# PCBs in Building Materials and Indoor Air Exposure/Health Risks

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NEWMOA PCBs in Building Products: Implications for Brownfields




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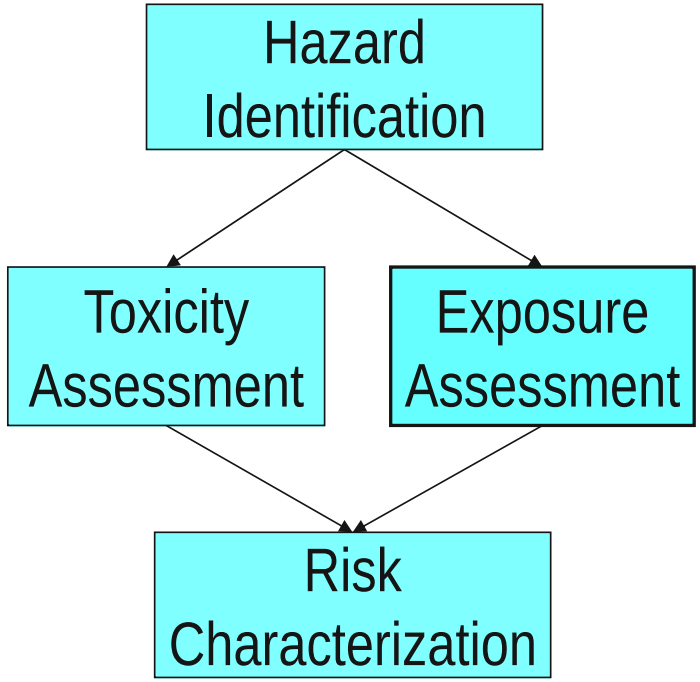
# Outline/Overview

- PCB sources in buildings
- Indoor air levels and profiles
- Toxicity values and approaches
- Case studies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# PCBs in Indoor Air - Burlington (VT) HS (September 2020)

| Field Sample No. | Sample Description | Results |
|---|---|---|
| **Building F** | | |
| F-312-06 | Child Care Center – Room F-312 | 720 ng/m$^3$ |
| F-312-Dup-07 | Child Care Center – Room F-312 | 640 ng/m$^3$ |
| F-312-HF-51 | Child Care Center – Room F-312 | 160 ng/m$^3$ |
| F-304-18 | Health Sciences – Room F-304 | 400 ng/m$^3$ |
| F-309-26 | Criminal Justice – Room F-309 | 760 ng/m$^3$ |
| F-205-30 | Metals Shop Jewelry – Room F-205 | 1300 ng/m$^3$ |
| F-210-28 | Welding Shop – Room F-210 | 5800 ng/m$^3$ |
| F-214-21 | Construction Trades Shop – Room F-214 | 6300 ng/m$^3$ |
| F-103-19 | Automotive Shop – Rom F-103 | 1900 ng/m$^3$ |

Other Buildings

A: 1 – 260 ng/m$^3$

B: 27 – 270 ng/m$^3$

C: 60 – 130 ng/m$^3$

D: 11 – 300 ng/m$^3$

E: 16 – 110 ng/m$^3$

VT DOH (2013) Recommended Exposure Level = 15 ng/m$^3$

Data from link at: https://vtdigger.org/2020/09/24/burlington-schools-knew-about-pcbs-in-soil-for-13-months-before-reporting-the-problem/

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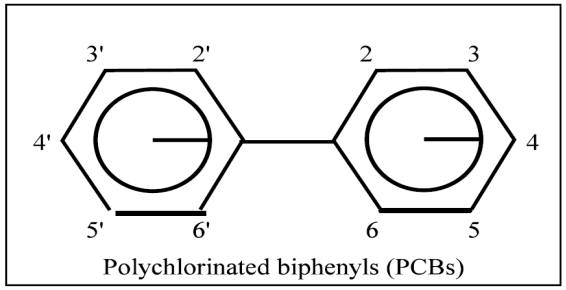
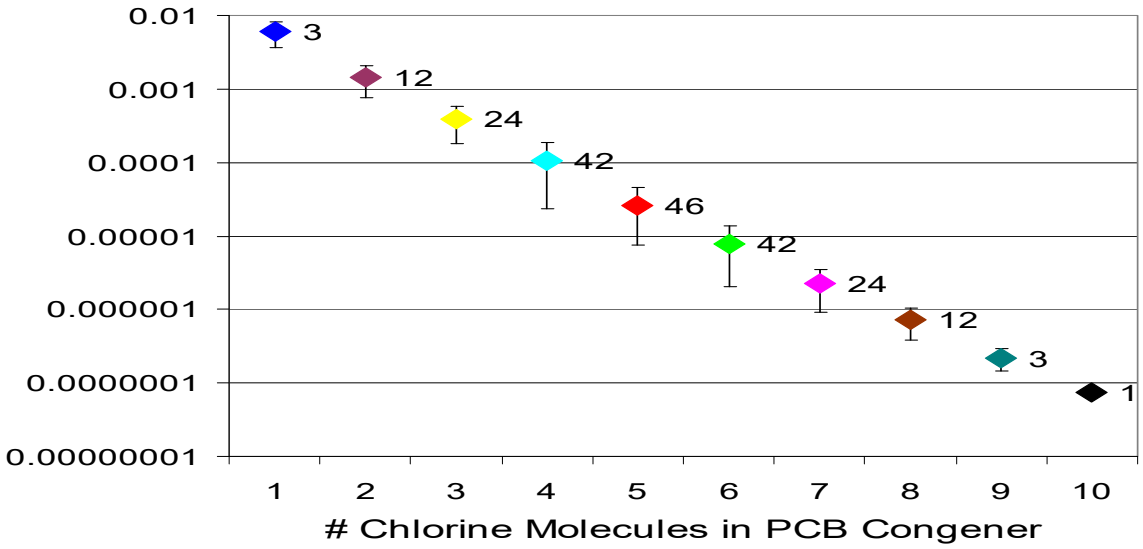
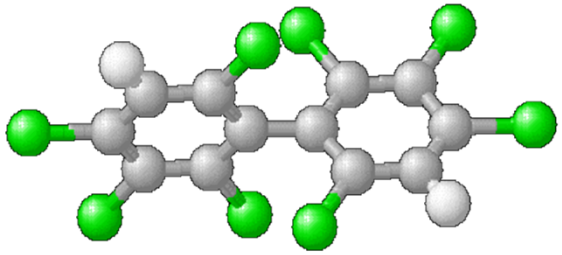
# PCB Properties



Polychlorinated biphenyls (PCBs)

- PCBs synthesized in 1929, banned in 1979
- Used in >1,000 products
- 209 congeners, produced as mixtures (*e.g.*, Aroclors)
  - 14 are "co-planar" dioxin-like congeners
- Vapor pressure depends on degree of chlorination



<= Data from Öberg (2001) in units of mm Hg

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# Commercial Uses of PCBs / Sources in Buildings

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

And spills onto floors

https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs#commercial

# Residual PCB Sources in Building Materials

- Caulk
- Fluorescent light ballasts
- Paint
- Ceiling tiles
- Secondary sources


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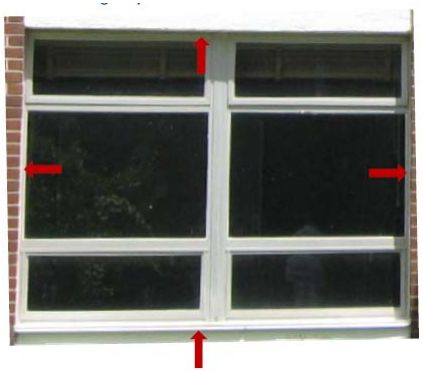
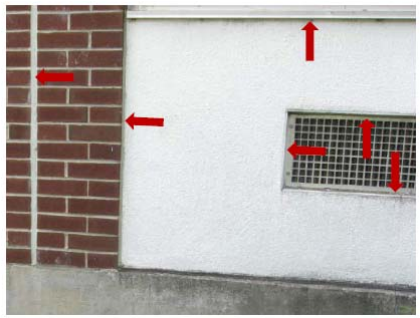
# PCBs Measured in Caulk

| 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 | 12.3 |
| 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 |
| | **6.0%** | **34%** |

*100,000 ppm is 10% by weight*

Also concerns over migration to adjacent materials





EPA (2012). Polychlorinated Biphenyls (PCBs) in School Buildings: Sources, Environmental Levels, and Exposures. EPA/600/R-12/051.

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# 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

EPA (2012). Polychlorinated Biphenyls (PCBs) in School Buildings: Sources, Environmental Levels, and Exposures. EPA/600/R-12/051.

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# Secondary Sources

| Material | Concentration (ppm by mass) | |
|---|---|---|
| | Median | Maximum |
| Paint | 39 | 750 |
| Fiberboard | 31 | 55 |
| Dust | 22 | 87 |
| Varnish | 11 | 62 |
| Ceiling tile | 7.6 | 14 |
| Laminate | 5.4 | 200 |
| Floor tile | 4.4 | 57 |

EPA (2012). Polychlorinated Biphenyls (PCBs) in School Buildings: Sources, Environmental Levels, and Exposures. EPA/600/R-12/051.

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# Emissions and Source Potential

- Emissions – Assuming:
  - 100 ng/$m^3$ of PCBs in indoor air
  - In a 5 m by 10 m by 10 m room
  - With 2 changes of air per hour
  - Translates to a mass flux of 0.1 mg/hour ≅ **2 g/year**
- Source Potential – Assuming:
  - A 2 ft by 4 ft window with a ¼ in triangular bead of caulk
  - Caulk density 1.5 g/$cm^3$ and 10% PCBs (by mass)
  - Equates to **354 g PCBs**
- Conclusion:  There can easily be enough PCBs present in building materials to sustain PCBs at levels of concern in indoor air

# PCB Concentrations Measured in Indoor Air

| Location | | Date | Concentrations (in ng/m³) |
|---|---|---|---|
| Housing Complex, CA | | 2002 | 96 – 234 |
| Lederle Center. U-Mass Amherst | | 2006 | 220 – 640 |
| Estabrook School, Lexington, MA | | 2010 | 300 – 1,800 |
| New York City Schools | P.S. 199M | 2010 | 410 – 1,500 |
| | P.S. 309K | | 540 – 5,000 |
| Burke School, Peabody, MA | | 2011 | 260 – 740 |
| Child Care Center, Boston, MA | | 2012 | 120 – 200 |
| Public Buildings, Germany | | 2002 | 720 – 4,200 |
| Apartment Complex, Denmark | | 2012 | 170 – 3,800 |

Estimated 13,000 to 26,000 U.S. schools impacted (Herrick *et al.*, 2016)

- Residential Screening Level
  4.9 ng/m³
- Industrial Screening Level
  21 ng/m³
- Public School Levels
  100 – 600 ng/m³

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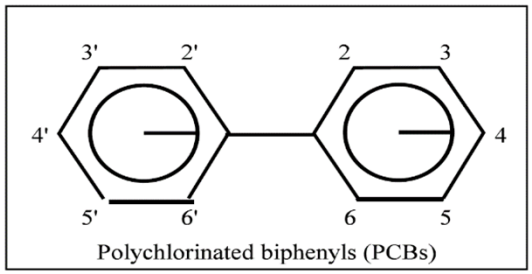
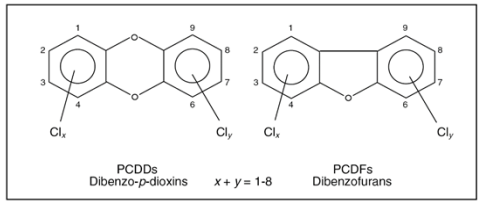
# Toxicological Values for Risk Assessment

- Carcinogenic Potencies (kg-day/mg) (EPA IRIS, 1996)
  - High risk/persistence 1 to 2
  - Low risk/persistence 0.3 to 0.4
  - Lowest risk/persistence 0.04 to 0.07
  - 2,3,7,8-TCDD 130,000 (TEQ/co-planar)



Polychlorinated biphenyls (PCBs)

- "Non-cancer" Reference Doses (ng/kg-day) (EPA IRIS, 1994 for Aroclors)
  - Aroclor 1254 20 higher risk
  - Aroclor 1016 70 lower risk
  - 2,3,7,8-TCDD 0.0007 TEQ/co-planar




- Neurological Equivalents Reference Doses (ng/kg-day) (Simon, 2007)
  - Aroclor 1254 8 higher risk
  - Aroclor 1016 70 lower risk

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# Effective Dioxin-Like Potencies and RfDs

| Aroclor mixture | Cancer Potency (d-kg/mg)<br>High Risk: 1 to 2<br>Low Risk: 0.3 to 0.4<br>Lowest Risk: 0.04 to 0.07 | Non-Cancer Reference Dose (ng/kg-d)<br>Low Risk: 70<br>High Risk: 20 |
|---|---|---|
| 1242 | 0.09 | 996 |
| 1248 (v1) | 0.22 | 415 |
| 1248 (v2) | 0.23 | 390 |
| 1254 | 3.55 | 26 |
| 1254 Late | 0.47 | 193 |
| 1260 | 0.06 | 1525 |

Based on:

- Potency of 130,000 mg/kg-d and RfD of 0.0007 ng/kg-d (EPA RSLs)
- EPA-recommended TEFs for 14 co-planar PCBs
- ATSDR (2000) PCB Toxicity Profile for Aroclor mixture compositions

# Indoor Air Screening Levels

EPA's Exposure Levels for Evaluating Polychlorinated Biphenyls (PCBs) in Indoor School Air ($ng/m^3$)

(https://www.epa.gov/pcbs/exposure-levels-evaluating-polychlorinated-biphenyls-pcbs-indoor-school-air)

| Age 1-<2 | Age 2-<3 | Age 3-<6 | Age 6-<12 | Age 12-<15 | Age 15-<19 | Age 19+ |
|---|---|---|---|---|---|---|
| 100 | 100 | 200 | 300 | 500 | 600 | 500 |

EPA's Regional Screening Levels ($ng/m^3$)

(https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables, TR=1E-06)

| | High Risk (dust) | Low Risk (evaporated) | Lowest Risk (99.5% <4 Cl) |
|---|---|---|---|
| Residential | 4.9 | 28 | 140 |
| Industrial | 21 | 120 | 610 |

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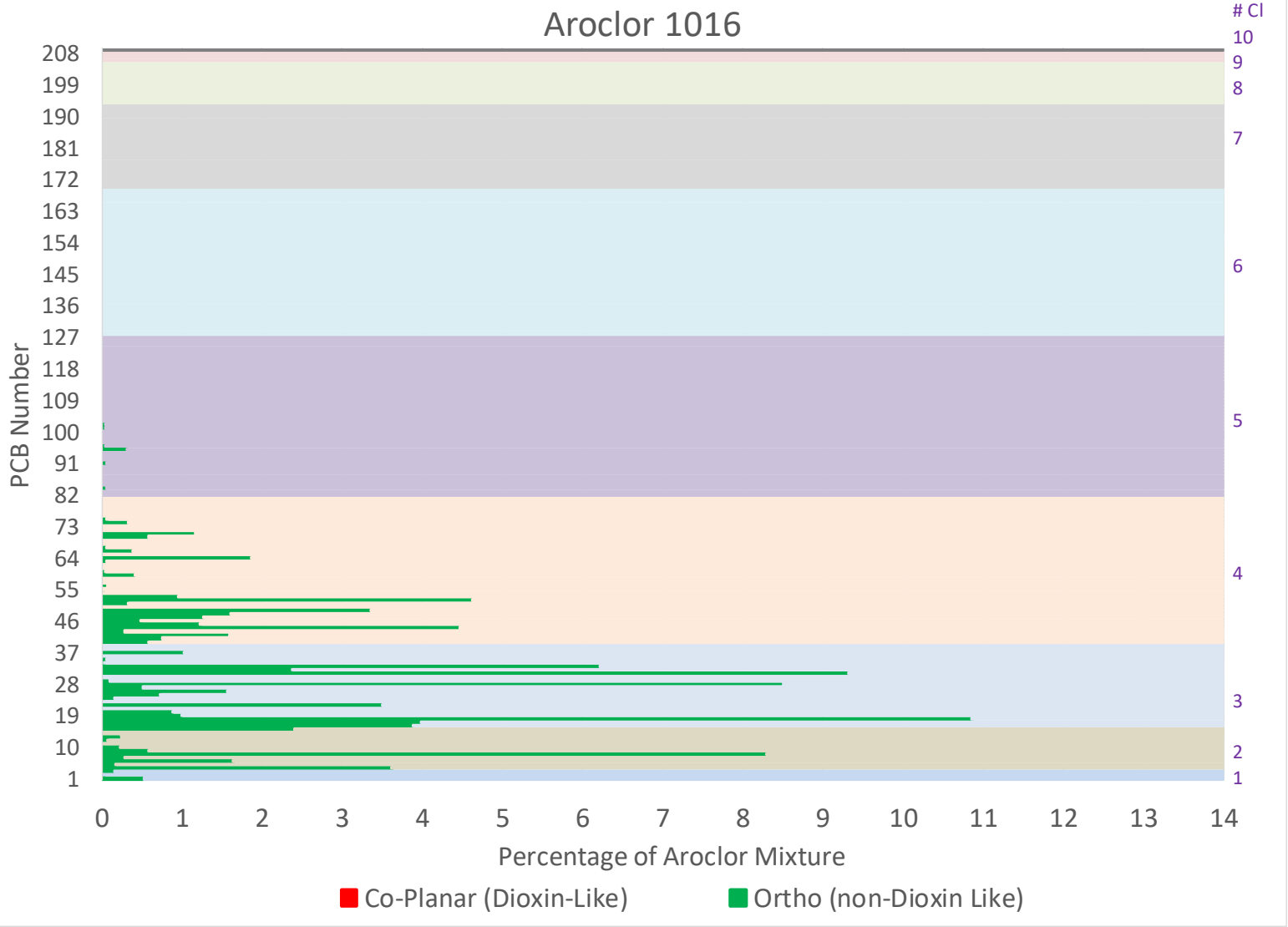


| PCB Congener | 2,3,7,8-TCDD TEF |
|---|---|
| 77 | 0.0001 |
| 81 | 0.0003 |
| 105 | 0.00003 |
| 114 | 0.00003 |
| 118 | 0.00003 |
| 123 | 0.00003 |
| 126 | 0.1 |
| 156 | 0.00003 |
| 157 | 0.00003 |
| 167 | 0.00003 |
| 169 | 0.03 |
| 170 | 0 |
| 180 | 0 |
| 189 | 0.00003 |

Composition data from ATSDR (2000) Toxicity Profile for PCBs

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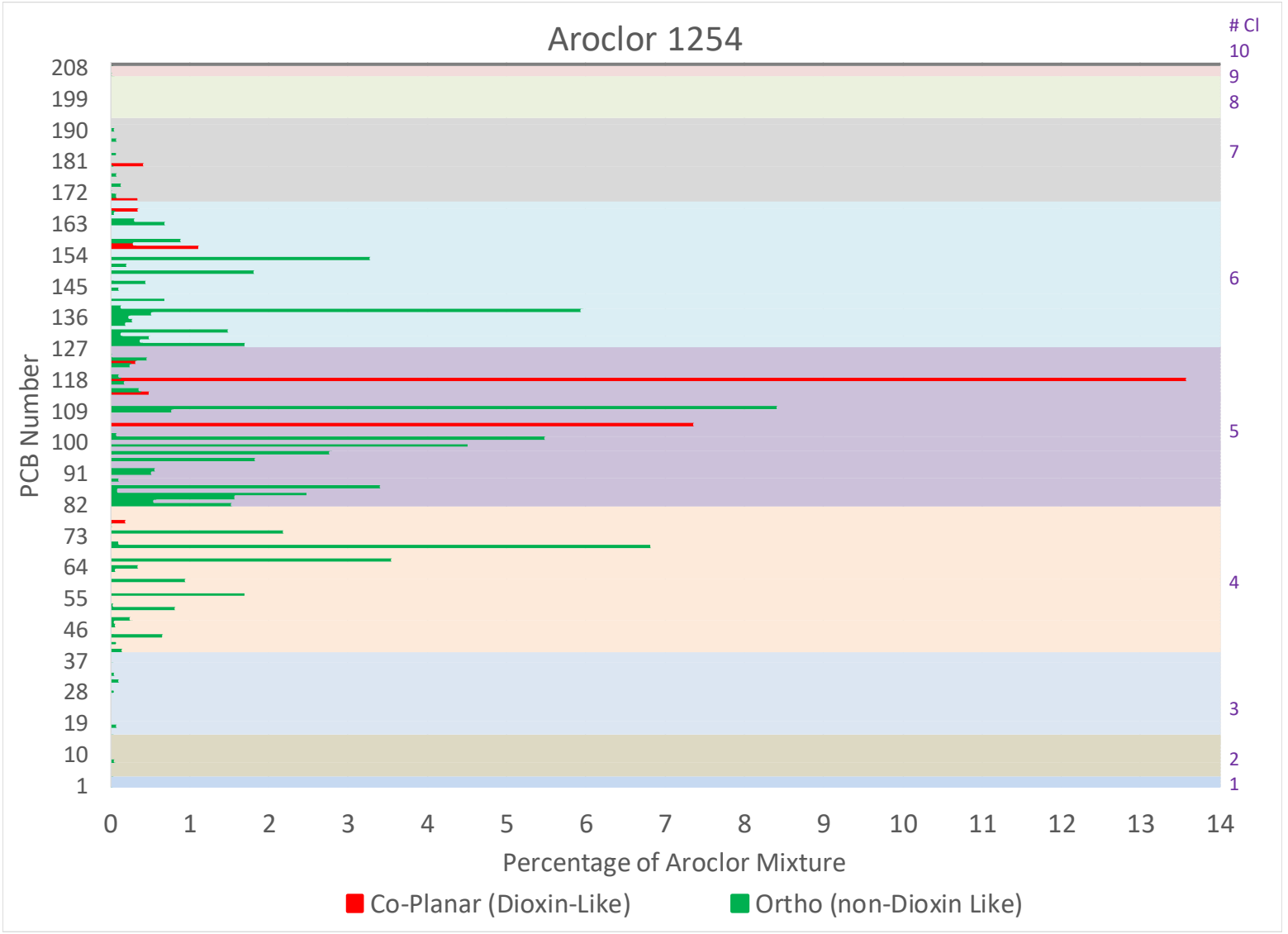


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| 114 | 0.00003 |
| 118 | 0.00003 |
| 123 | 0.00003 |
| 126 | 0.1 |
| 156 | 0.00003 |
| 157 | 0.00003 |
| 167 | 0.00003 |
| 169 | 0.03 |
| 170 | 0 |
| 180 | 0 |
| 189 | 0.00003 |

Composition data from ATSDR (2000) Toxicity Profile for PCBs

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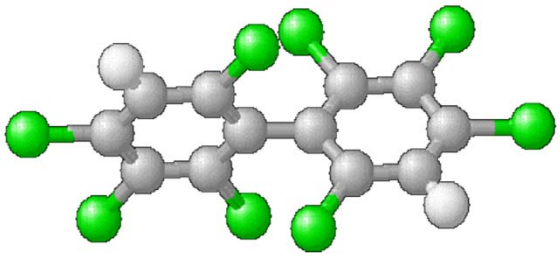
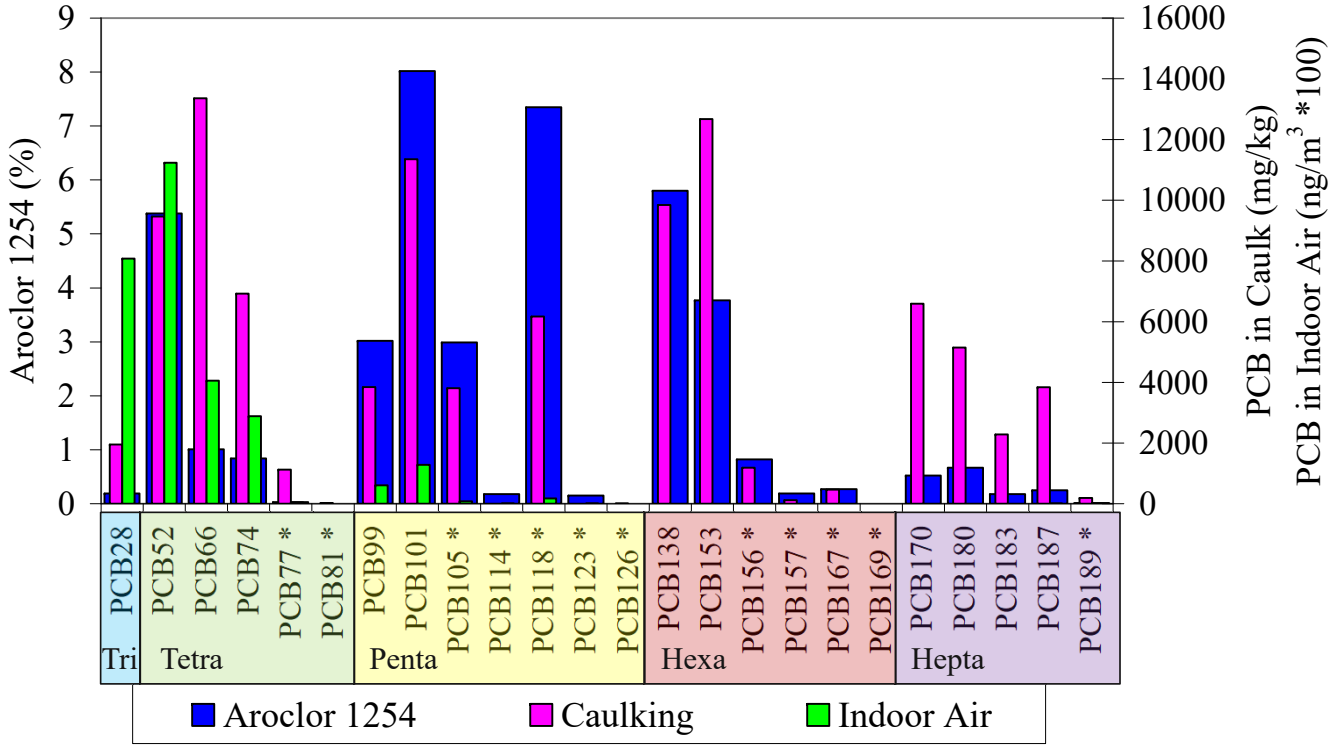
# PCBs in Denmark Homes

## Danish Health Protection Agency, 2012

- 83 PCB-contaminated apartments
- 27 congeners in caulking, indoor air, & serum
- Plotted against Aroclor 1254 composition






* indicates dioxin-like (co-planar) congener

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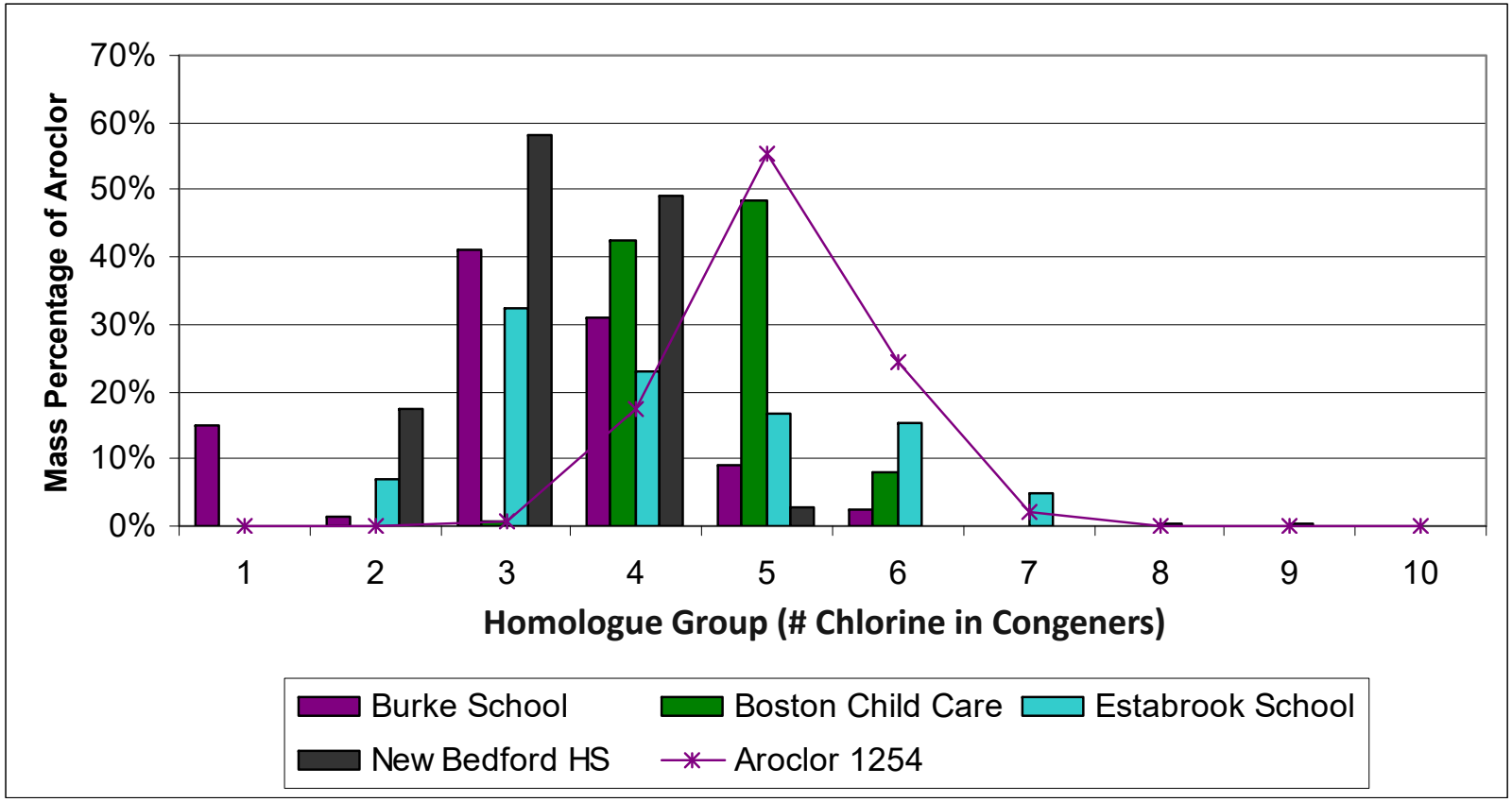
# PCB Homologue Groups in Indoor Air in MA Schools

- Patterns shift to lower chlorinated congeners
- Child care center an exception

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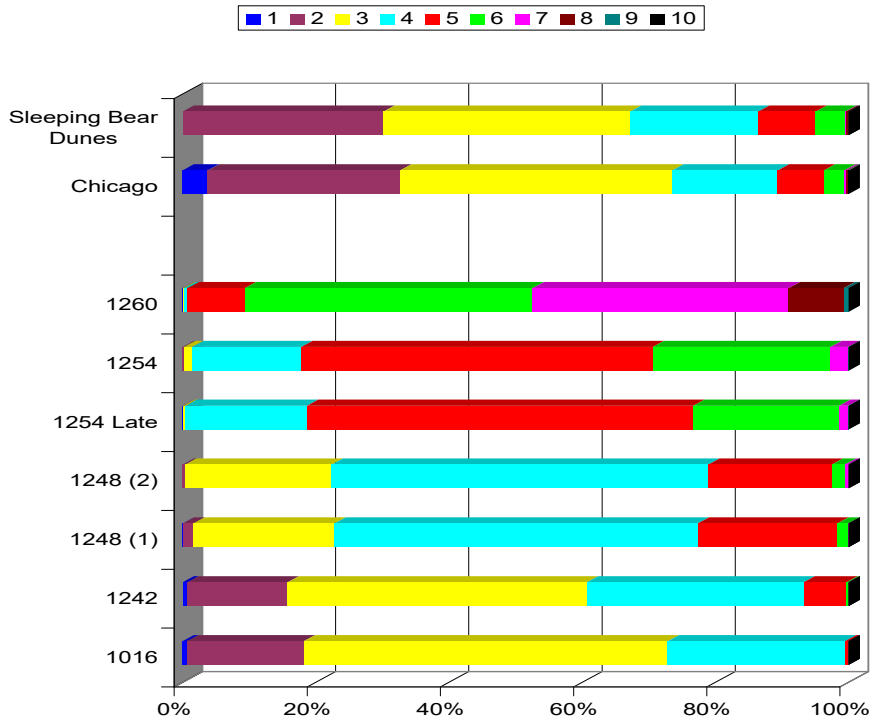
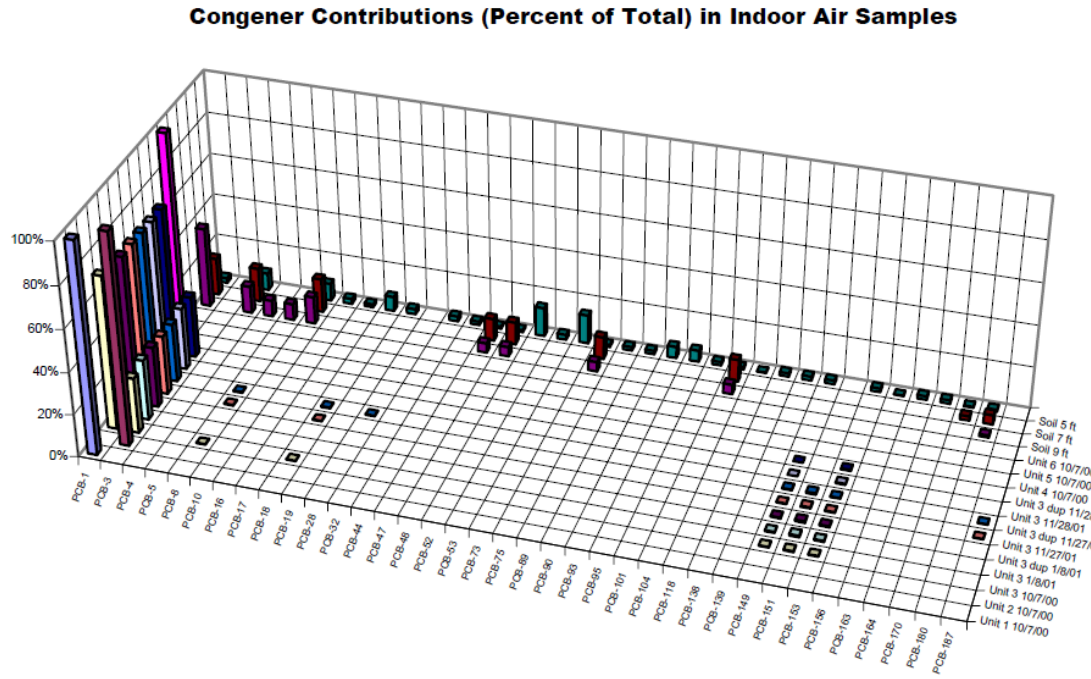
# PCB Homologue Groups & Congeners in Air Sampling




- Norström et al (2010) & ATSDR (2000)
- Outdoor air contains 0.04 – 0.5 ng/m$^3$ PCBs




- Davis et al (2002) vapor intrusion investigation
- Soils contain up to 160,000 mg/kg PCBs
- PCBs up to 220 ng/m$^3$, >97% mono PCBs

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# Case Study #1: "Brownfield" Redevelopment

- Mill building conversion to condominiums
  - PCB-impregnated floors
  - Renovation workers at risk?

- Exposure estimate
  - Assume 3.3 mg/m$^3$ of dust (high level)
  - 5.8 mg/kg PCB in dust
  - Yields exposure to 20 ng/m$^3$ of PCBs

- Acceptable/safe levels
  - OSHA PEL: 500,000 µg/m$^3$
  - More recent studies: 10,000 µg/m$^3$

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# Case Study #2: Child Care Center

- PCB concentrations measured in indoor air
  - 110 – 200 ng/$m^3$ at time of study
  - > 300 ng/$m^3$ previously
  - Exceed EPA guideline of 100 ng/$m^3$ for 1-2 and 2-3 yr-olds
- Questions
  - Should center be closed?
  - What about < 1 yr-olds?
- Issues and perspectives
  - Homologue profile resembles Aroclor 1254
  - EPA guidelines derive from toxicity study in monkeys
    - Safety factor of 250 applied
    - Humans may be less sensitive to PCBs than monkeys
  - Nursing infants receive ~ 20 times more exposure than EPA's Reference Dose

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# Case Study #3: "Brownfield" Redevelopment

- Industrial building conversion to luxury apartments
  - PCB-impregnated concrete floors to remain in place
  - Future residents at risk?

- Exposure estimate
  - Measured volatilization rate
  - Indoor air model 44 ng/$m^3$
  - Homologue pattern indicates low-risk PCBs
- Acceptable/safe level 98 ng/$m^3$ based on EPA school methodology
- Mitigation through encapsulation (concrete layer plus epoxy)
- Confirmatory indoor air samples:
  - 1st round: All ND
  - 2nd round: 2 of 5 low detects (0.5 ng/$m^3$ and 1.2 ng/$m^3$)

Developed in conjunction with Paul Muniz, Environmental Partners, LLC

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# Acceptable Concentration (Case Study #3)

Public Health Level exposure methodology (EPA 2009 Exposure Estimation Tool:

Allowable incremental + Background ≤ Safe level

$$C_{Indoor} = \frac{B_w}{I_r}\left(R_{fD} - e_{diet}\right) - C_{outdoor}$$

- $C_{Indoor}$ Allowable PCB concentration in indoor air (ng/m$^3$)
- $B_w$ Body weight = 11.4 kg (small child)
- $I_r$ Inhalation rate = 8 m$^3$/d
- $R_{fD}$ Reference dose (ng/kg-d) – 20 ng/kg-d (high risk) or 70 ng/kg-d (low risk)
- $e_{diet}$ Background exposure = 1.2 ng/kg-d (Total Diet Study) – EPA default 8 ng/kg-d
- $C_{outdoor}$ Background PCBs in outdoor air = 0.5 ng/m$^3$

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# Acceptable Concentration (Case Study #3)

$$C_{Indoor} = \frac{B_w}{I_r}\left(R_{fD} - e_{diet}\right) - C_{outdoor}$$

- Application of formula yields:
  - $C_{Indoor}$ = 98 ng/m$^3$ if $R_{fD}$ = 70 ng/kg-d – EPA RSL = 28 ng/m$^3$
  - $C_{Indoorl}$ = 26 ng/m$^3$ if $R_{fD}$ = 20 ng/kg-d – EPA RSL = 4.9 ng/m$^3$

- Compare to building estimates:
  - 44 ng/m$^3$ flux chamber model
  - 4.5 ng/m$^3$ static test
  - ND for encapsulant test


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# Encapsulation / Risk Mitigation (Case Study #3)

- Diffusion model to predict effectiveness of epoxy and concrete encapsulants
  - 1” concrete layer delays PCB volatilization over practical lifetime of building (100s of years)
  - Epoxy effective for over 60 years

Diffusion model through porous medium

| | |
|---|---|
| $x$ | Distance into layer |
| $\delta$ | Encapsulant thickness |
| $D$ | Diffusivity in layer |
| $C_0$ | Concentration at $x = 0$ |
| $t$ | Time. |

PCB concentration distribution in the concrete layer:

$$C(x,t) = C_0\frac{\delta - x}{\delta} + C_0\sum_{n=1}^{\infty}(-1)^n\frac{2}{n\pi}\sin\left(n\pi\frac{\delta - x}{\delta}\right)\exp\left(-\frac{n^2\pi^2 Dt}{\delta^2}\right)$$

PCB Flux from concrete:

$$D\frac{C_0}{\delta}\left(1 + 2\sum_{n=1}^{\infty}(-1)^n\exp\left(-\frac{n^2\pi^2 Dt}{\delta^2}\right)\right)$$

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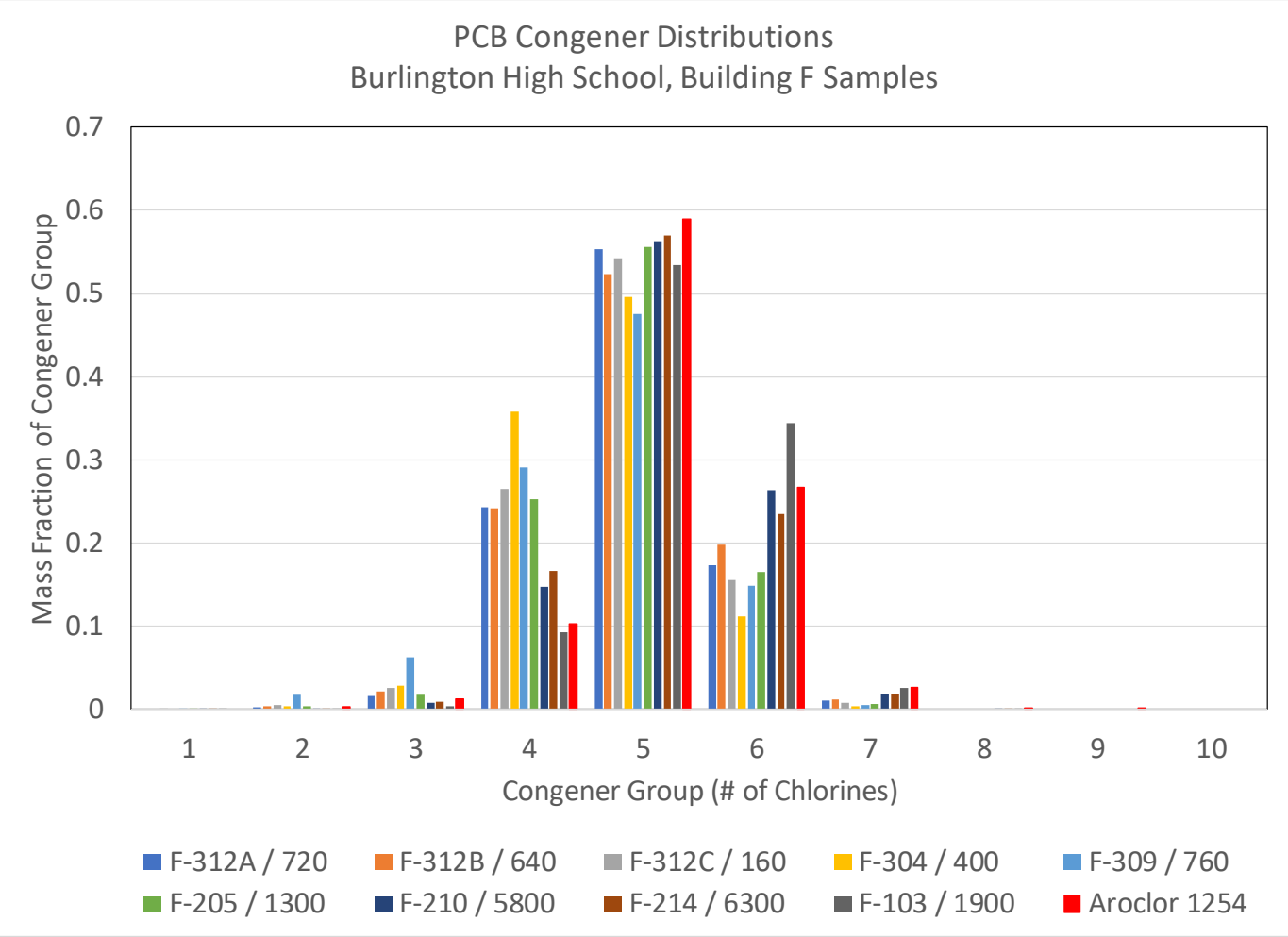
# Congener Distributions – Burlington HS Data




Aroclor 1254 Distribution in Red

Limited Shift Toward Low-Cl Congeners

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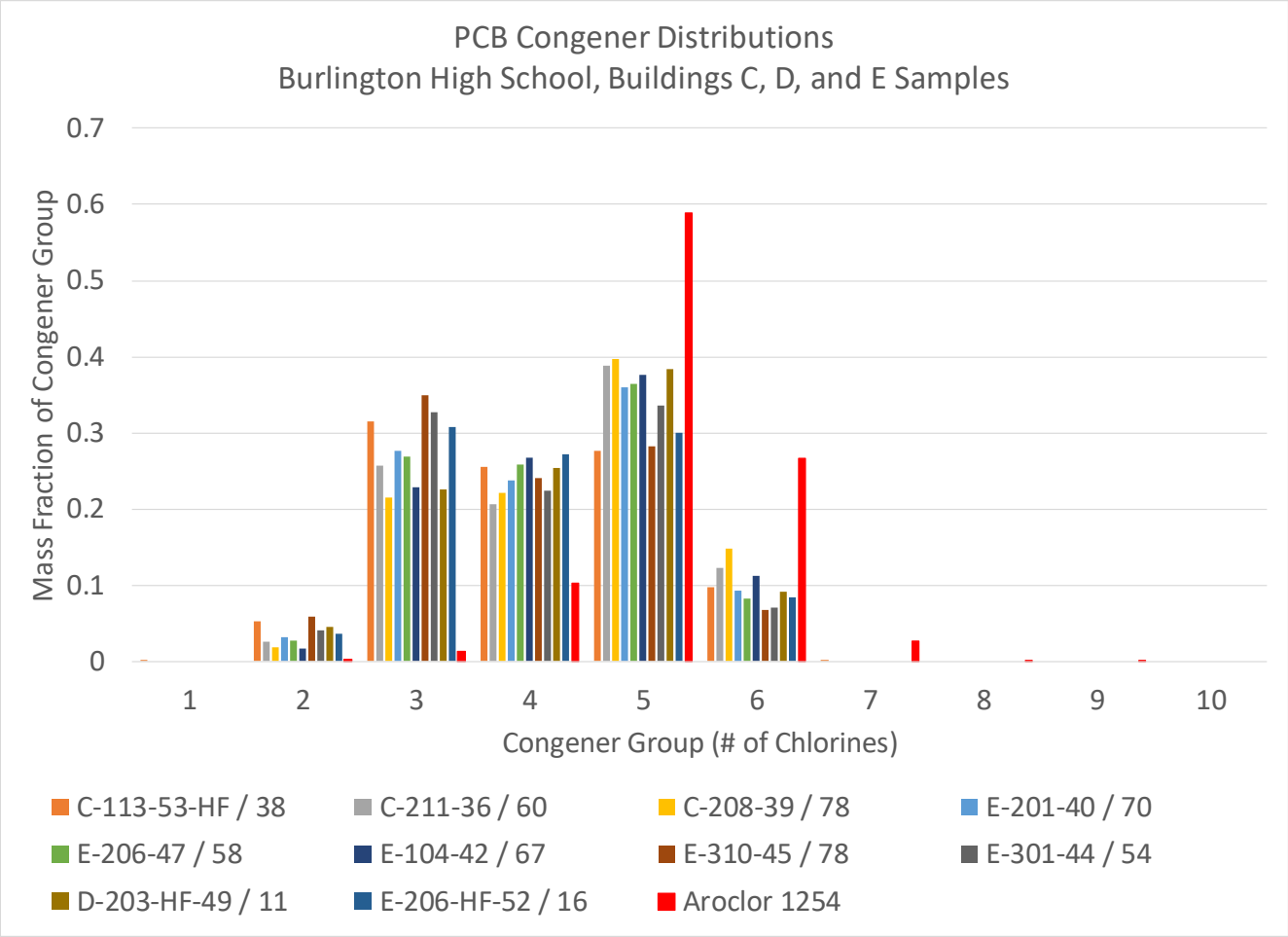
# Congener Distributions – Burlington HS Data




Concentrations < 80 ng/m$^3$

Aroclor 1254 Distribution in Red

Considerable Shift Toward Low-Cl Congeners

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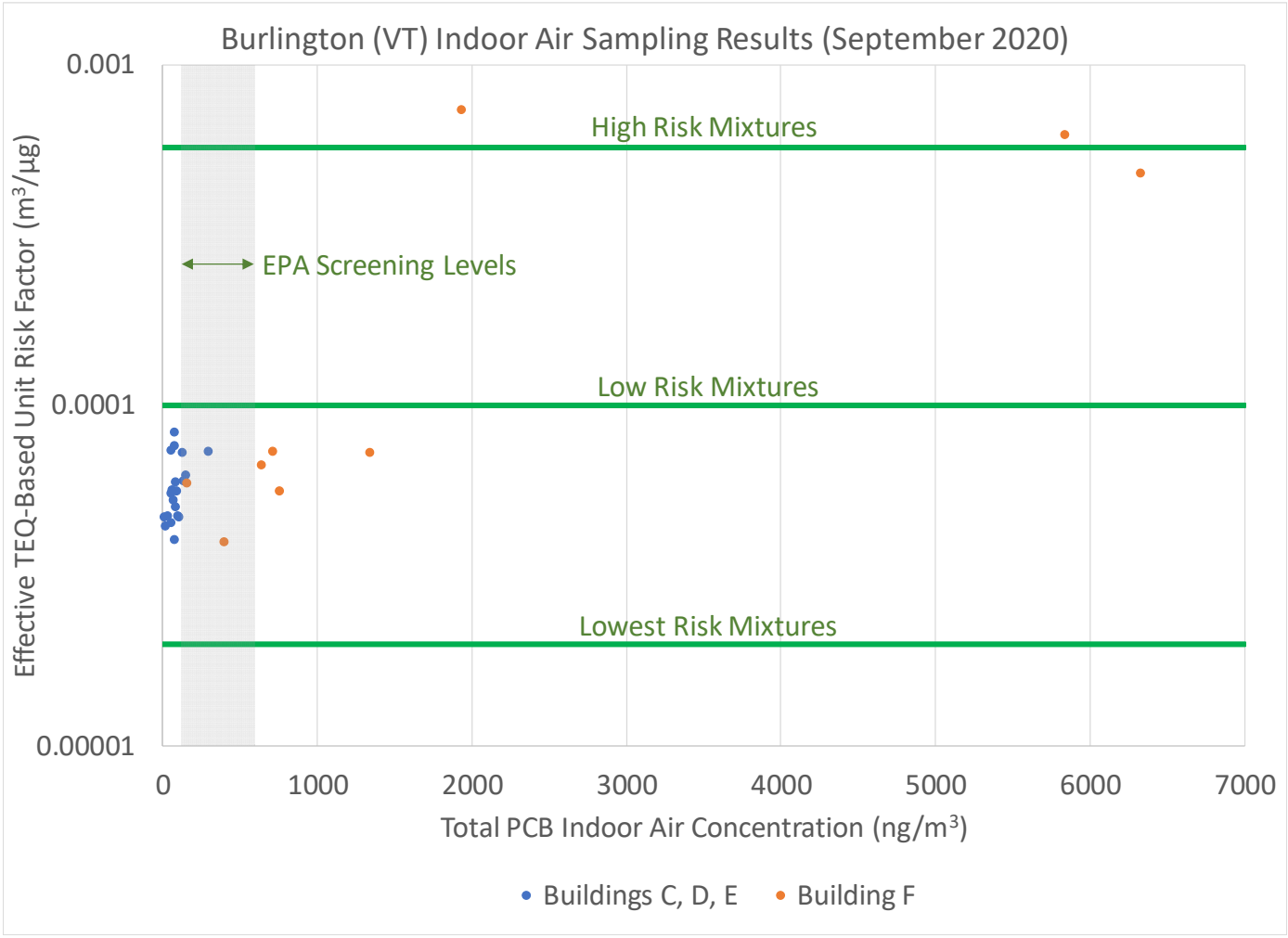
# Carcinogenic Unit Risk Factors for PCB Mixtures




Sample-specific unit risk factors estimated from weighting congener distributions and dioxin-like PCBs

Green Lines at Unit Risk Factors for PCB Mixtures per EPA RSL Tables

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# Summary

- Levels of PCBs measured in indoor air due to building material sources have been near or greater than recommended exposure levels
- PCBs found in many (but not all) indoor air emphasize the less chlorinated, and generally less toxic, congeners of the parent mixtures
- Actual risks to health may be substantially overestimated (or conversely, exposure guidelines are highly protective)
- PCB-containing building materials remain a source of PCBs to indoor air for many years
- PCB risk assessment methods are uncertain, could be improved, and will likely evolve


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# Thank you!

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