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?

Information needed for:

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

For buildings constructed or renovated between about 1950 and the late 1970s
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
# PCB Sources – Caulk and Other Sealants

<table>
<thead>
<tr>
<th>Total PCBs in Caulk</th>
<th>Interior Caulks From 5 Schools</th>
<th>Exterior Caulks From 3 Schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Samples:</td>
<td>427</td>
<td>73</td>
</tr>
</tbody>
</table>

**Percent of Caulk Samples**

<table>
<thead>
<tr>
<th></th>
<th>Interior Caulks</th>
<th>Exterior Caulks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 50 ppm</td>
<td>82.2</td>
<td>37.0</td>
</tr>
<tr>
<td>50 – 999 ppm</td>
<td>7.7</td>
<td>6.8</td>
</tr>
<tr>
<td>1,000 – 99,999 ppm</td>
<td>4.0</td>
<td>21.9</td>
</tr>
<tr>
<td>100,000 – 199,999 ppm</td>
<td>2.3</td>
<td>12.3</td>
</tr>
<tr>
<td>200,000 – 299,999 ppm</td>
<td>3.3</td>
<td>15.1</td>
</tr>
<tr>
<td>300,000 – 399,999 ppm</td>
<td>0.2</td>
<td>6.8</td>
</tr>
<tr>
<td>&gt; 400,000 ppm</td>
<td>0.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Note: Multiple samples of the same type of caulks were collected*

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

<table>
<thead>
<tr>
<th></th>
<th>School 1</th>
<th>School 2</th>
<th>School 3</th>
<th>School 4</th>
<th>School 5</th>
<th>School 6**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Examined</td>
<td>727</td>
<td>487</td>
<td>619</td>
<td>927</td>
<td>--</td>
<td>33</td>
</tr>
<tr>
<td>Likely PCB-Containing</td>
<td>417</td>
<td>373</td>
<td>275</td>
<td>879</td>
<td>--</td>
<td>8</td>
</tr>
<tr>
<td>% Ballasts Likely w PCBs</td>
<td>57%</td>
<td>77%</td>
<td>44%</td>
<td>95%</td>
<td>--</td>
<td>24%</td>
</tr>
</tbody>
</table>

** 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.
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
There are considerable uncertainties in these estimates.

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

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.
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.
## PCB Levels in the School Environment

Summary of measurements from six schools

<table>
<thead>
<tr>
<th>Environmental Medium (units)</th>
<th>Median</th>
<th>75&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Air (ng/m&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>318</td>
<td>730</td>
<td>2920</td>
</tr>
<tr>
<td>Indoor Surface Wipes (µg/100cm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-contact surfaces (tables/desks)</td>
<td>0.15</td>
<td>0.33</td>
<td>2.8</td>
</tr>
<tr>
<td>Low-contact surfaces (floors/walls)</td>
<td>0.20</td>
<td>0.42</td>
<td>2.3</td>
</tr>
<tr>
<td>Indoor dust at one school (ppm)</td>
<td>22</td>
<td>53</td>
<td>87</td>
</tr>
<tr>
<td>Outdoor Soil (ppm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5' from building; 0 – 2” soil depth</td>
<td>&lt;QL</td>
<td>2.1</td>
<td>210</td>
</tr>
<tr>
<td>3' from building; 0 – 2” soil depth</td>
<td>&lt;QL</td>
<td>0.55</td>
<td>21</td>
</tr>
<tr>
<td>8' from building; 0 – 2” soil depth</td>
<td>&lt;QL</td>
<td>&lt;QL</td>
<td>5.3</td>
</tr>
<tr>
<td>Outdoor Air (ng/m&lt;sup&gt;3&lt;/sup&gt;)</td>
<td>&lt;QL</td>
<td>&lt;QL</td>
<td>&lt;QL</td>
</tr>
</tbody>
</table>

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/100cm²
  - 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

### Spearman Correlation

<table>
<thead>
<tr>
<th>Schools/Sample Media</th>
<th>N</th>
<th>r</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schools 1 - 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor Air</td>
<td>64</td>
<td>0.531</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>High-Contact Surface Wipe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor Air</td>
<td>64</td>
<td>0.247</td>
<td>0.050</td>
</tr>
<tr>
<td>Low-Contact Surface Wipe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-Contact Surface Wipe</td>
<td>64</td>
<td>0.220</td>
<td>0.081</td>
</tr>
<tr>
<td>Low-Contact Surface Wipe</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Pearson Correlation

<table>
<thead>
<tr>
<th>Schools/Sample Media</th>
<th>N</th>
<th>r</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>School 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor Air</td>
<td>7</td>
<td>0.81</td>
<td>0.029</td>
</tr>
<tr>
<td>Dust</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Aroclor vs Congener Analysis

### One School with Congener Measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>N</th>
<th>Units</th>
<th>Aroclor Analysis Mean</th>
<th>Congener Analysis Mean</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Air</td>
<td>7</td>
<td>ng/m³</td>
<td>630</td>
<td>500</td>
<td>21</td>
</tr>
<tr>
<td>Surface Wipe</td>
<td>10</td>
<td>µg/100 cm²</td>
<td>0.51</td>
<td>0.41</td>
<td>20</td>
</tr>
<tr>
<td>Indoor Dust</td>
<td>4</td>
<td>ppm</td>
<td>36</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>Exterior Caulk</td>
<td>3</td>
<td>ppm</td>
<td>143,000</td>
<td>114,000</td>
<td>20</td>
</tr>
<tr>
<td>Other Materials</td>
<td>18</td>
<td>ppm</td>
<td>47</td>
<td>37</td>
<td>22</td>
</tr>
</tbody>
</table>

*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.
PCB Congener Concentrations & Patterns

In One School with Congener Measurements

Aroclor 1254

Exterior Caulk

Indoor Air

Indoor Dust

PCB Congener Number
Exposures to PCBs in the School Environment

- 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

Input Databases
- Human Activity
- Ambient Conc.
- Food Residues
- Recipe/Food Diary

Exposure Factor Distributions

Algorithms
- Calculate Individual Exposure/Dose Profile

Output
- Population Exposure

Example Distributions of Estimated Doses

- Inhalation
- Ingestion
- Dermal
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
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
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

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

U.S. EPA. Steps to Safe Renovation and Abatement of Buildings that Have PCB-Containing Caulk

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
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Keith Kronmiller Alion, Inc.
Paulette Yongue Alion, Inc.
NEA Pace Analytical Laboratory

New York City
NYC School Construction Authority
TRC Engineers, Inc.