to nine schools that have PCBs in caulk that would subsequently be selected for full monitoring.

For schools selected for full monitoring, samples will be collected in each school to characterize school environmental levels in air, on surfaces, and in dust and soil; to measure levels of PCBs in caulks; and to evaluate other potential primary and secondary sources of PCBs in other materials. A summary of the types of samples to be collected is shown in Table 2. Materials other than caulk that are of potential interest also are shown in Table 2. These materials are included based on reports of PCB-containing materials in older schools or other buildings and the potential of the materials to contribute to exposures based on prevalence and area. However, not all of these materials will be available in each school and school location, and school permission will be needed to collect samples of materials when they are present.

Table 2. Summary of Sample Types

Sample Type	Sample Type Code
School Environment	
Indoor air	IA
Surface wipe – desk/table surfaces[a]	ST
Surface wipe – floor/wall/windowsill surfaces[b]	SB
Bulk dust	BD
Outdoor air	OA
Exterior soil	OS
Caulks	
Caulk from exterior window/door	EC
Interior caulk	IC
Exterior building joint caulk	JC
Other Materials of Interest[c]	
Material adjacent to caulk	AC
Floor tile mastic	FM
Floor tile	FT
Cove/molding mastic	CM
Cove/molding	CV
Wall paint	WP
Ceiling tile	CT
Gasket	GK
Vent coating	VC
Window glazing	WG
Foam padding	FP
Floor finish	FF
Carpet and pad	CA
Light ballast wipes	LB
Others, to be determined (TBD)	OT

[a]Two wipe samples, collected from a student desk and classroom table in selected rooms
[b]Up to three wipe samples, collected from the floor, a windowsill, and a wall
[c]Materials to be collected will depend on their presence and availability at each school and school location. Specific plans will be developed for each school.

Other materials of interest may be identified based on school scouting visits.

The types and locations of samples in this research study are intended to support the research goals identified in Section 2. The research focus is on developing a better understanding of potential exposures and relationships between sources and environmental levels. The sampling approach in this research effort is not intended to provide data for characterization of sampling for PCB remediation waste or for verifying completion of cleanup and disposal.

5.2 Sampling Locations

It will not be possible to characterize PCB levels in all school building locations. The focus of this research is on areas where children and staff spend the most time during the school day and during after-school programs. As such, samples will not be collected in basements (unless classrooms or other student activity areas are present at that level) or mechanical equipment rooms, even though there may be PCB sources present. A proposed list of sample collection locations for the environmental and caulk samples is shown in Table 3. One study goal is to collect samples in as many interior locations as is feasible and affordable, so seven rooms and the HVAC system (when one is present) have been identified, resources permitting.

Table 3. Locations for Collection of Environmental Samples and Caulk

	Environmental Samples						Caulk Samples		
	IA	ST	SB	BD	OA	OS	EC	IC	JC
Indoor Locations[a]									
Classroom 1	O	O	O	O			O	O	
Classroom 2	O	O	O	O			O	O	
Classroom 3	O	O	O	O			O	O	
Hallway	O		O	O				O	
Cafeteria	O	O	O				O	O	
Gymnasium	O		O	O				O	
Library	O	O	O				O	O	
HVAC system				O				O	
Outdoor Locations[a]									
First side of building					O	O	O		O
Second side of building						O	O		O
Play area						O			

[a]Locations will depend on their presence and availability at each school; specific plans will be developed for each school.

Rooms with primary sources of PCBs, such as caulk or window glazing, are likely to have the highest levels of PCBs in the air and dust and on surfaces. Because a goal of this research is to better understand relationships between sources and environmental levels, rooms with known sources of PCBs are of most interest, and their selection for monitoring would take precedence.

At least three classrooms will be selected for sample collection. The three classrooms will be used for the most intensive measurements, where the greatest numbers and types of environmental and material samples will be collected to enable the most complete assessment of potential relationships between PCB sources and indoor environmental levels. Depending on the school layout, classrooms will be selected for as much diversity as possible based on characteristics such as construction material differences, location (different wings or floors), and different HVAC zones (if present). When multifloor buildings are monitored, precedence will be to first select rooms on different floors and, then, to select on other factors. For buildings with three floors used for instruction, one classroom will be selected on each floor. For schools with two floors used for instruction, two of the classrooms will be chosen from the ground floor with the remaining classroom from the second floor. A decision may be made to collect samples in an additional classroom if a library or separate cafeteria and gymnasium are not present.

One air sample will be collected outside of the school building at the same time indoor samples are collected. When present, caulk used in exterior building joints will be collected from up to three locations outside of the school building. Caulk also will be collected from exterior window and door frames, when present. Soil samples will be collected from up to two areas outside and adjacent to the school building. When exterior joint caulk is present, a soil sample will be collected at one of those locations. A soil sample may be collected below windows with exterior caulk, particularly if PCBs are present. Another soil sample will be collected in one area (i.e., playground, athletic playing field) where children spend time, provided that such an area is present on school grounds.

Up to 34 samples of materials, in addition to caulk, may be collected from interior or exterior locations in each school. One focus for material collection will be the three rooms with the most intensive monitoring. In these rooms, attempts will be made to collect bulk dust; any materials that potentially could contain PCBs; and samples of materials, such as window glazing, floor tile, tile mastic, ceiling tile, and wall paint, that make up the bulk of the room's surface area. Other potential primary PCB source materials would be scheduled for collection from other rooms where air, wipe, and caulk samples are collected when such materials can be identified.

Some "hidden" materials such as insulation also may serve as sources or sinks for PCBs. Although these materials are of interest from an indoor modeling perspective, it may be difficult to collect such materials. Some caulks may be present in inaccessible locations between windows and buildings or between building structural components. Also, although collection of some “subsystems” or groups of materials could be of interest, it is unlikely that such systems easily could be collected and analyzed. Samples of hidden materials will be considered on a case-by-case basis, but no destructive methods will be used to gain access to such materials.

The selection of materials to be collected will be made during the scouting visit to the school and will depend on both the availability of the material and the school’s permission for collection of a sample of sufficient size for PCB analysis. Identification of suitable materials will be a collaborative effort by research staff and school staff. An example of what materials might be collected is shown in Table 4.

Table 4. Example Location Template for Collection of Other Material Samples[a]

	VC	AC	FM	FT	CM	CV	WP	WG	LB	CT	LA	LM	CA	GK	FP	FF	OT
Indoor Locations																	
Classroom 1		O	O	O	O	O	O	O	O	O							
Classroom 2		O	O	O	O	O	O	O	O	O							
Classroom 3		O	O	O	O	O	O	O	O	O							
Gymnasium														O	O	O	
Library								O					O		O		
HVAC system	O																

[a]Materials to be collected will depend on their presence and availability at each school and school location. Specific plans will be developed for each school and location. Up to 34 noncaulk material samples will be collected from each school. Where feasible, multiple materials will be collected from three rooms to aid source assessment analyses.

5.3 Numbers of Samples

The number of caulk and window glazing samples that might need to be collected to identify eligible schools is not known. It is anticipated that up to 10 to 15 samples and QC samples may need to be collected at each school, but this will vary on the presence and extent of materials of interest in locations where students spend the most time.

The proposed number of samples to be collected for PCB analysis at each school selected for full monitoring and the total number estimated for collection across the study is shown in Table 5. The estimated total number of samples is based on sample collection in nine schools and collection of samples in the locations indicated in Tables 3 and 4. The actual final number of samples will be based on the specific measurement plans developed for each school that take into account the availability of space and materials.

Some samples will be collected for laboratory chamber emissions testing by NRMRL, in addition to samples being collected for PCB analysis. The numbers and types of samples proposed for collection to support chamber testing are shown in Table 6. Collection of these materials will depend on the availability of sufficient amounts to support chamber measurements. Collection of these materials has been proposed to be completed with the first five schools in the measurement study to enable sufficient time for the laboratory testing.

5.4 Sample Collection Methods

Sample collection methods are described below. General guidance is provided regarding collection locations in some cases; however, it is recognized that final decisions regarding collection locations will be based on the presence and availability of the location or material.

5.4.1 Indoor and Outdoor Air Samples

U.S. EPA Method TO10A will be used to collect total PCBs in air, using a low-volume sampling approach to minimize the size and noise of the pumps to be used in school buildings. Sample filters (ORBO 1000 or similar glass tubes), which are 30-mm x 70-mm tubes filled with precleaned open-cell polyurethane foam (PUF), will be used. Collection will occur without use of the optional XAD (highly absorbent resin) sandwich. The optional total suspended particle (TSP; quartz) filter collection apparatus will be used as part of the sample filter assembly; however, the filter and the PUF will be extracted and analyzed together as a single sample. Separate particle- and gas-phase air concentrations will not be obtained. Collection of inline backup filters will be performed for 5% of the samples to assess whether breakthrough may be occurring using this sampling approach.

Sample collection tubes will be situated with the inlet in a downward facing position at a height of 1 m from ground or floor level. A sampling stand or similar apparatus will be used to secure the sampler, as well as to provide weather proofing for the outdoor monitor. An active air-flow pump, capable of unattended 24-h operation (battery or AC) will be used to provide a flow of 3.5 to 5.0 L/min through the PUF. The highest flow capacity pump that is available will be used to maximize the volume of air sampled. However, if samples are collected during school days, it may be necessary to minimize pump noise and protect systems from contact. Flow measurements will be performed and recorded at the initiation of sampling and then again at the completion of the nominal 24-h sampling period. Start

Table 5. Estimated Number of Samples To Be Collected for PCB Analysis

Sample Type	Samples Collected per School	Number of Schools[a]	Estimated Total School Samples	Estimated QA/QC Samples[b]	Total Estimated Samples
School Environment					
Indoor air	7	9	63	18	81
Surface wipe – desk/table surfaces	10	9	90	9	99
Surface wipe – floor/wall/windowsill	17	9	153	9	162
Bulk dust	6	9	54	9	63
Outdoor air	1	9	9	0	9
Exterior soil – adjacent to building	6	9	54	18	72
Exterior soil – from play area or field	1	9	9	0	9
Caulks					
Caulk from exterior windows and doors	7	9	63	6	69
Interior caulk	8	9	72	6	78
Exterior building joint caulk	2	9	18	6	24
Material Adjoining Caulk					
Material directly adjoining	3	9	27	0	27
Material at increasing distance	3	9	27	0	27
Other Materials of Interest[c]	34	9	306	0	306
Total Estimate	106	9	954	81	1026

[a]Up to nine schools will be monitored.
[b]QC samples may include field blanks, spiked field controls, and duplicate or side-by-side samples. These do not include laboratory QC and quality assurance (QA) analyses that are part of a standard laboratory QA program.
[c]Materials to be collected will depend on their presence and availability at each school and school location. Specific plans will be developed for each school and location. Up to 34 non-caulk-material samples will be collected from each school. Where feasible, multiple materials will be collected from three rooms to aid source assessment analyses.

Table 6. Estimated Number of Samples To Be Collected for Laboratory Chamber Testing[a]

Sample Type	Number of Schools	Samples Collected per School	Estimated QA/QC Samples	Total Estimated Samples
School Environment				
Bulk dust	5	1	0	5
Caulks				
Caulk from exterior window/door	5	2	0	10
Interior caulk	5	1	0	5
Other Materials of Interest[a]	5	1	0	5
Total Estimate		5		25

[a]Materials are to be collected from the first five schools monitored. Materials to be collected will depend on their presence and availability at each school in amounts sufficient to support chamber emissions testing.

and stop times will be recorded, so that a cumulative amount of time at an average flow rate can be calculated to yield a volume of air sample. It is anticipated that approximately 5 to 7 m^3 of air will be sampled over the monitoring event, depending on the pump flow rate and actual sampling duration.

Devices to record the interior and exterior building temperature during sample collection will be deployed along with the air monitors. Ambient atmospheric pressure readings will be collected from the nearest official recording station for the area.

5.4.2 Wipe Samples

Two types of wipe samples will be collected. The first type will be individual samples collected from two surfaces that may be contacted routinely by a student. In classrooms, this may be a student desk and a classroom table. The second type will be samples collected from building surfaces. In classrooms, this will be a floor wipe sample, a wall wipe sample, and a sample collected from a window sill. Window sill samples would not be collected in rooms other than classrooms. Thus, up to five wipe samples could be collected from classrooms, and four samples in libraries and cafeterias. Two samples (wall and floor) will be collected from hallways or gymnasiums that do not have tables or desks.

Wipe samples will be collected based on the wipe sample collection procedure described in ASTM Method D6661-01 [2006], "Standard Practice for Field Collection of Organic Compounds from Surfaces Using Wipe Sampling." PCB-free gauze wipes will be wetted with hexane to collect surface wipe samples. Each wipe sample will be collected in a 100-cm^2 area. Transfer of PCBs from the surface will occur through physical wiping of the defined surface area while applying moderate pressure. Wipes will be handled using appropriate chemical-resistant gloves, followed by storage in a clean amber glass jar having a Teflon-lined cap.

5.4.3 Dust Samples

There is the potential for loose (accumulated and visible) dust to be evident in schoolrooms or in the HVAC system (if present). If a whole-building HVAC system is not present, dust will be collected from up to two single-room heating/cooling systems if they are present. Where sufficient quantities of dust are available in several predefined locations, the dust will be collected using precleaned stainless steel implements or other appropriate means and transferred into a clean amber vial with Teflon-lined cap. A sample size of 2 g for each sample is preferred, whereas 1 g is the minimum sample size. Vacuum devices using an EPA-approved collection media (filter or chamber) represent an alternative method for dust collection. Any vacuum device being reused will have separate collection manifold inlets (trapping media), so that cross-contamination effects are minimized through use of precleaned inlets between sampling sites. Dust samples will be collected following the completion of air sample collection.

In a subset of locations, a dust sample will be collected, when available, to support laboratory emissions testing research. To the extent feasible, samples of 10 g or more of dust are preferred to support this effort.

5.4.4 Outdoor Soil Samples

Soil samples will be collected at two locations adjacent to the building and below joint material or exterior caulk. These samples will be collected where PCB-contaminated caulk or joint material is known to be present or may be present if the PCB content of the caulk or joint material is unknown. At each of the two locations, soil samples will be collected at three distances from the building: 0.5 ft, 3 ft, and 8 ft. (Note: Samples at the two greater distances may be analyzed only if the closest sample concentration exceeds 1 ppm total PCBs). Each soil sample will be collected to a 2-in depth. The sample will include soil from the root zone if vegetation is present but will not include vegetation. A total sample size of approximately 100 g will be collected at each sampling location. Soil sampling will take place using a precleaned stainless scoop and deposited into a clean amber glass container having a Teflon-lined cap.

Another soil sample will be collected from an area where children spend time, such as a playground or athletic playing field. In this case, a composite sample will be collected. This sample is not intended to fully characterize a school yard but is intended to assess whether there is a potential for soil exposures in play areas that would need to be considered in exposure modeling efforts. An area 10 ft x 10 ft will be identified. Soil samples will be collected from the 0 to 2-in depth line at five locations within the designated area, and equal amounts of soil from each location will be combined into a single container. A total sample size of approximately 100 g will be collected.

5.4.5 Caulk Samples

Caulk samples will be collected from rooms selected for sampling in a building. Samples of interior and exterior caulk will be collected, when present. Samples of known PCB-containing caulk have the highest priority for collection. Samples of other caulks will be collected if their PCB content is not known. The exact number and locations for collection will be decided on a room-by-room basis.

Sample collection will generally follow the standard operating procedure, "Sampling Porous Surfaces for Polychlorinated Biphenyls (PCBs)" (U.S. EPA, 2008a). However, only one sample of each selected type of caulk will be collected, rather than three, with duplicate samples collected in designated rooms to examine variability. Also, a sample size of 2 to 4 g will be collected, rather than 10 g. Caulk samples will be collected by physically removing sections of caulk using clean knives, scalpels, and tweezers (or other clean implements, as needed). A piece or pieces of caulk of at least 2 g will be removed from the site of interest and placed in a single precleaned amber glass jar having a Teflon-lined cap. Caulk samples will be collected as they exist in the selected rooms; no emphasis will be made on collecting samples of deteriorating caulk because intact caulk potentially may contain higher levels of PCBs.

In a subset of locations, a second caulk sample will be collected, when available, to support laboratory emissions testing research. For this sample subset, a 10-in section of caulk will be removed. To the extent feasible, it is preferred that the section be kept as intact as possible. However, it is understood that it may not be possible to remove intact 10-in sections. Collection efforts should focus on removing the largest intact pieces possible to support the laboratory emissions testing research.

In addition to room location, additional descriptive information will be collected regarding the caulk collected for analysis. Information on its location, use, current condition, and the presence of any paints or coatings will be collected.

5.4.6 Caulk-Adjacent Material Samples

Materials adjoining PCB-contaminated caulk may absorb PCBs over long periods of time. In some situations, remediation practices may call for removal of the contaminated adjoining material, as well as the contaminated caulk. However, there is uncertainty regarding how much material would have to be removed for remediation. To address this uncertainty, samples of porous materials directly adjoining caulk will be collected, where feasible. And, in a subset of locations (one set of samples per school), up to four samples will be collected perpendicularly from caulk at the distances of 0, 1.0, 2.0, and 4.0 in from the caulk. It is preferred that a range of different types of materials be assessed in this way across the study, including wood, brick, block and other masonry, and drywall or plaster. Material samples will be collected only after air sample collection has been completed.

Sample collection generally will follow the standard operating procedure, "Sampling Porous Surfaces for Polychlorinated Biphenyls (PCBs)" (U.S. EPA, 2008a). However, multiple-depth sampling will not be used. Samples will be collected from the first 0.5 in from the surface that is available for contact. It is likely that power tools will be required to collect these samples, and steps must be taken to minimize contamination of school areas with dust. Different approaches will be considered, depending on the material. The method should minimize the potential for alteration of PCB content via heating or loss of fine material. Appropriate methods will be discussed with the school managers to ensure that collection of the material is acceptable, and that the method used therefore is acceptable. Alternative approaches that produce less dust in the school environment may be considered.

5.4.7 Other Material Samples

As described in earlier sections, selected materials other than caulk will be collected, when available and accessible, as potential primary or secondary sources of PCBs in school buildings. Each of these materials may require different collection methods. Where possible, 10 g of material is the preferred material sample size, with a minimum sample size of 2 g. Samples will be collected using instruments such as a scalpel, razor, spatula, utility knife, putty knife, or other hand tool, as needed. All tools will be precleaned to prevent cross-contamination of PCBs. Other approaches, including some limited use of power tools, may be considered for collection of materials; however, these approaches will need to be discussed and agreed to by all parties prior to implementation, and steps be taken to avoid contamination of school areas. It is not certain how fluorescent light ballast samples will be collected. One approach may be to use wipe material to wipe the ballast if accessible or an area around the ballast if this can be done safely. Materials collected for PCB analysis will be stored in clean amber glass containers with Teflon-lined lids. Material samples will collected following the completion of air sample collection.

Several materials may be scheduled for collection for laboratory emissions testing. Although obtaining intact material for chamber testing is preferred, it is recognized that it may not be possible to collect and store large intact pieces of material. In these cases, the largest material pieces consistent with availability and adequate sample storage will be collected.

5.5 Sample Transport, Storage, and Custody

All samples will be transported and stored for analysis under conditions appropriate for minimizing contamination by PCBs or losses of PCBs. In general, it is anticipated that transport at refrigerator temperatures (approximately 4° C) and storage at general freezer temperatures (approximately –20° C) will be adequate. Samples with potentially high levels of PCBs (such as caulks or other primary PCB source materials) must be stored and transported in a way that will prevent cross-contamination of samples with low levels of PCBs (such as air and wipe samples). Chain-of-custody procedures will be followed to document the custodian and transfer of samples from sample collection through sample analysis.

6. Sample Analysis

6.*1 Background Information*

Decisions regarding sample analysis methods are complicated for PCBs, in general, and for this study, in particular, given the large number of congeners, the large range in congener vapor pressures, the variety of Aroclors that were manufactured and used in different products, the age and weathering of materials in older schools, and the differences in toxicity and potential mechanisms of action for different congeners. Information from the extensive monitoring at New Bedford High School, MA, may be relevant for selecting analysis procedures.

- Aroclor 1254 appears to be the primary Aroclor found in caulk, but other Aroclors were found in other bulk materials.
- Aroclors 1242, 1254, and 1260 were found most often in the many bulk material samples from New Bedford High School; however, laboratory reports state that most samples exhibited altered PCB patterns for the Aroclors, suggesting potential weathering over the long time span since construction.
- Aroclors 1248 and 1260 were reported most often for surface wipe samples collected from New Bedford High School; however, laboratory reports indicated that Aroclor 1248 was not actually present but was used to represent the PCB congeners observed; Aroclor 1260 exhibited an altered PCB pattern when it was reported.
- Wipe samples collected in New Bedford High School often were reported with no PCBs above the detection limit.
- Air samples collected in New Bedford High School were measured as homologs; most of the detectable PCBs came in the di-, tri-, and tetrachlorobiphenyl homolog series, suggesting greater emissions of PCBs with higher vapor pressures and the relative absence of PCBs with lower vapor pressures.

Assessing relative contributions of different materials to the PCBs found in indoor air is difficult because, while Aroclor 1242 has much higher percentages of the di-, tri-, and tetrachlorobiphenyls than do Aroclors 1254 and 1260, there could be large amounts of caulk containing high levels of Aroclor 1254 in some buildings, so even minor fractions of the di-, tri-, and tetrachlorobiphenyls in Aroclor 1254 could be an important contributor to air levels. It also appears that PCBs found on surfaces may not correspond well to standard Aroclor patterns.

Under ideal circumstances, a high-resolution gas chromatography/high-resolution mass spectrometry method (HRGC/HRMS; such as EPA Method 1668B) would be used to quantify as many of the individual PCB congeners as possible in every sample collected in this study. Congener-specific data would facilitate assessments of the contribution of sources to environmental levels and potentially could provide information regarding specific congeners, based on their relative toxicity. However, HRGC/HRMS methods are very costly to perform.

The following were important considerations in selecting analytical methods and PCB reporting for this study.

- The resources available for analyzing more than 1000 samples
- The ability to assess relationships between sources and PCB levels in environmental media
- The need to obtain measurable results for as many samples as possible to perform source assessments
- The need to obtain total PCB measurements for comparisons to standards or recommended levels and to inform school decisionmaking
- A desire to obtain some congener-specific information regarding the PCBs present in school environments and for source evaluations

The proposed analysis approach for this study is similar to the approach used in the New Bedford High School measurement studies; analysis of Aroclors in caulk, wipe, dust, and other material samples and the analysis of chlorine number homologs in air samples. Total PCBs will be reported for every analysis to facilitate comparisons to other samples and to relevant regulatory or action levels. To better evaluate these measurements, a small number of samples from each school also will be selected for additional congener-specific analysis. More specific information is provided below.

6.2 Analysis of Air Samples

All air samples will be analyzed for the PCB homolog series and total PCBs shown in Table 7, using EPA Method 8082A (GC with electron capture or electrolytic conductivity detectors) if appropriate and applicable. EPA Method 680 may be considered if Method 8082A is not appropriate. Air samples are solvent extracted and analyzed by GC with an appropriate detector. The method must be sufficiently sensitive to measure PCBs in ambient outdoor air and to ensure measurable results at sufficiently low concentrations for a majority of the samples to be collected indoors. Proposed quantifiable limits are shown in Table 7. Final detection limits selected for the analyses will be based on laboratory capabilities and resource considerations. To better understand how quantitation for homolog series compares with the three-Aroclor quantitation approaches as described in Method 10A, up to 10% of the air sample extracts (those with the highest measurable results) will be quantified using both the homolog and Aroclor approaches.

Table 7. Air Sample Analytes and Target Detection Limits

Homolog Series	Proposed Quantifiable Limit[a]
Monochlorobiphenyls	0.5 ng/m^3
Dichlorobiphenyls	0.5 ng/m^3
Trichlorobiphenyls	0.5 ng/m^3
Tetrachlorobiphenyls	0.5 ng/m^3
Pentachlorobiphenyls	1 ng/m^3
Hexachlorobiphenyls	1 ng/m^3
Heptachlorobiphenyls	1 ng/m^3
Octachlorobiphenyls	2 ng/m^3
Nonachlorobiphenyls	2 ng/m^3
Decachlorobiphenyls	2 ng/m^3
Total PCBs	—

[a]Assuming a sample volume in the range of 5 to 7 m^3. Actual detection limit will be based on the volume collected for each sample and laboratory method and capability.

6.3 Analysis of Wipe Samples

All wipe samples will be analyzed for the Aroclors and total PCBs listed in Table 8 using the EPASW-846 extraction method EPA Method 3540C (soxhlet extraction) and analysis method EPA Method 8082A. Obtaining measurable results (values above a detection limit) for a large percentage of the samples will be challenging, but it is an important goal of this study to inform source assessment analyses and to provide information for SHEDS model development. Proposed quantifiable limits for the Aroclors are shown in Table 8. Final detection limits selected for the analyses will be based on laboratory capabilities and resource considerations.

Table 8. Wipe Sample Analytes and Target Detection Limits

Aroclor	Proposed Quantifiable Limit[a]
1016	0.1 µg/100 cm^2
1221	0.1 µg/100 cm^2
1232	0.1 µg/100 cm^2
1242	0.1 µg/100 cm^2
1248	0.1 µg/100 cm^2
1254	0.1 µg/100 cm^2
1260	0.1 µg/100 cm^2
Total PCBs	—

[a]Actual detection limit will be based on the area collected and analyzed for each sample and laboratory method and capability.

6.4 Analysis of Dust, Soil, Caulk, and Material Samples

All dust, caulk, and material samples will be analyzed for the Aroclors and total PCBs listed in Table 9 using the EPA SW-846 extraction method EPA Method 3540C (soxhlet extraction) with analysis method EPA Method 8082A. Proposed quantifiable limits for the Aroclors are shown in Table 9. Final detection limits selected for the analyses will be based on laboratory capabilities and resource considerations. Quantifiable limits may vary among materials and samples because of matrix effects and interferences.

Table 9. Material Sample Analytes and Target Detection Limits

Aroclor	Proposed Quantifiable Limit[a]
1016	0.1 µg/g
1221	0.1 µg/g
1232	0.1 µg/g
1242	0.1 µg/g
1248	0.1 µg/g
1254	0.1 µg/g
1260	0.1 µg/g
Total PCBs	—

[a]Assuming a minimum sample size of 2 g for each sample. Actual detection limit will be based on the amount of material analyzed and laboratory method and capability.

6.5 Congener-Specific Analysis for a Subset of Samples

It will not be possible to analyze all samples collected in this study using congener-specific analysis methods. However, congener-specific analysis can provide important information on source relationships with environmental levels, about aging and weathering impact on sources, and, possibly, for limited toxicity assessments by risk assessors. Therefore, a subset of samples will be selected for high-resolution congener-specific analysis, using EPA Method 1668B or equivalent (HRGC/HRMS) following the original sample analysis. This approach may depend on the ability to utilize the original sample extract for the congener-specific analysis. Otherwise, collection of duplicate samples for this analysis will be needed at the time of the original sample collection.

It is anticipated that no more than 40 congener-specific analyses can be supported. The most preferable approach will be to select an air, surface wipe (desk/table), dust, and caulk sample extract from one room in each of the nine schools for congener-specific analysis. The sample set will be selected based on results from the original Aroclor and air homolog series analyses. The sample set with the highest values in the air, wipe, and dust samples will be selected to improve the ability to detect minor congeners. However, this selection approach may need to be modified if it is not possible to obtain all four samples from a single location with PCB levels sufficiently high to support congener analysis. A decision also may be made to include another type of material extract in place of or in addition to the dust sample. This approach may miss important congeners in other locations and from other sources.

It is also important to recognize that a number of congeners may still co-elute when using a single-column high-resolution analysis method.

7. Quality Assurance and Quality Control

The overall QA/QC objective is to generate measurement data of high and known quality. A QA project plan (QAPP) will be developed for this research study and will be approved prior to the collection of samples. The QAPP will define organizational responsibilities, data quality goals, assessment procedures, and review and auditing requirements. The plan also will describe sample coding and chain of custody requirements. Key QC elements will include

- defining organizational responsibilities;
- setting target goals for accuracy, precision, completion rates, and detection limits;
- accuracy assessment using spiked field controls;
- precision assessment using duplicate samples and replicate sample analyses;
- background assessment using field and laboratory blank materials and analyses;
- detection limit goals and procedures; and
- analytical control plans and evaluations.

Some of the key QA elements will include

- accuracy assessment using independent analytical standards,
- field and laboratory audits,
- data review procedures and data reviews, and
- developing and maintaining adequate sample custody procedures.

Field sample collection and laboratory analyses are likely to involve contract organizations. These organizations will have certification or accreditation for PCB sample collection and analysis or will be able to demonstrate experience and performance.

A number of different types of QC samples will be generated or collected as part of this research study. Ideally, at least one set consisting of a field blank, a spiked field control, and a duplicate sample would be collected for each type of environmental sample at each school. It will be possible to meet this goal for air samples. For some sample media (surface wipes, soil, and caulk), the duplicate sample will represent not only the sample collection and analysis precision but also will incorporate any nonhomogeneity in surface loading or content. For some materials, such as caulk and other building materials and for soil, it may not be feasible to prepare appropriate blank or spiked control materials. Laboratory QA and QC analyses will be incorporated into the study as defined in the QAPP.

8. Data Analysis and Modeling

8.1 Data Receipt and Compilation

The field study contractor will provide sample collection and school information to EPA. The sample analysis contractor will provide sample analysis, QC, and QA data to EPA. Copies of sample custody, data collection, and sample analysis report forms will be provided by the contractors and maintained by the investigator. Electronic data files will be organized and compiled by the EPA data manager. All electronic data files will be maintained on an access-controlled networked server with daily backup.

8.2 Descriptive Statistics

Simple descriptive statistics will be generated for each sample type collected at an individual school and for each sample type collected across all schools in the study. Statistics will include central measures (both the mean and standard deviation and the geometric means and geometric standard deviation) and a range (minimum and maximum). If warranted with sufficient measurable data, box plot summaries will be prepared by sample type to show the distributions within and across schools in this study. The distributional parameters will apply only to the schools in this study and will not be used for making inferences to other schools on a regional or national basis. The results for air, wipe, soil, and caulk measurements for the schools in this study may be used for comparison to recommended or regulated concentration levels.

8.3 Analysis of Within- and Between-School Variability

Defining the variability in environmental levels of PCBs in schools in this study will help guide development of future school monitoring plans with regard to the numbers and types of samples to collect. It is also important to characterize within- and between-school variability for subsequent model development. In addition to generating media-specific standard deviations, an assessment of within- and between-school measurement results will be performed using an appropriate statistical approach (e.g., covariance parameter estimation).

8.4 Indoor Modeling: PCB Source Evaluations and Relationships with Environmental Levels

Indoor models are used to describe and predict relationships between various sources of pollutants and their distributions and movements in indoor environments. Indoor models are valuable for understanding how different kinds of pollutant sources and conditions in the building relate to the amount of pollutant that may become available for contact and exposure. Models are also important to help understand which risk mitigation actions are likely to be most effective in reducing the potential for exposures.

To the best of our knowledge, no peer-reviewed indoor model has been published for PCBs in buildings such as schools. Developing and evaluating such models is complex because there are potentially multiple sources of PCBs in indoor environments, both vapor and particle phases must be considered with regard to emissions and transfers, and PCBs are found as mixtures of congeners often having a wide range in vapor pressures. To construct an indoor model, information would be needed regarding

- emission rates of PCBs from primary source materials into the air;
- indoor air concentrations of PCBs;
- absorption rates of PCBs from the air onto or into other materials and dust (secondary sources);
- emission rates from secondary sources;
- estimation of source surface areas;
- particle generation rates from primary and secondary sources;
- levels of PCBs in dust;
- particle transfer or distribution rates within a room or building;
- operational parameters and usage of HVAC systems;
- temperature and humidity data during sample collection, as well as information on the relationships between those factors and PCB emission and transfer rates;
- air exchange rates between building zones and with outdoor air; and
- removal rates of particles and dust from cleaning, filtration, or other mechanisms.

Some of the necessary information will be collected in this measurement study, particularly with regard to concentrations of PCBs in different media, and, potentially, the identification of primary and secondary source materials. The laboratory chamber material PCB emission and transfer experiments to be performed by NRMRL will provide some additional information. However, some of the information for development of a full indoor PCB model will be difficult or impossible to collect. For example, the scope of this research plan does not include measurement of air exchange rates. Such measurements are difficult to perform accurately in large buildings, particularly those with no or multiple forced air handling systems. Also, it will not be feasible to assess PCB source particle generation and distribution factors in-situ. Thus, the development of an indoor model will rely on estimations and assumptions for some factors.

Although recognized as important for indoor pollutant modeling, accurate measurement of ventilation conditions (indoor-outdoor air exchange and interzonal flows) in large old buildings (and for specific rooms within those buildings) is very difficult. Among the difficulties for implementation in this research study are that

- many schools of this age do not have central HVAC systems;
- the actual operating conditions of existing HVAC systems may not be to design specifications, and those specifications may not be known;
- it will not be feasible to sufficiently instrument a building to collect flow and pressure data because of cost and time constraints;
- it will not be possible to release tracer gases to characterize ventilation;
- the assumption of a well-mixed single zone required for simple ventilation assessments is unlikely to be met for many schools; and
- ventilation is likely to be quite variable and highly dependent on short-term changes in which doors and windows are open.

The use of occupant-generated carbon dioxide (CO_2) has been used to provide information regarding ventilation, either in a decay mode, when people leave a room or the building, or in equilibrium mode, when the CO_2 respiration can be estimated from the number of people present, the size of the people, and the room volume. Background information on this approach and the conditions that must be met to do this have been described (Persily, 1997), and an ASTM method has been developed ("Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation," ASTM D6245-07 [2007]). A central tenet of the procedure for producing accurate ventilation rate information (whether using decay or equilibrium procedures) is that the space to be evaluated is a single zone (an indoor space or spaces wherein the CO_2 concentration is uniform, and that exchanges air only with the outdoors). By definition, the CO_2 concentration must not differ by more than 10% from the average across all locations. It will be difficult to meet the single-zone and concentration uniformity requirements in buildings with large spatial variability in air flow and occupancy. For spaces that do not meet the 10% criterion, it must be demonstrated that there is no significant airflow from other building spaces (hallways or other rooms) into the test space. There are literature reports of CO_2-based ventilation measurements in schoolrooms (e.g., Godwin and Batterman, 2007; Scheff et al., 2000). However, it is not clear from these reports whether a single well-mixed zone was present, and the relative contributions of outdoor air and indoor air from other school spaces to the ventilation of a single room is not clear. In a recent report (Nazaroff et al., 2010), the authors describe CO_2-based ventilation measurements made in individual classrooms. In this work, ventilation rates were measured under several different unoccupied sessions in which conditions were manipulated and, then, while the building was occupied, using an observer to monitor specific room and occupancy conditions throughout the measurement. The authors note that many classrooms are likely to be coupled by means of airflow to other occupied spaces, that the coupling is unlikely to be strong enough to produce a larger well-mixed space, and that the coupling could be too large to be ignored. Bartlett et al. (2004) describe some of the issues associated with the transient nature of occupancy and door openings on the ability to accurately assess ventilation. There is a very large difference in ventilation rates in response to changes in air handler settings, opening classroom windows, and with the classroom door open or closed. For modeling purposes, it would be necessary to assess ventilation under multiple conditions and determine or estimate the amount of time each condition applies (again assuming or determining that the ventilation is from outdoor air and not indoor air from other spaces). This research study will not include direct ventilation measurements because accurate measurements will not be feasible within the resources and likely availability of time within the schools when occupied, and also because ventilation and air PCB concentration measurements would be required under different school conditions to fully characterize relationships. A range of air exchange rates will be included in the modeling effort to include both the high and low ventilation rates, as suggested by literature.

Analysis results for PCBs in materials will be compiled for each school location and across each school to examine relative differences in magnitude. Correlation analyses will be performed between environmental media. Correlation analyses will be performed between material PCB levels and the levels of total PCBs in air, surface wipes, and dust inside rooms and across a school. Where warranted with sufficient measurement data, potential source contributions will be considered with regard to surface areas and estimated or measured emission factors and school conditions. Multivariate regression modeling may be feasible, using data from multiple locations with intensive source and environmental data. Alternatively, cluster analysis may be applied for assessing multiple potential source materials with regard to relationships to environmental levels. Analyses will need to consider effects of differences in vapor pressure and weathering with regard to the distribution of different congeners or sets of congeners. Some source assessment analyses may be done best, or may only be achievable, with congener-specific data, which will be limited in this study.

8.5 SHEDS Model Development and Application

Models are important for predicting the potential exposures to PCBs in school environments. Results from modeling can be used to estimate the overall exposure and the relative routes of exposure. Such information can inform the need for remediation actions by schools, as well as the most effective ways to reduce exposures. The SHEDS-Multimedia Version 3 is ORD's state-of-the-science probabilistic aggregate residential exposure model (Hore et al., 2006; Zartarian et al., 2000). SHEDS-Multimedia is a physically based, probabilistic model that predicts, for user-specified population cohorts, exposures incurred via inhaling contaminated air, touching contaminated surface residues, and ingesting residues from hand- or object-to-mouth activities (U.S. EPA, 2009). Inputs include chemical usage (optional); environmental concentration data; and exposure factor information, including activities and time spent in specific microenvironments. Outputs include population and individual outputs for various exposure or dose metrics and key factors and pathways.

PCB measurement data and school operations information will be used as inputs into the SHEDS-Multimedia model to improve the model's ability to predict exposure distributions for school-age children under selected scenarios. Exposure determinants, such as PCB concentrations in air, in dust, and on surfaces students contact most frequently, are important model inputs, and covariance of these determinants with PCB sources and school operation factors, such as cleaning methods and frequencies and HVAC conditions, will be used to develop SHEDS factors and subsequent exposure distributions. Data from various media from the study will be fitted for the distribution and its parameters. Results will be compared with those of other studies. SHEDS can be used to estimate the main contributions from various pathways, such as inhalation, dermal, and indirect ingestion. Sensitivity analyses will identify key inputs, and this analysis may help guide risk management decisions for schools.

8.6 Assessment of Potential Exposures and Exposure Routes

School environmental measurement data and the models described above will be used to develop estimates of potential exposures and exposure ranges. The relative exposures by exposure route (inhalation, dermal contact, and ingestion) will be examined. Different conditions of PCB sources, the school environment, and activities will be assessed for their impact on exposures. This information can be used to assess whether exposure levels exceed levels of concern and to help determine what risk management or remediation efforts will be most effective in reducing exposures.

9. Reporting Results

9.1 Reporting Analysis Results to Schools

Measurement data collected for each school will be provided to the designated representative for each school or school district. Measurement results will be provided in tabular format. Results will be provided immediately following QA review and approval by the designated EPA QA manager and approval for release by EPA management. Measurement data will not be withheld pending completion of data analysis and reporting by EPA scientists. Reports will note measurements that exceed EPA recommended values.

9.2 EPA Reporting

An EPA research report will be prepared to more completely describe the study, compile measurement results across all schools, and report on data analysis results. Recommendations may be included regarding approaches and methods for future school assessments and effective ways to manage and reduce PCB exposures of children and school staff. It is anticipated that one or more science journal articles will be prepared based on this research effort. The information and study results will be provided to the EPA Administrator, regions, offices, and other stakeholders to improve school PCB exposure assessments, source characterization, and risk management or reduction efforts.

10. Proposed Study Timeline

The overall objective is to complete this research study in a 12- to 18-mo time period. To meet this objective, the following timeline is proposed.

- External peer review of study plan, March 2010
- School recruitment, winter/spring/summer 2010
- Initiate PCB screening in candidate schools, spring 2010
- Final research plan, June 2010
- QA project plan prepared, June 2010
- Field study and sample analysis contracts in place, summer 2010
- Initiate sample collection in study schools, summer 2010
- Sample analysis, summer/fall 2010
- Data receipt and QA review, fall 2010
- Provide measurement data to schools, fall/early winter 2010
- Data analysis and modeling, winter 2010/2011
- Draft report, February 2011
- Final report, March 2011

The timeline and schedule depend on the ability to identify and reach agreement with schools to participate in the research.

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APPENDIX

Study Summary Information for Schools

U.S. EPA Research Study to Investigate PCBs in School Buildings

Need for the Research
Caulk containing polychlorinated biphenyls (PCBs) was used in some buildings, including schools, in the 1950s through the 1970s. Other sources of PCBs may also be present in some older school buildings. To better understand the potential problem and improve risk management decisions by schools, EPA is conducting a study on mitigation methods to reduce exposure to PCBs in caulk, and is planning to conduct an exposure monitoring study in schools on PCB-contaminated caulk and other potential sources of PCBs. We are soliciting your help in identifying schools that could participate in this monitoring study.

Research Goals
EPA research on PCBs in schools is designed to identify and evaluate potential sources of PCBs to better understand exposures to children, teachers and other school workers; and to improve risk management decisions. The research will:

- characterize potential sources of PCBs in schools (caulk, coatings, light ballasts, etc.);
- investigate the relationship of these sources to PCB concentrations in air, dust, and soil;
- improve PCB exposure assessment models; and
- develop data that can be used to help identify best practices for risk management.

Study Design
Information below describes the general approach for collection of data to address the research goals. The final design of the study will be prepared in collaboration with staff in the participating EPA Regions, OPPT and other stakeholders. Measurement plans for each school will be developed in collaboration with responsible parties at the school. The study will not involve any measurements of PCBs in the children or school staff, nor will there be changes needed to school activities.

Study Dates
It is anticipated that the sample collection in schools will be able to commence in summer of 2010, contingent on the successful recruitment of schools.

Number of Schools
Up to nine schools could participate in the research study.

Type of Schools
Primary or secondary schools constructed prior to 1975 and that are in use or in good condition are of most interest. College buildings may be considered. Schools that have not received extensive renovations are preferred.

Screening Caulk Sample Collection
If it is not known whether a school has PCB-containing caulk, an initial screening walk-through and collection of caulk samples would be scheduled, requiring 2- 4 hours on one day or evening when students are not present.

Time Needed in the School
If a school participates in the full monitoring study, we expect that EPA contractors will need to have access to the school on three days, including an initial scouting day, followed some days or weeks later by sample collection on two consecutive days.

Samples to Be Collected

- Air samples collected over a 24-hour period in up to nine areas in the schools (including classrooms and other areas) and at one exterior location during the same period.
- Wipe samples collected from surfaces in each of up to nine areas in the school (including classrooms and areas such gyms, cafeterias, libraries, or halls). Samples would be collected from contact surfaces such as desks and tables, and others will be from building surfaces such as floors and windowsills.
- Dust bulk dust samples collected in the HVAC system (if present) and other locations.
- Soil samples from up to three locations outside the school building.
- Small samples of caulk around windows/doors, exterior joints, and interior joints in each of the nine areas sampled.

- Small samples of other potential primary and secondary PCB containing materials. These may include wallboard, masonry, paint, adhesives, tile or other materials from locations in each school.
- A few larger samples of caulk, dust, and materials for laboratory chamber testing.

Other Information Needed

No personal information will be collected from or about any student, teacher or staff member. Some additional information about the school is needed to help interpret the measurement results and improve models used to estimate PCB exposures. In general, the types of information include:

- School building history (year built, renovation dates, etc.);
- School dimensions, layout, and materials;
- School operation (start/end dates and times, other uses);
- Enrollment (total students, class sizes, number in each grade, classes per day);
- HVAC information (type of HVAC, areas served, use during year and during sample collection period); and,
- Cleaning information (cleaning methods and frequency of cleaning for each method).

Impact on Students and Staff

Efforts will be made to minimize any impact or disruptions because of the research.

- The scouting can be performed on a day when school is not in session.
- It is preferable, but not required, that air samples be collected while school is in session because activities and HVAC conditions can affect levels of dust in the air.
- Air sample collection devices will require an electrical outlet. Pumps will be small and efforts will be made to make the pumps as quiet as possible.
- Other types of samples would be collected after school hours to minimize disruptions.

Some staff time will be needed to facilitate access to and within the school building and to provide information about the school.

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