United States Environmental Protection Agency

Sources and Levels of PCBs in Indoor Environments

NIEHS Superfund Research Program and EPA Clu-In Webinar
PCBs in Schools: Session 1 Overview and Exposure Assessment, April 21, 2014

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Presentation Topics

- Sources of PCBs in school buildings
- PCB source emissions
- Environmental levels of PCBs in schools
- Congener-specific measurements
- Potential for exposures to PCBs in schools
- Additional resources for information/guidance

Why Study PCBs in School Buildings?

Assessment

Whether to test?
- School age?
- To determine if PCBs present?
- To reduce exposures?
- Renovations/demolition planned?

What to test (and how)?
- Indoor air?
- Dust/surfaces?
- Caulk? Adjoining material?
- Light ballast survey?
- Other materials?
- Soil?

Information needed for:

- Characterizing the problem
- Informing decision-making
- Building assessment approaches/methods
- Best practices for exposure reduction and remediation

Remediation

Whether to remediate?
- Based on source?
- Based on PCB level(s)?
  - Air, surfaces, soil?
- Based on potential exposure?

How to remediate?
- By Cleaning?
- By Ventilation?
- By source? Which one(s)?
  - How?
    - Removal?
    - Encapsulation?

For buildings constructed or renovated between about 1950 and the late 1970s

EPA/ORD Research

EPA/ORD research reports on PCBs in schools are available at:

http://www.epa.gov/pcbsincaulk/caulkresearch.htm

- **Study of sources, environmental levels and exposures in school buildings**
- Laboratory studies of PCB emission, transport and absorption
- Laboratory study of encapsulant effectiveness
- Laboratory study of in-situ treatment method
- Literature review of remediation methods (conducted by EH&E)

Research Questions

Can we characterize important primary and secondary sources of PCBs in school buildings?

What levels of PCBs can be found in air, dust, soil and on surfaces in schools with PCB sources?

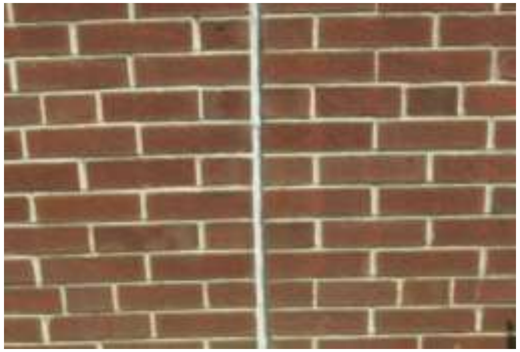
How much exposure might occur to building occupants?

What are the most important routes of exposure?

Research Approach

- Source assessment
  - Primary sources – caulk and light ballasts (6 schools)
  - Secondary sources – paint, tile, furnishings, etc. (3 schools)
  - Emission rate estimation
- Environmental levels (6 schools except dust)
  - Air, surface, dust, soil PCB concentrations
  - Within and between-school variability
- Congener and homolog measurements for one school
- Exposure modeling
  - Estimate PCB exposure distributions for different age groups
  - Assess relative importance of different exposure pathways

PCB Sources – Caulk and Other Sealants



- U.S. Production of Aroclors as a plasticizer ingredient
  - 1958 - 4 million lbs.
  - 1969 - 19 million lbs.
  - 1971 – 0 lbs.
- PCBs were sometimes added to caulk during construction
- Used for
  - Exterior and interior windows and doors
  - Exterior and interior joints
  - Window glazing
  - Other locations/seams (plumbing, casework, etc.)
- Caulk with PCBs ≥ 50 parts per million (ppm) is not an allowed use

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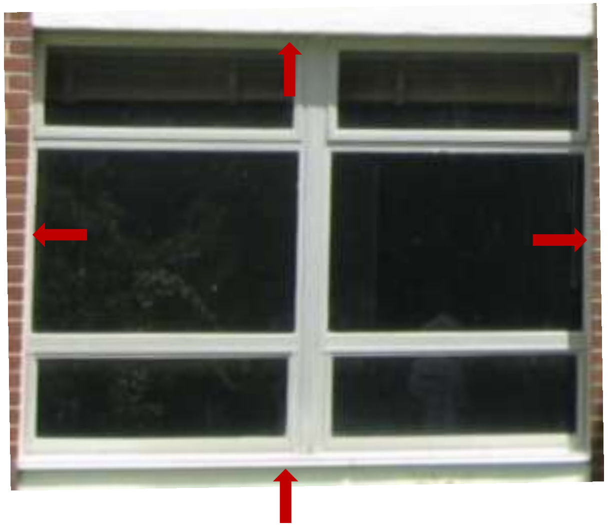
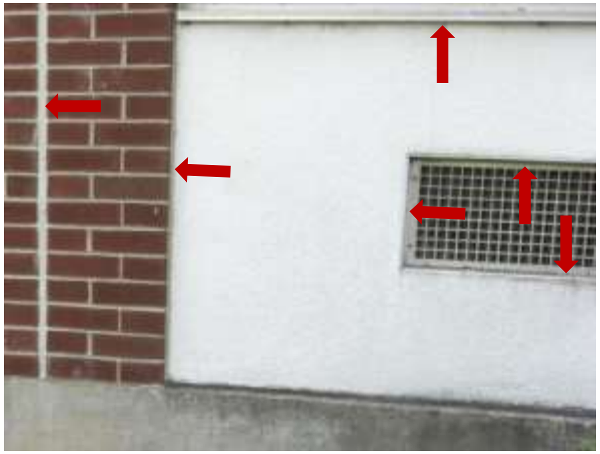
PCB Sources – Caulk and Other Sealants

Total PCBs in Caulk	Interior Caulks From 5 Schools		Exterior Caulks From 3 Schools	
Note: Multiple samples of the same type of caulks were collected				
Number of Samples:	427		73	
	Percent of Caulk Samples			
< 50 ppm	**82.2**		**37.0**	
50 – 999 ppm	7.7		6.8	
1,000 - 99,999 ppm	4.0		21.9	
100,000 – 199,999 ppm	2.3	**6.0%**	12.3	**34%**
200,000 – 299,999 ppm	3.3		15.1	
300,000 – 399,999 ppm	0.2		6.8	
> 400,000 ppm	0.2		0.0	

100,000 ppm is 10% by weight

PCB Sources – Caulk and Other Sealants





- PCBs in caulk/sealants move over time into:
  - Adjoining wood, cement, brick
  - Air and dust inside schools
  - Soil near school buildings
  - Other materials/furnishings
- Although installed 40 – 60 years ago, high PCB levels remain and emissions will continue far into the future
- We have found that caulk with high PCB levels is usually still flexible and often largely intact
- Visual identification of caulk with PCBs is not reliable

PCB Sources – Fluorescent Light Ballasts

- Fluorescent and high intensity light ballast capacitors
  - Prior to 1977 - Most contained PCBs
  - 1977 – 1978 - Some new ballasts contained PCBs
  - After 1978 - No new ballasts manufactured w PCBs
- Most ballasts with measurements found to contain A1242 (or similar A1016); one has been found with A1254
- Most PCB-containing ballasts have exceeded their expected lifetimes
- Failure and release of PCBs will continue and may increase

PCB Sources – Fluorescent Light Ballasts

	School 1	School 2	School 3	School 4	School 5	School 6**
Total Examined	727	487	619	927	--	33
Likely PCB-Containing	417	373	275	879	--	8
% Ballasts Likely w PCBs	**57%**	**77%**	**44%**	**95%**	--	**24%**

** Only a small subset of ballasts in the school were surveyed

PCB Sources – Fluorescent Light Ballasts

- PCBs are continuously released into the air from intact, functioning light ballasts
  - When lights are off, emissions are low
  - When lights are on, the ballast heats up, and emissions increase several-fold
- PCB ballasts can fail, releasing PCB vapors into the air and liquid PCBs onto surfaces
  - Air levels of PCBs can become quite large
  - Surfaces can be contaminated
  - Significant impact/costs to remediate
- Residues from previously failed ballasts can remain in light fixtures even if the ballast is replaced

PCB Sources – Secondary Sources/Sinks

- PCBs released from primary sources are absorbed into other materials in the school environment over time
- Following removal of primary sources, PCBs in secondary sources may be released into the school environment and result in continuing exposures
- In some cases, secondary sources may need to be considered for additional remedial actions following removal/remediation of primary sources

PCB Sources – Secondary Sources/Sinks

- In three schools with caulk and fluorescent light ballast PCB sources, 93% of 411 building material samples had measurable levels of PCBs
- Examples of some median and maximum PCB levels in different materials:

Paint	39 ppm	(max. 720 ppm)
Fiberboard	31 ppm	(max. 55 ppm)
Dust	22 ppm	(max. 87 ppm)
Varnish	11 ppm	(max. 62 ppm)
Ceiling tile	7.6 ppm	(max. 14 ppm)
Laminate	5.4 ppm	(max. 200 ppm)
Floor tile	4.4 ppm	(max. 57 ppm)

- Paint may be an important secondary source due to its high surface area
- Dust is important as a source of ingestion and inhalation exposures

Predictions of PCB Emissions from Building Materials

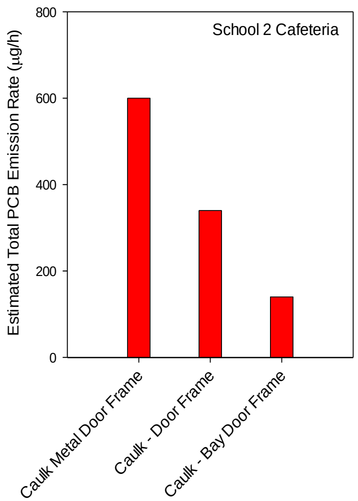
- Goals:
  - Relative comparisons for multiple materials (mitigation decisions)
  - Assess importance of potential secondary sources

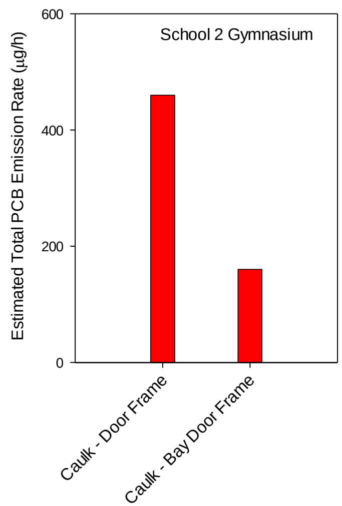
- PCB emission rate predictions based on EPA laboratory chamber emissions measurements of caulks and light ballasts

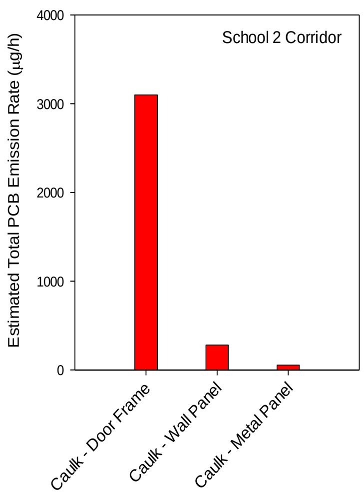
- Caulk PCB emission parameters applied to “other materials”

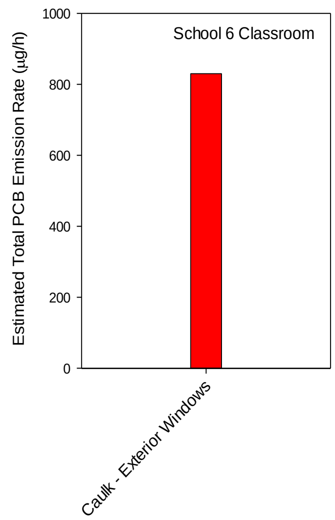
- Relies on several assumptions and there are uncertainties
  - Ballast and “other materials” results should be considered screening-level only

Example Estimates of Total PCB Emission Rates from Caulk









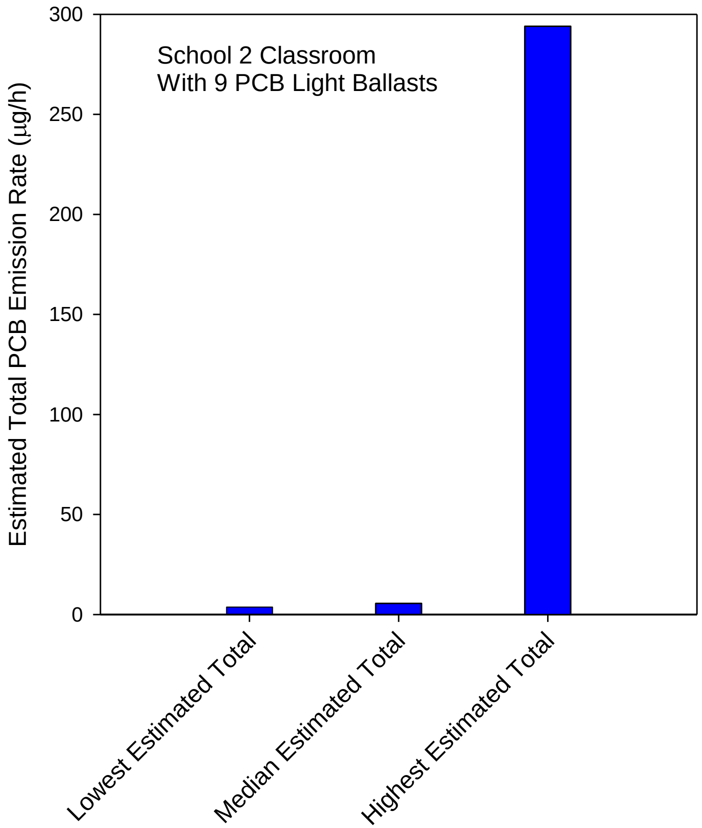
For several caulks with >50,000 ppm PCBs

Estimated total PCB emission rates ranged from 53 to 3100 µg/hour

Depended on PCB concentration in caulk and caulk surface area

Temperature effects not assessed in this analysis – chamber studies show PCB emission rates increase with increasing temperature

Example Screening-Level Estimates of Total PCB Emission Rates from Light Ballasts



There are considerable uncertainties in these estimates

Total PCB emissions estimated based on emission rates measured for several congeners in chamber tests of 4 intact ballasts at 45° C

There was an approximately 60-fold difference in emissions among the four ballasts.

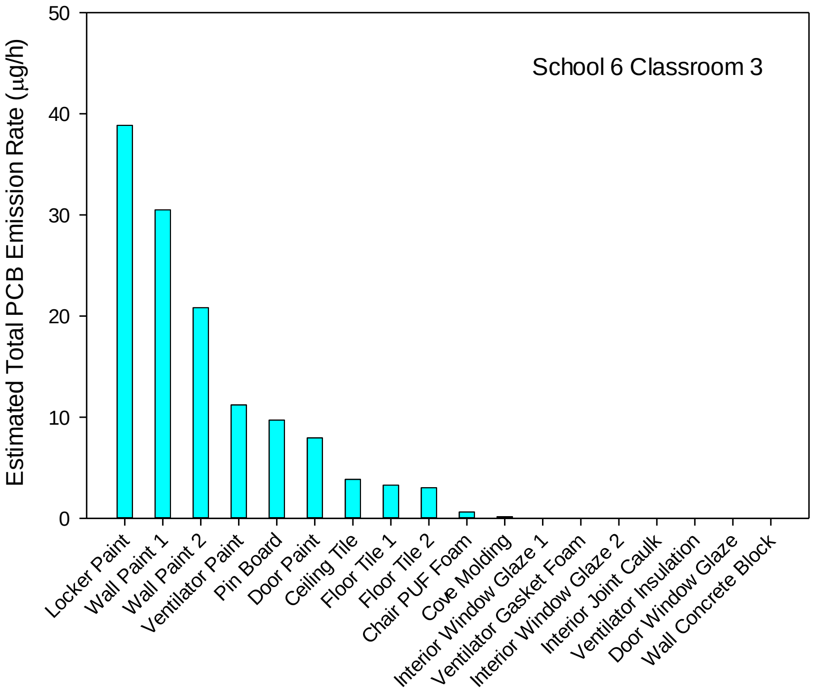
Estimated total PCB emission rates from intact operating ballasts ranged from

1.2 µg/hour for a classroom with 3 ballasts emitting at lowest rate to

290 µg/hour for a classroom with 9 ballasts emitting at the highest rate

Emissions from leaking ballasts or contaminated light fixtures not assessed but may to be significant

Example Screening-Level Estimates of Total PCB Emission Rates from Other Materials



There are considerable uncertainties in the ”other materials” estimates

Total PCB emission rates estimated based on emission parameters for caulk in chamber tests

Emission rates for individual materials ranged from <1 to 100 µg/hour in classrooms

Emission rates for individual materials ranged from <1 to 1100 µg/hour in gymnasiums

Paints had highest estimated emission rates due to relatively high PCB levels and high surface areas

Effect of emissions on indoor air PCB levels is complicated because the materials also act as “sinks” – absorbing PCBs from the air

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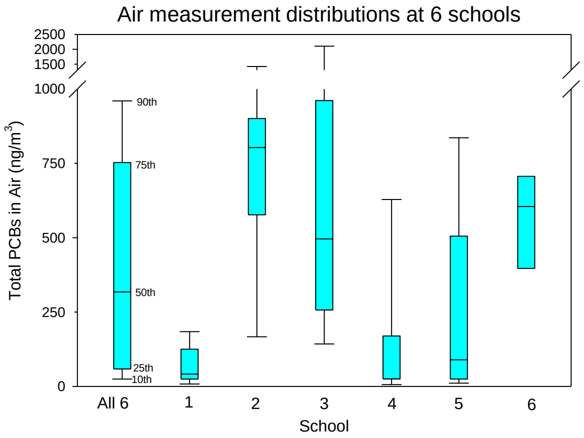
PCB Levels in the School Environment

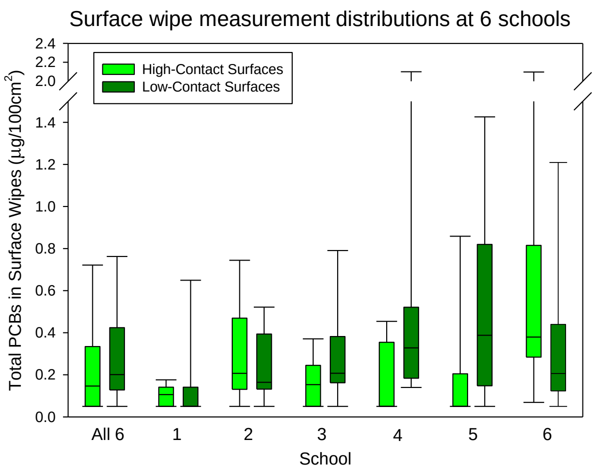
Summary of measurements from six schools

	Total PCB Levels		
Environmental Medium (units)	Median	75th Percentile	Maximum
Indoor Air (ng/m^3)	**318**	730	**2920**
Indoor Surface Wipes (µg/100cm^2)			
High-contact surfaces (tables/desks)	**0.15**	0.33	**2.8**
Low-contact surfaces (floors/walls)	**0.20**	0.42	**2.3**
Indoor dust at one school (ppm)	**22**	53	**87**
Outdoor Soil (ppm)			
0.5’ from building; 0 – 2” soil depth	**<QL**	2.1	**210**
3’ from building; 0 – 2” soil depth	**<QL**	0.55	**21**
8’ from building; 0 – 2” soil depth	**<QL**	<QL	**5.3**
Outdoor Air (ng/m^3)	**<QL**	<QL	<QL

QL = Quantifiable Limit

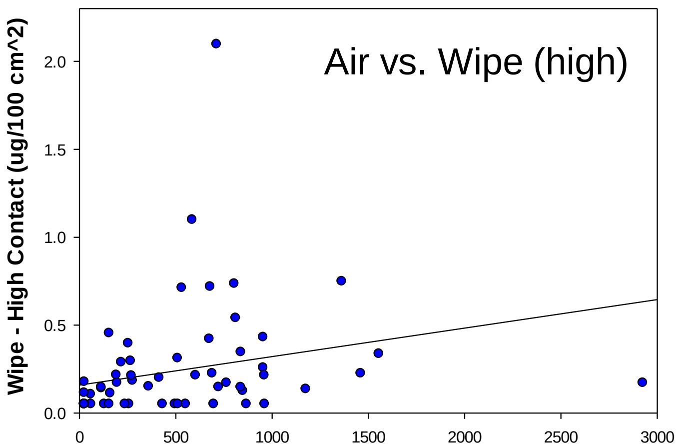
PCB Levels in the School Environment

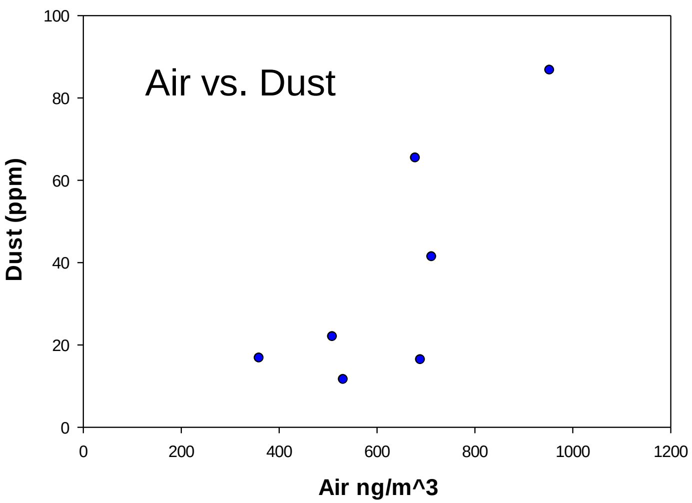




- Indoor Air
  - PCB concentrations in air exceeded EPA-recommended levels in many school rooms
  - There was considerable within- and between-school variability in indoor air concentrations
- Surface Wipes
  - Most surface wipes were less than 1 µg/100cm^2
  - There was considerable within- and between school variability in surface wipe levels
- Soil
  - Soil concentrations varied greatly between schools
  - Some levels were greater than 1 ppm
  - In general, levels decreased with increasing distance from buildings

Correlations Between Media PCB Concentrations





Schools/Sample Media	N	Spearman Correlation *r*	*p*-value
<u>Schools 1 - 6</u>			
Indoor Air High-Contact Surface Wipe	64	**0.531**	**<0.001**
Indoor Air Low-Contact Surface Wipe	64	**0.247**	**0.050**
High-Contact Surface Wipe Low-Contact Surface Wipe	64	0.220	0.081

Schools/Sample Media	N	Pearson Correlation *r*	*p*-value
<u>School 6</u>			
Indoor Air Dust	7	**0.81**	**0.029**

Aroclor vs Congener Analysis

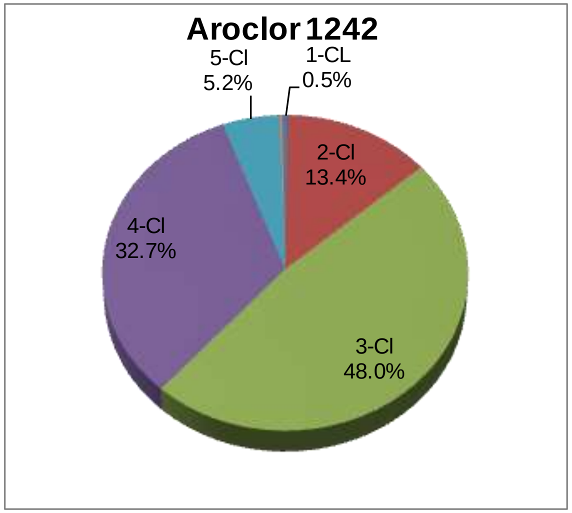
One School with Congener Measurements

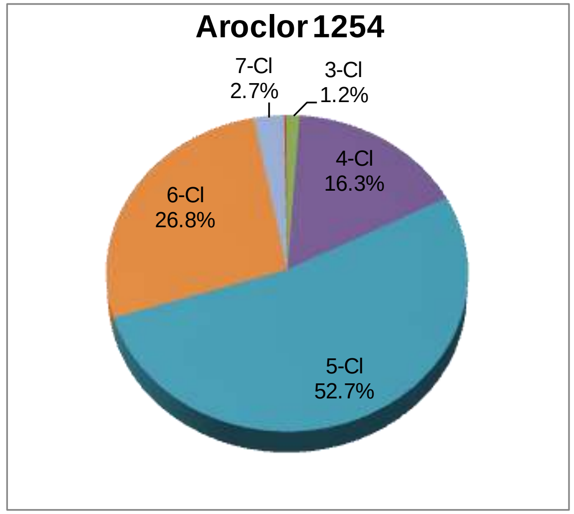
Measurement	N	Units	Aroclor Analysis Mean	Congener Analysis Mean	**% Difference**
Indoor Air	7	ng/m^3	630	500	**21**
Surface Wipe	10	$\mu g/100\ cm^2$	0.51	0.41	**20**
Indoor Dust	4	ppm	36	31	**14**
Exterior Caulk	3	ppm	143,000	114,000	**20**
Other Materials	18	ppm	47	37	**22**

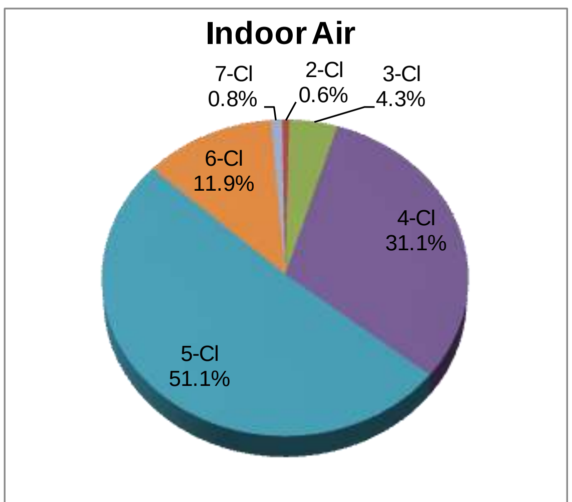
Aroclor analyses for "weathered" indoor and outdoor PCB mixtures could be biased high or low depending on calibration approach.

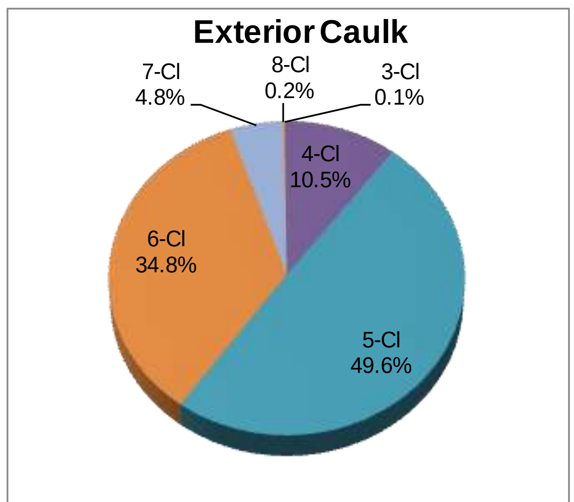
Homolog Patterns – Aroclors, Indoor Air, Caulk

In One School with Congener Measurements









Compared to A1254, air is weighted towards more volatile congeners

Compared to A1254, caulk is weighted towards less volatile congeners

Air has higher levels of less volatile congeners than might be expected based on vapor emissions alone

May reflect air vapor + particle phase congeners

A1242 pattern is not reflected in these air samples

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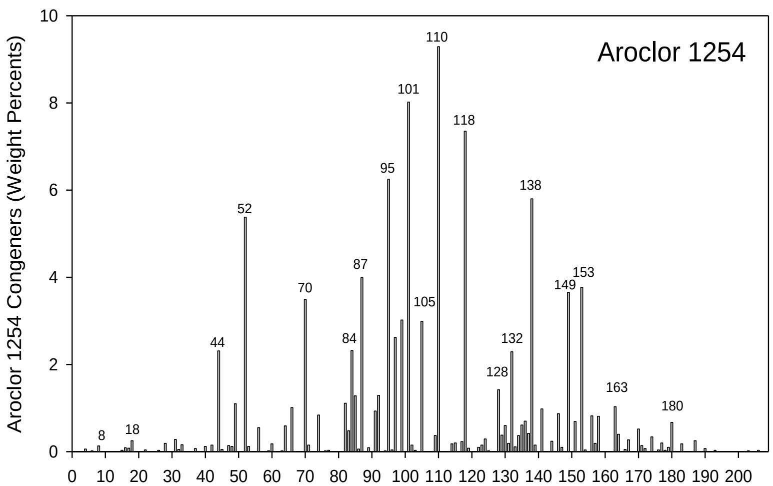
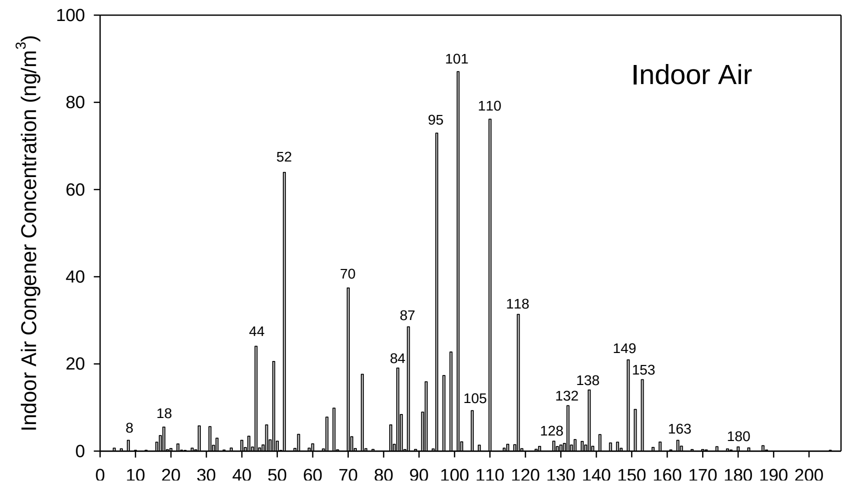
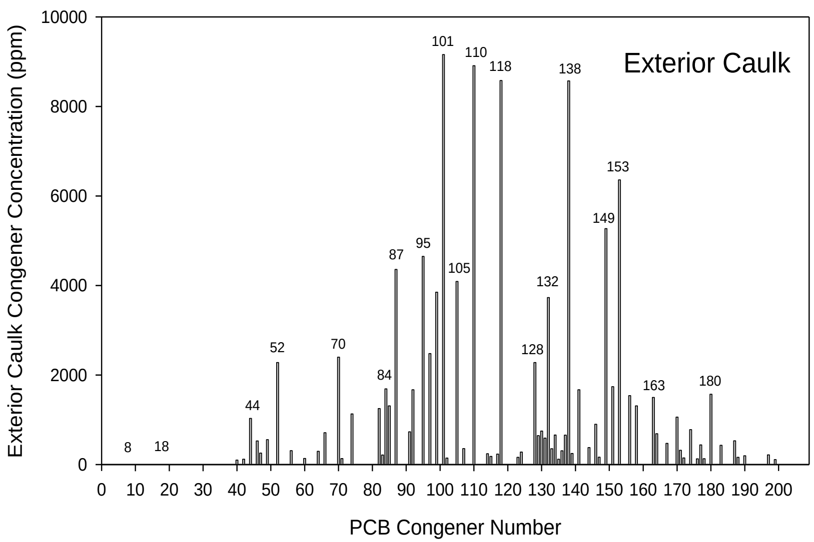
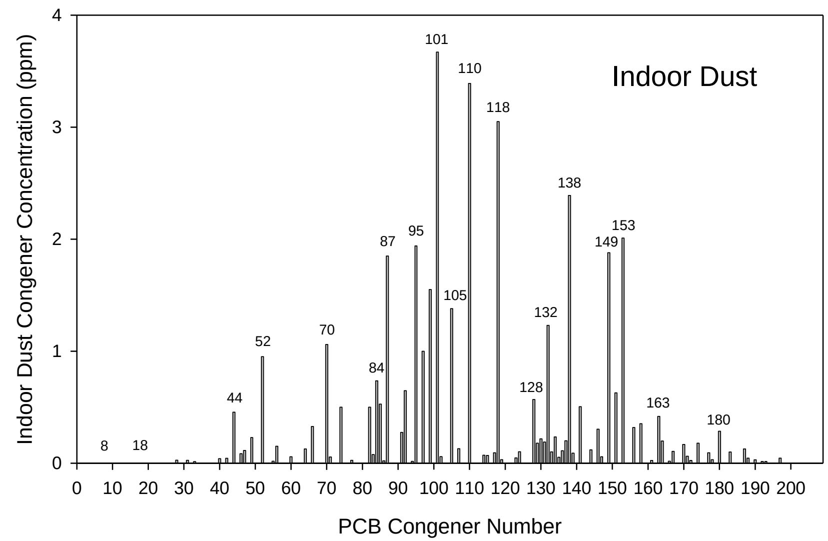
PCB Congener Concentrations & Patterns

In One School with Congener Measurements









Exposures to PCBs in the School Environment

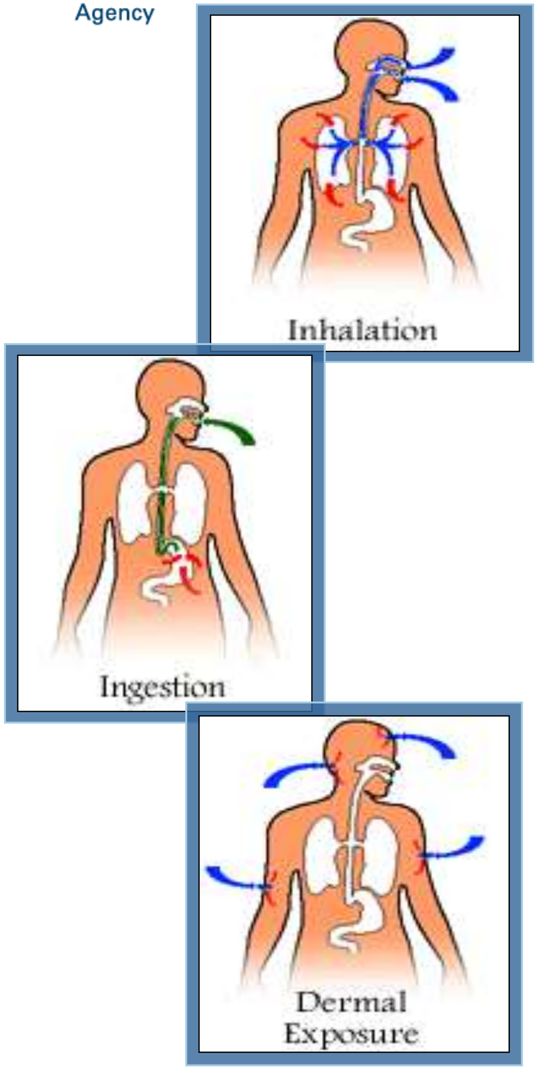
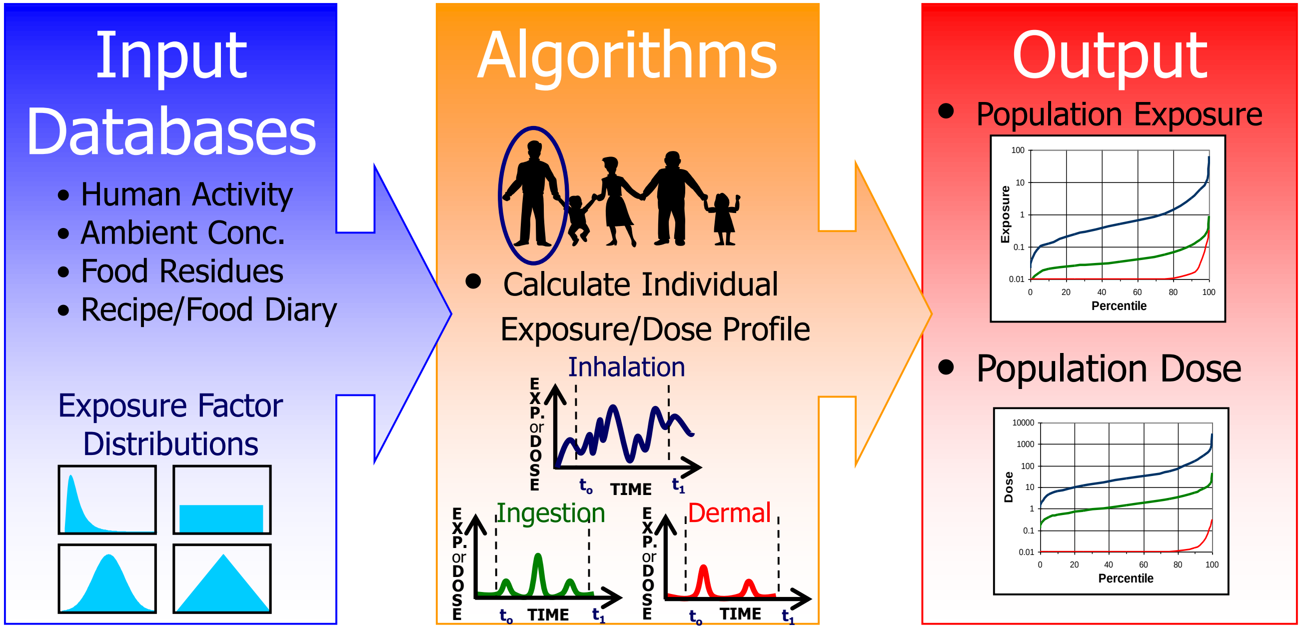


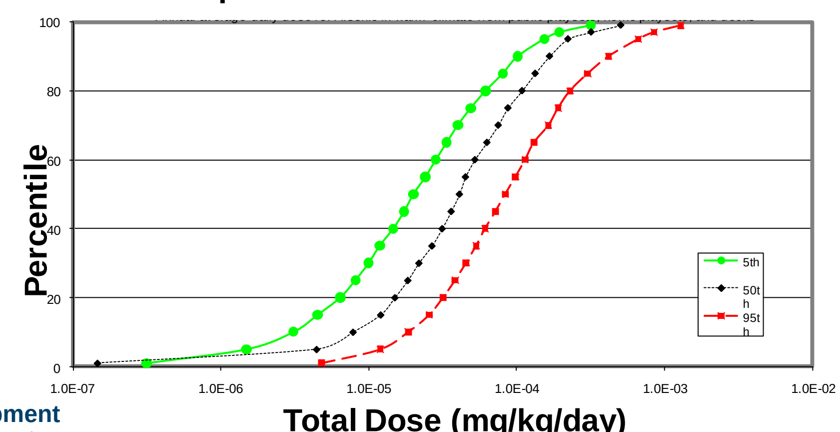
Figure from 2009 NIEHS L. Birnbaum presentation

- Occupants in schools with interior PCB sources can be exposed to PCBs in the indoor air, dust, and on surfaces through their normal activities
- In school buildings with exterior PCB sources, exposures may occur through contact with contaminated soil
- Exposures can occur through inhalation, ingestion, and dermal contact

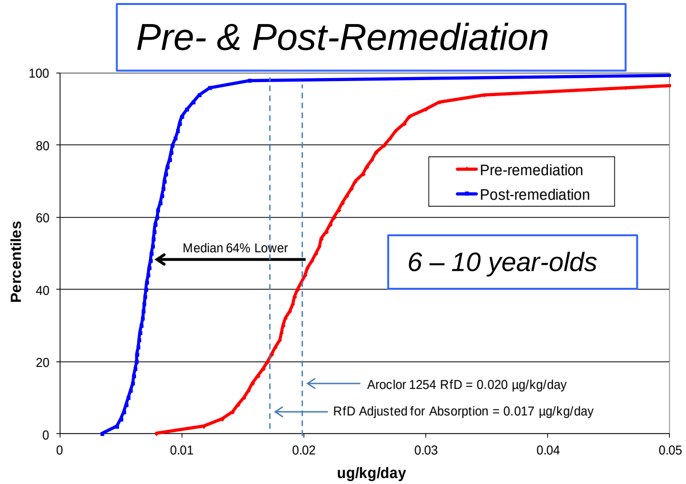
Stochastic Human Exposure and Dose Simulation Model

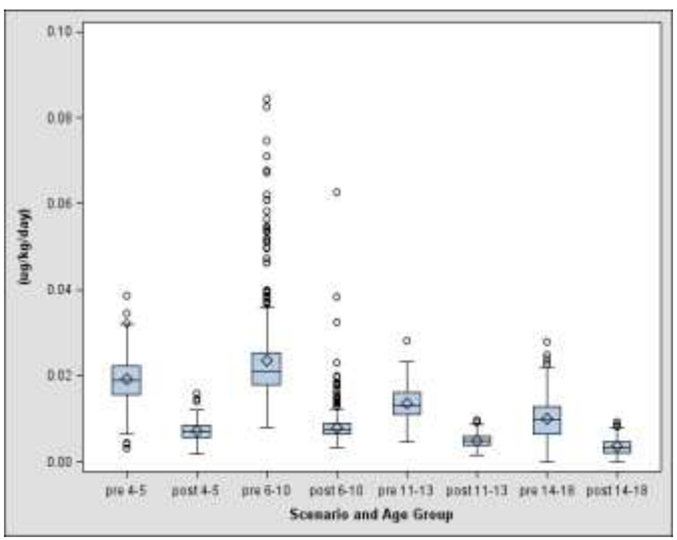


Example Distributions of Estimated Doses



Exposures to PCBs in the School Environment

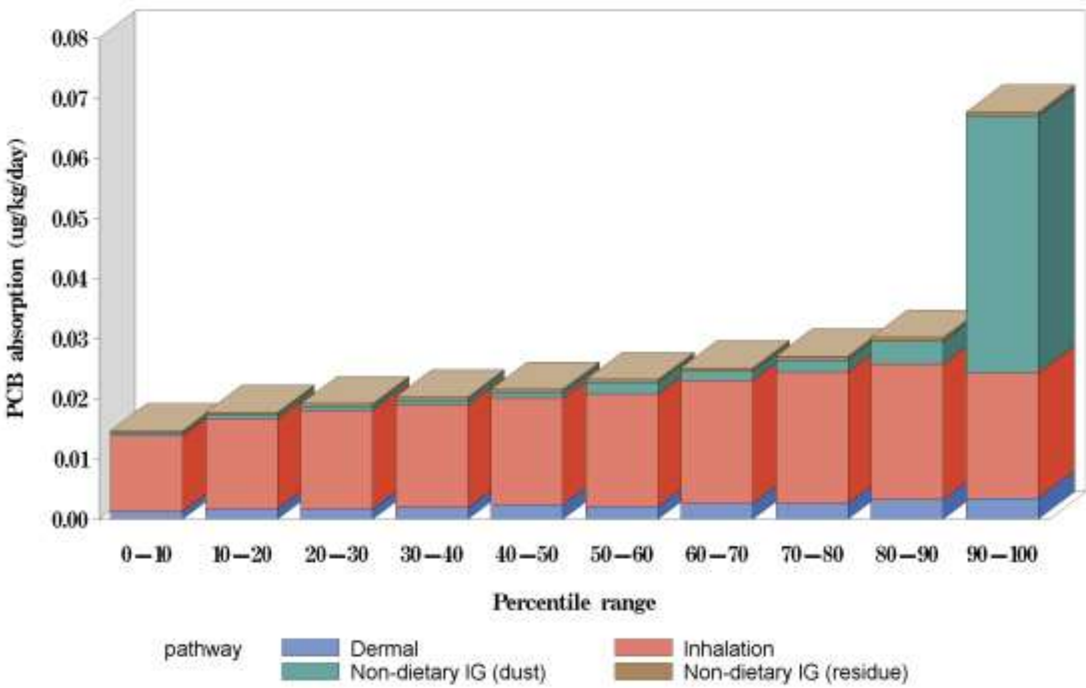




- An exposure model was used to estimate what exposures children might experience, using PCB levels measured across six schools
- Many children would be predicted to receive exposures above the EPA IRIS Reference Dose for Aroclor 1254
- With PCB levels measured following remediation efforts at several schools, most children would be predicted to receive exposures below the RfD
- *These exposure estimates do not include PCB exposures from diet or other sources away from school*

Exposures to PCBs in the School Environment

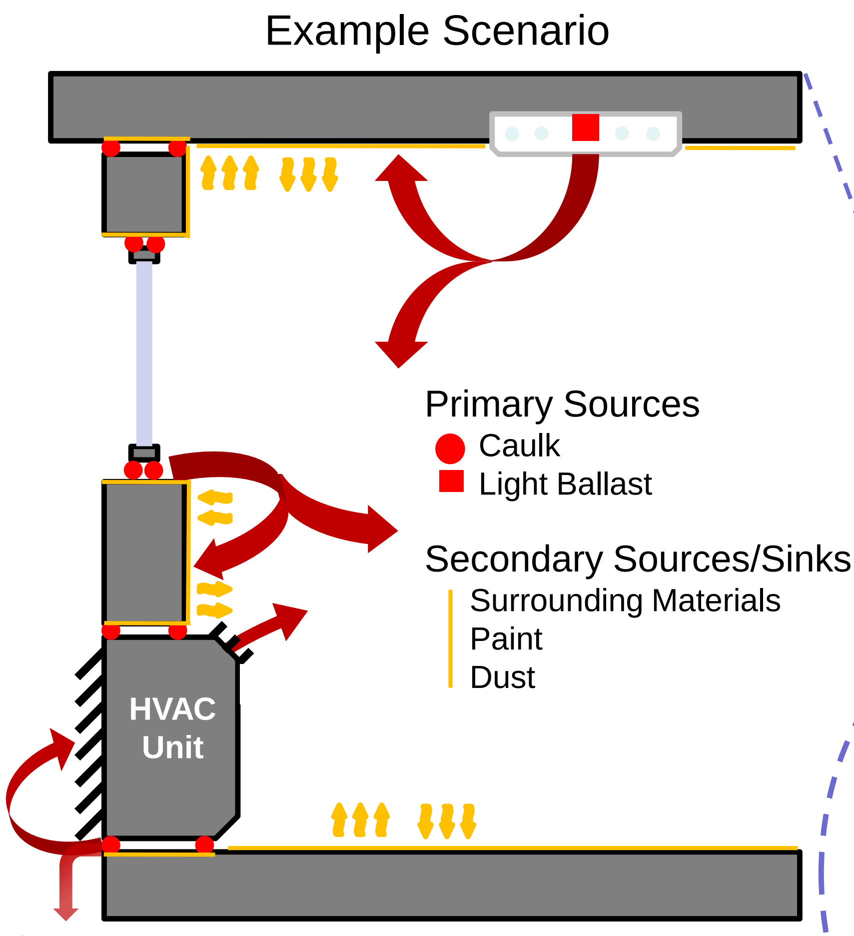
Estimation of PCB Dose From Different Pathways
(6 - 10 year olds; units: µg/kg day^{-1})



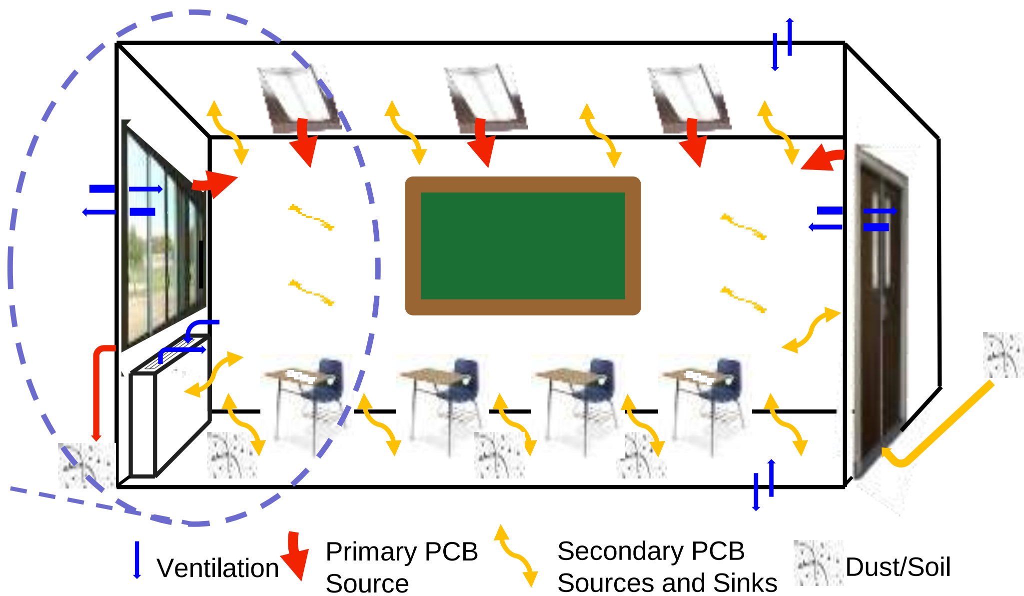
- For the environmental levels found in the six schools, >70% of the exposure would be predicted to result from inhalation of PCBs in the school air

- Dust ingestion may also be an important route of exposure in some situations

PCBs - A Complex Problem in Buildings



- Over 100 PCB chemicals
- Multiple primary sources possible
- PCBs move from sources to air, surfaces, dust, soil
- Secondary sources are created
- Ventilation and temperature effects can be important
- Exposures through multiple pathways



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Research Limitations and Uncertainties

- Representativeness of schools tested is not known
- It is not known if results for schools apply to other types of buildings
- Relative importance of caulk and light ballasts as primary sources has been difficult to determine
- Impact of contaminated light fixtures has not been determined
- Other primary sources may be present in other school buildings (ceiling tile coatings, spray-on fireproofing)
- There are uncertainties in modeled emission, exposure, and dose estimates

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Additional Information

EPA Information and Guidance:
See “Additional Resources”

- Current best practices for minimizing exposures
- Public health levels for PCBs in indoor air
- PCBs in caulk
- PCB-Containing fluorescent light ballasts
- Testing, renovation, waste, regulations

Get Professional Advice and Information:

- Assessing and remediating PCBs in buildings can be challenging
- Contact your EPA PCB Coordinator
- Work with certified contractors experienced in PCB assessment and remediation in buildings

Additional Resources

U.S. EPA. Find your EPA Regional PCB Coordinator
http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/coordin.htm

U.S. EPA. Current Best Practices for PCBs in Caulk Fact Sheet – Interim Measures for Assessing Risk and Taking Action to Reduce Exposures
http://www.epa.gov/pcbsincaulk/caulkinterim.htm

U.S. EPA. PCBs in Caulk in Older Buildings
http://www.epa.gov/pcbsincaulk/

U.S. EPA. PCB-Containing Fluorescent Light Ballasts (FLBs) in School Buildings; A Guide for School Administrators and Maintenance Personnel
http://www.epa.gov/osw/hazard/tsd/pcbs/pubs/ballasts.htm

U.S. EPA. Public Health Levels for PCBs in Indoor School Air
http://epa.gov/pcbsincaulk/maxconcentrations.htm

U.S. EPA. Current Best Practices for PCBs in Caulk Fact Sheet – Removal and Clean-Up of PCBs in Caulk and PCB-Contaminated Soil and Building Materials
http://www.epa.gov/pcbsincaulk/caulkremoval.htm

U.S. EPA. Current Best Practices for PCBs in Caulk Fact Sheet – Testing in Buildings
http://www.epa.gov/pcbsincaulk/caulktesting.htm

Additional Resources

U.S. EPA. How to Test for PCBs and Characterize Suspect Materials
http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/guide/guide-sect3.htm

U.S. EPA. Steps to Safe Renovation and Abatement of Buildings that Have PCB-Containing Caulk
http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/guide/index.htm

U.S. EPA. Contractors: Handling PCBs in Caulk During Renovation
http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/caulk/caulkcontractors.htm

U.S. EPA. Management, Cleanup, and Disposal of PCB Wastes
http://www.epa.gov/epawaste/hazard/tsd/pcbs/index.htm

U.S. EPA. Fact Sheets for Schools and Teachers About PCB-Contaminated Caulk
http://www.epa.gov/pcbsincaulk/caulkschoolkit.htm

U.S. EPA. PCBs in Schools Research
http://www.epa.gov/pcbsincaulk/caulkresearch.htm

Acknowledgements

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Jackie McQueen	OSP

Contract Support

Tamira Cousett	Alion, Inc.
Carlton Witherspoon	Alion, Inc.
Keith Kronmiller	Alion, Inc.
Paulette Yongue	Alion, Inc.

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