Inadvertently Generated PCBs in Consumer Products: Concentrations, Fate and Transport, and Preliminary Exposure Assessment

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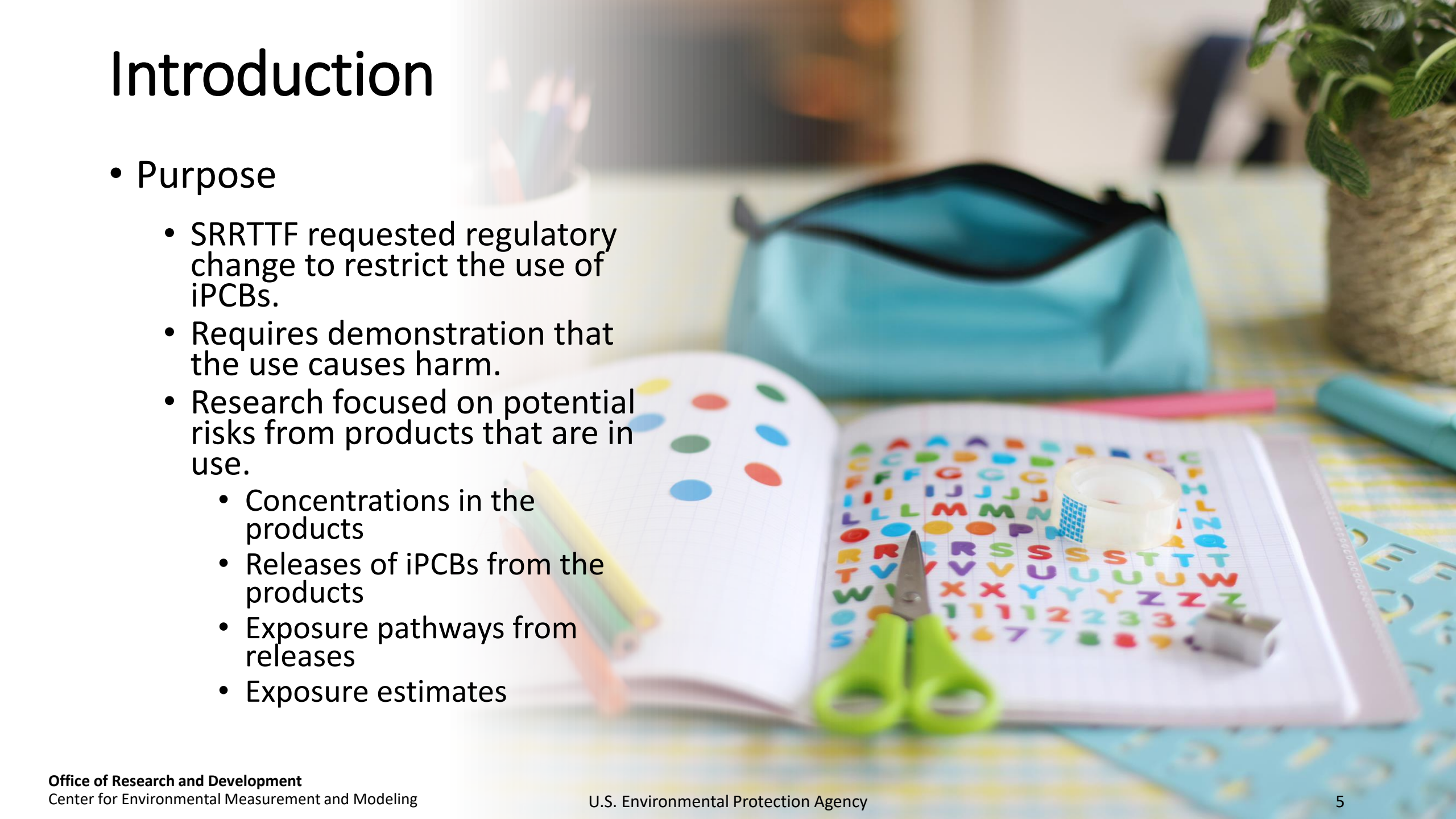
Outline

- Introduction
  - Exposure pathways
  - Research Efforts
- Materials and Methods
- Results
- Preliminary Exposure Estimation
- Implications
- Future Work

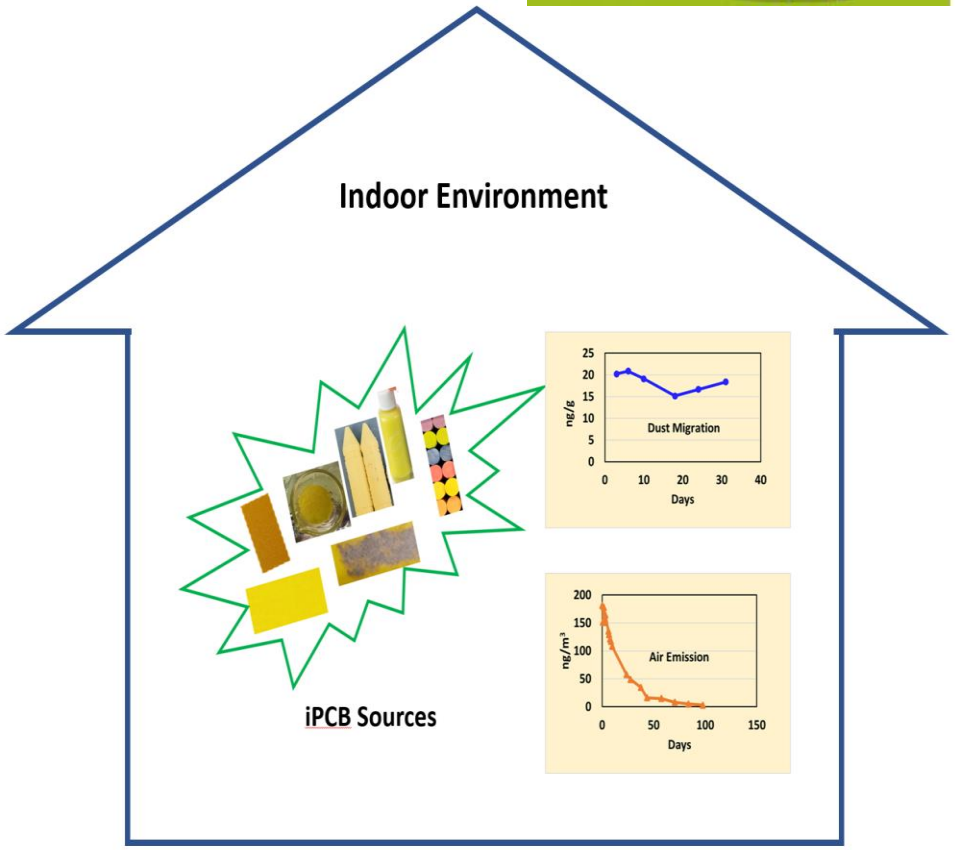
Introduction

- Purpose
  - SRRTTF requested regulatory change to restrict the use of iPCBs.
  - Requires demonstration that the use causes harm.
  - Research focused on potential risks from products that are in use.
    - Concentrations in the products
    - Releases of iPCBs from the products
    - Exposure pathways from releases
    - Exposure estimates



Introduction

- Pathways of iPCB exposure are through ingestion, inhalation, dermal contact, and dietary intake.
- Products used in schools may be contributors to indoor air and dust exposures.
- Dietary exposure is the highest amongst subsistence fishers including tribes and immigrants.
- Tribal and immigrant children may have the highest exposure rates from the combination of consumption of a heritage fish-based diet and exposure in schools.



Introduction

- Research Efforts
  - Identification of iPCBs from 39 consumer products purchased on the current retail market
  - Selection of PCB-11 as the major conger to be studied for fate and transport and exposure assessment
  - Measurement of PCB-11 emissions from consumer products
  - Investigation of PCB-11 migration from the source to settled dust
  - Preliminary assessment of potential exposure to PCB-11

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Article

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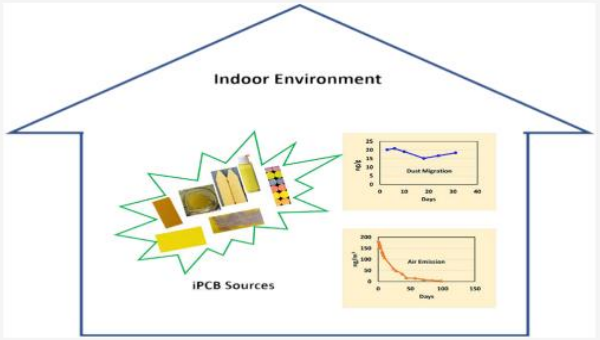
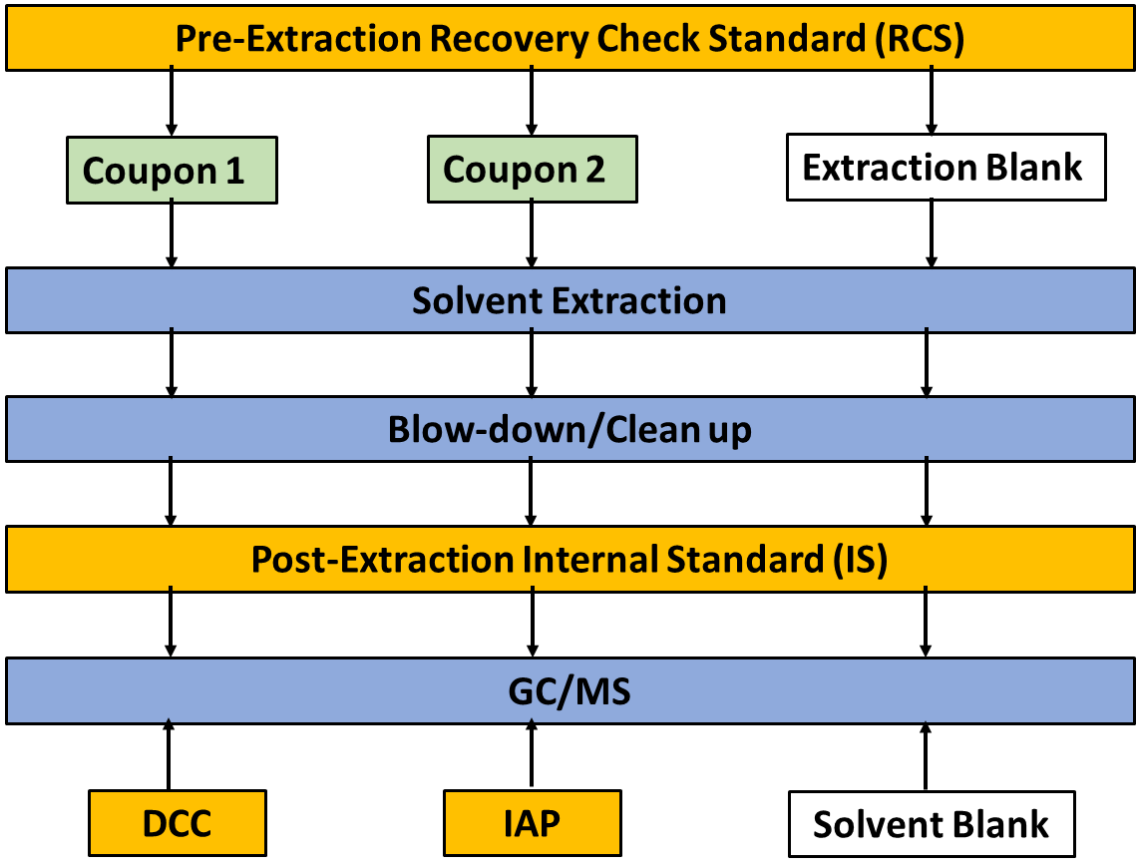
ABSTRACT: Although commercial polychlorinated biphenyl (PCB) production was banned in 1979 under the Toxics Substance Control Act, inadvertent generation of PCBs through a variety of chemical production processes continues to contaminate products and waste streams. In this research, a total of 39 consumer products purchased from local and online retailer stores were analyzed for 209 PCB congeners. Inadvertent PCBs (iPCBs) were detected from seven products, and PCB-11 was the only congener detected in most of the samples, with a maximum concentration exceeding 800 ng/g. Emission of PCB-11 to air was studied from one craft foam sheet product using dynamic microchambers at 40 °C for about 120 days. PCB-11 migration from the product to house dust was also investigated. The IAQX program was then employed to estimate the emissions of PCB-11 from 10 craft foam sheets to indoor air in a 30 m^3 room at 0.5 h^{-1} air change rate for 30 days. The predicted maximum PCB-11 concentration in the room air (156.8 ng/m^3) and the measured concentration in dust (20 ng/g) were applied for the preliminary exposure assessment. The generated data from multipathway investigation in this work should be informative for further risk assessment and management for iPCBs.

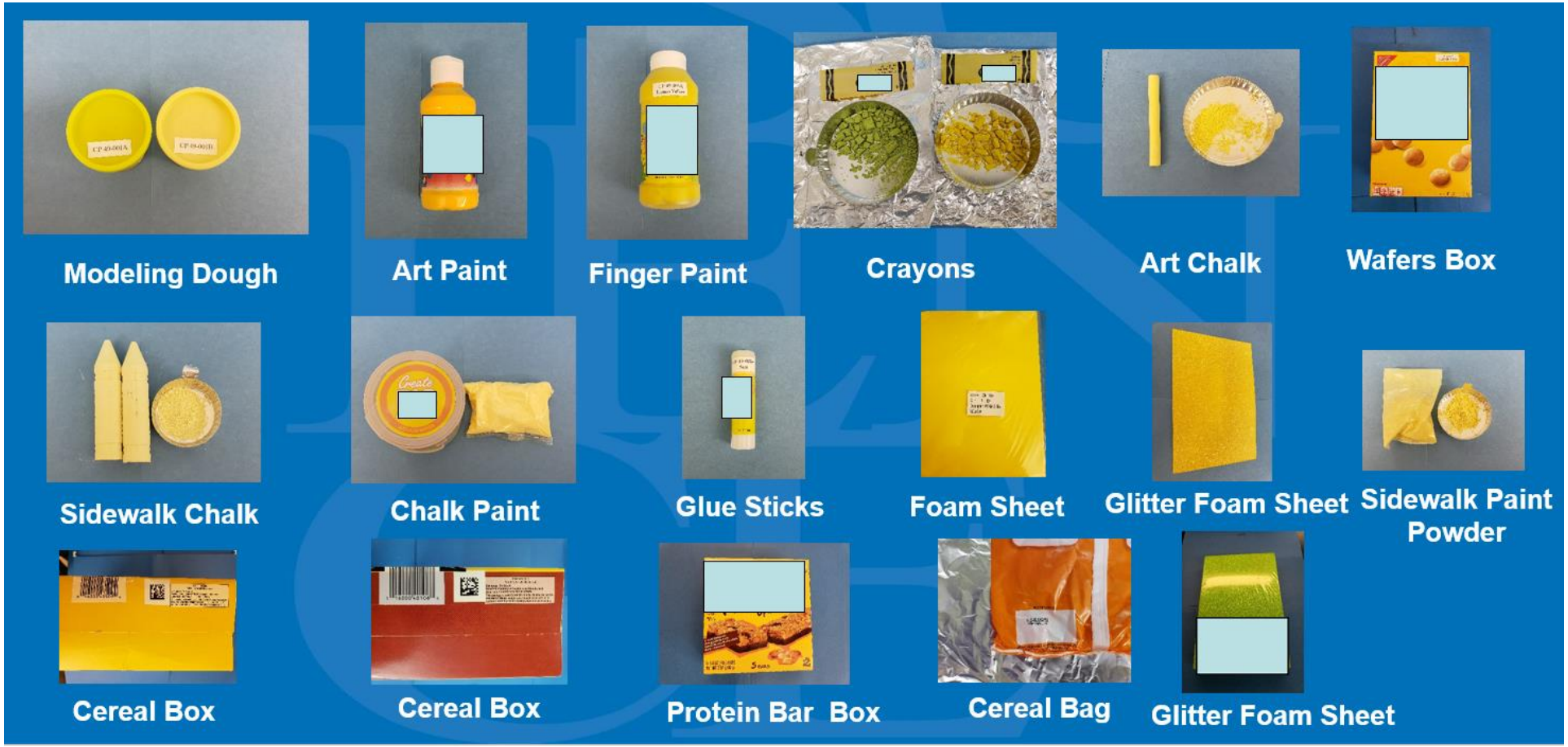


KEYWORDS: *inadvertent PCBs, emission, dust migration, source characterization, exposure assessment, PCB-11, indoor air*

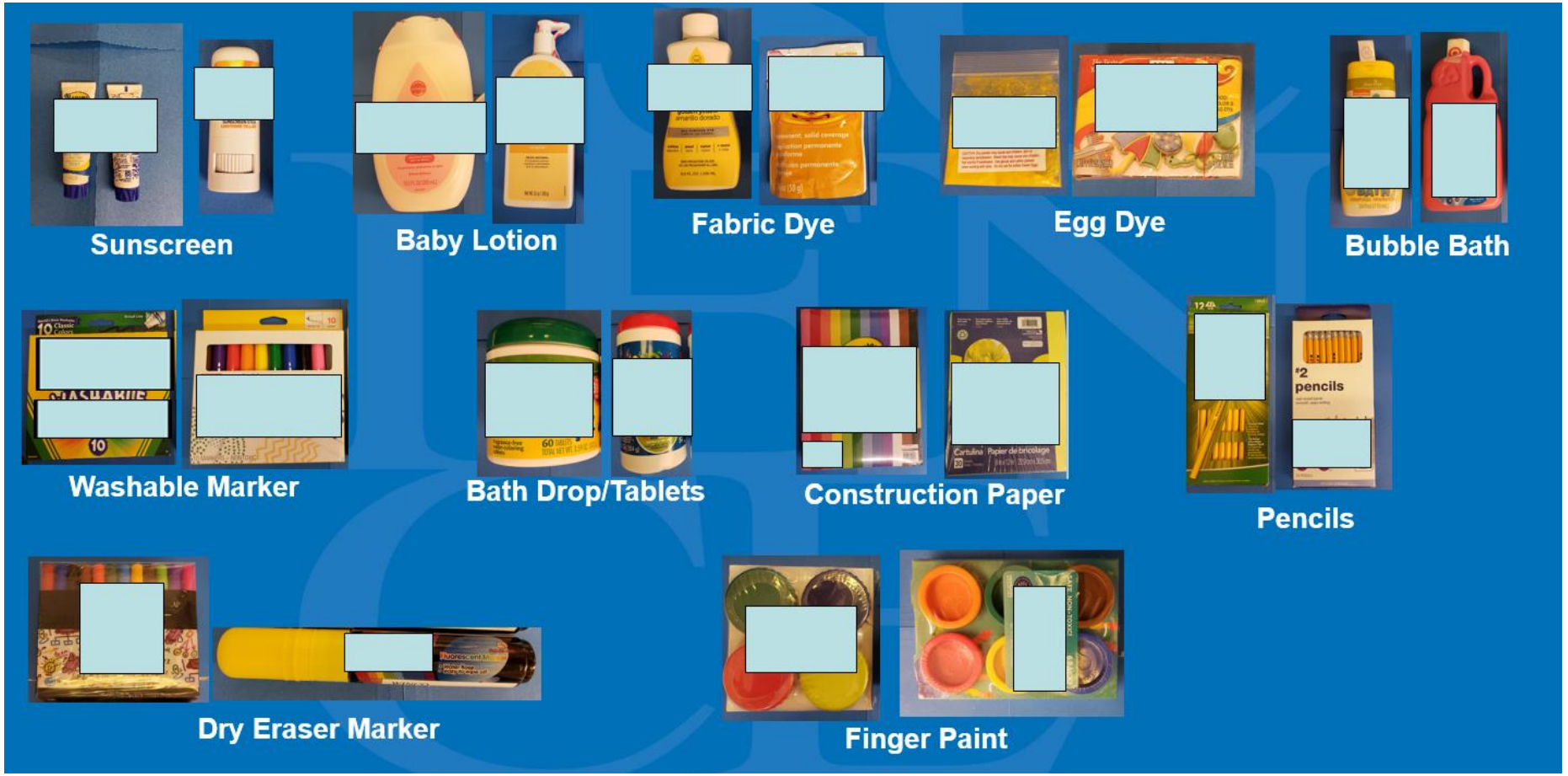
Determination of iPCBs in Consumer Products



Determination of iPCBs in Consumer Products



Determination of iPCBs in Consumer Products

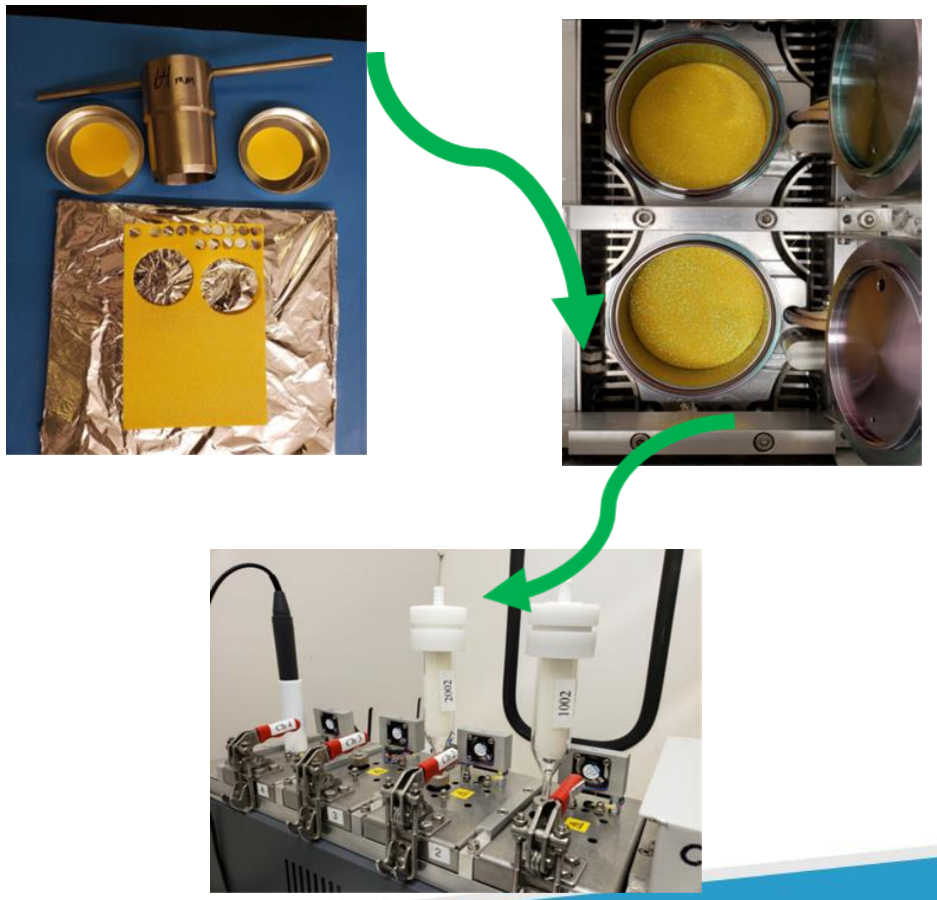


Determination of iPCBs in Consumer Products

- Tested 39 Products
  - Agilent 6980/5973 GC/MS
  - 5 sets of calibration mixtures covering all 209 congeners
  - Analytical recovery, method precision, instrument detection limit, QA/QC followed
- Evaluated Variability of PCBs
  - 13 yellow glitter foam sheets within the same package and between different packages

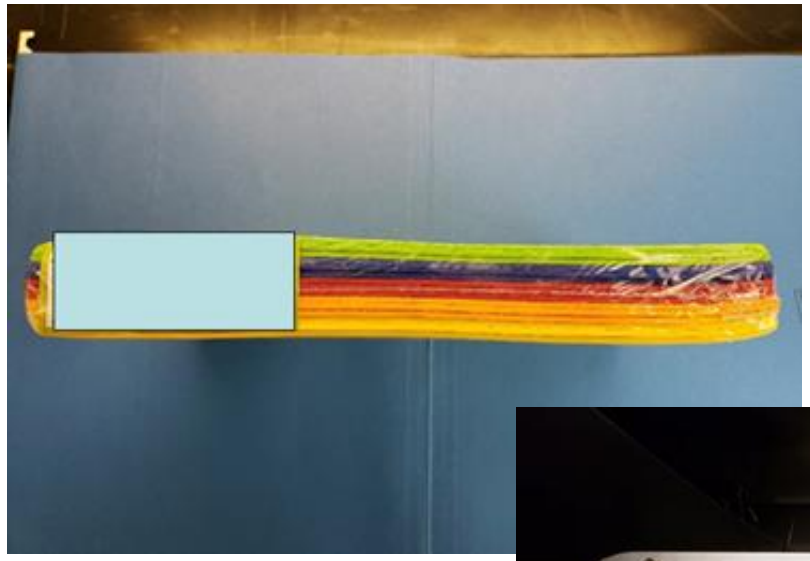
Emission of iPCBs in Consumer Products

- 64 mm diameter yellow glitter foam sheet in 114 mL chamber
- 40 °C, 28% RH, 100 mL/min air flow (54 h^{-1} air change rate)
- PUF cartridge sampling at different time interval
- Duplicate test for 120 days



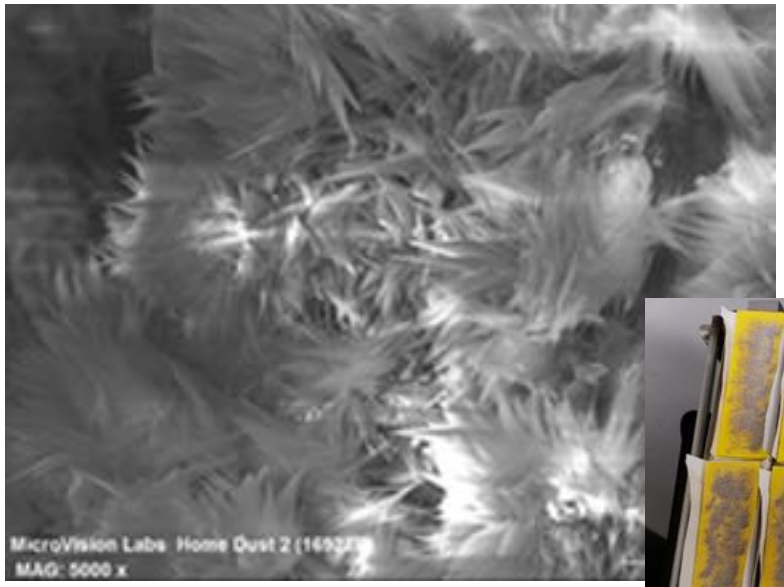
Migration of iPCBs from Consumer Products to Dust

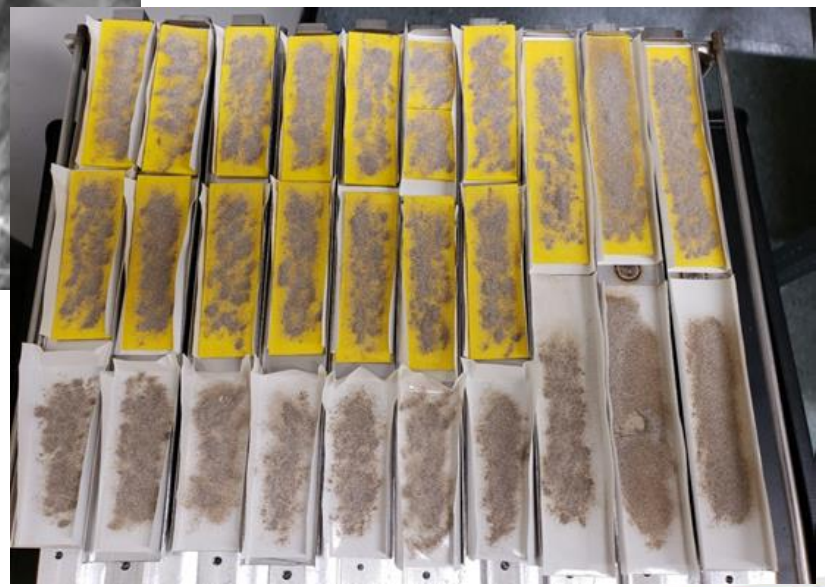
- Small chamber 53 L
- Typical indoor air conditions
  - 23 °C / 73.4 °F
  - 48 % RH
  - 1 h^{-1} air change rate



Migration of iPCBs from Consumer Products to Dust

- Tested both sides and PCB-free release paper for 33 days
  - 6 (+1 duplicate) samples loaded and collected at different time interval
  - 3 more samples loaded with different amounts of dust and collected at the end of the test





iPCB in Consumer Products

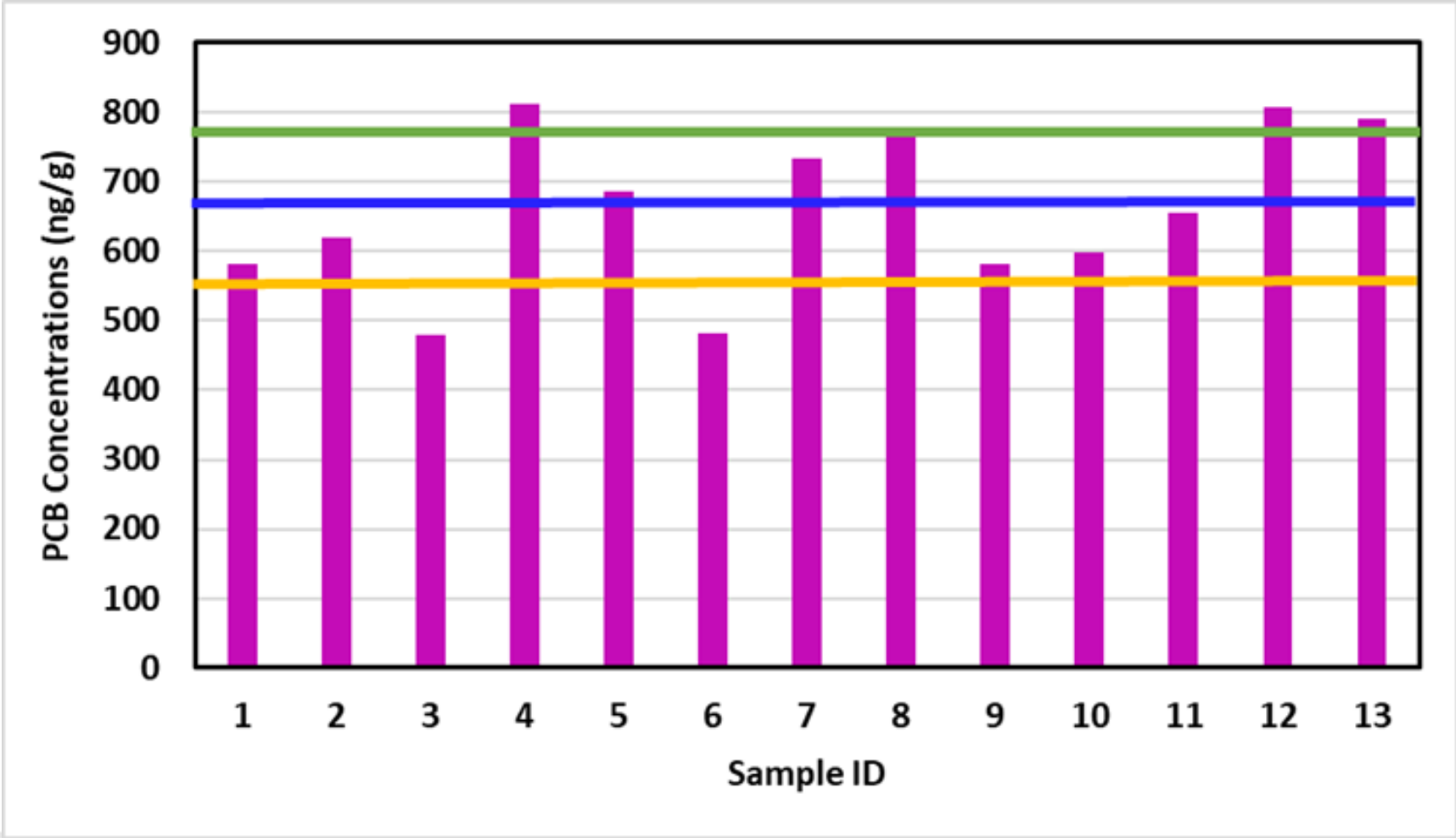
Table 1. iPCB Average Concentrations in Consumer Products Tested

Product IDs	Concentration (ng/g) ± %RSD (n=2)							
	PCB-11	PCB-95	PCB-121	PCB-85	PCB-181	PCB-149	PCB-153	PCB-138
Crayon-Yellow	71.5 ± 1.08	ND [a]	ND	ND	ND	ND	ND	ND
Crayon-Green	43.3 ± 1.34 [b]	ND	ND	ND	ND	ND	ND	ND
Sidewalk Chalk	167.5 ± 9.71	ND	ND	ND	ND	ND	ND	ND
Foam Sheet	122.1 ± 0.67	ND	ND	ND	ND	ND	ND	ND
Fiberboard Box (Wafers)	ND	66.7 ± 4.46 [b]	101.1 ± 5.08	137.2 ± 3.78	85.3 ± 4.53 [b]	63.9 ± 8.69 [b]	67.5 ± 2.89 [b]	122.3 ± 4.03
Glitter Foam Sheet [c]	345.7 ± 2.61	ND	ND	ND	ND	ND	ND	ND
Sidewalk Chalk Paint	18.5 ± 8.39 [b]	ND	ND	ND	ND	ND	ND	ND
Glitter Foam Sheet [d]	696.7±23.39	ND	ND	ND	ND	ND	ND	ND

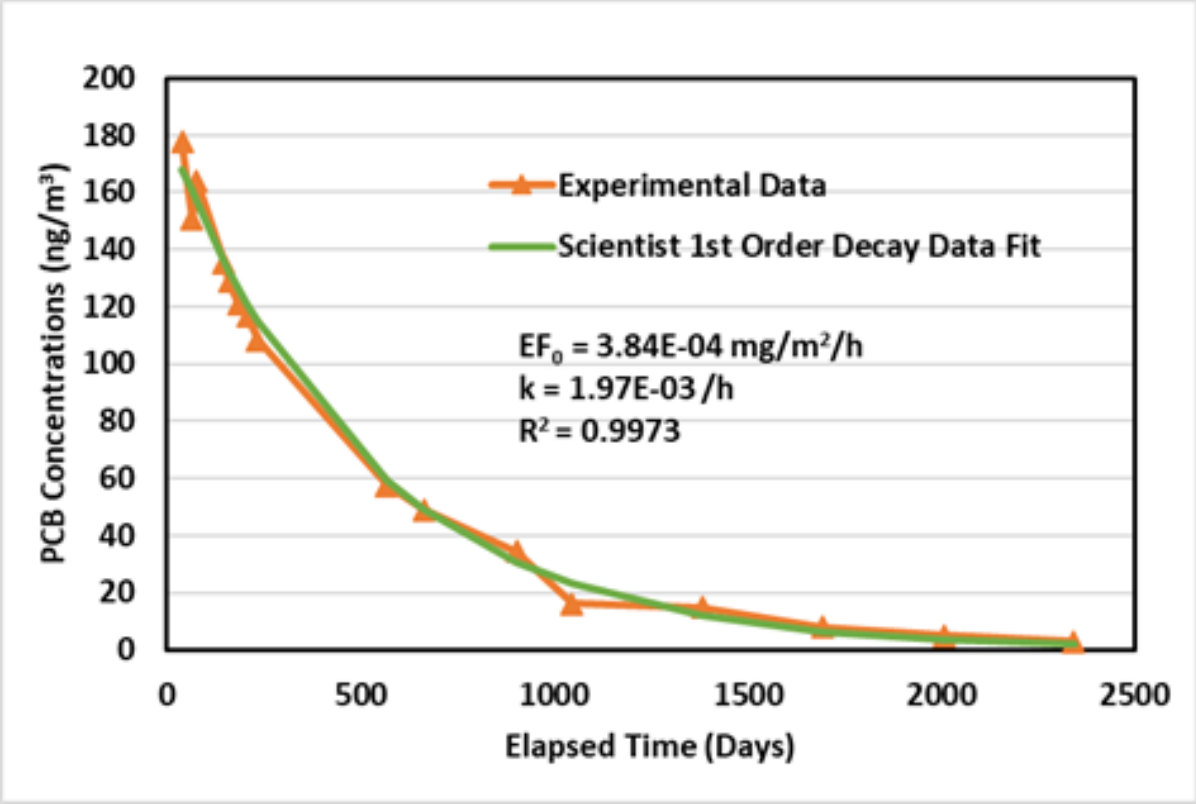
[a.] Not detected; [b] Concentration above the instrument detection limit but below the lowest calibration concentration; [c] From Washington State; [d] Purchased online

iPCB in Consumer Products

Figure S2. PCB-11 concentrations in 13 yellow glitter foam sheets that were analyzed in duplicate for each sheet (blue line –average concentration of all analysis (661.7 ng/g); green line – average concentration + 1SD (778.0 ng/g); yellow line – average concentration - 1SD (545.5 ng/g).



iPCB Emissions from Products



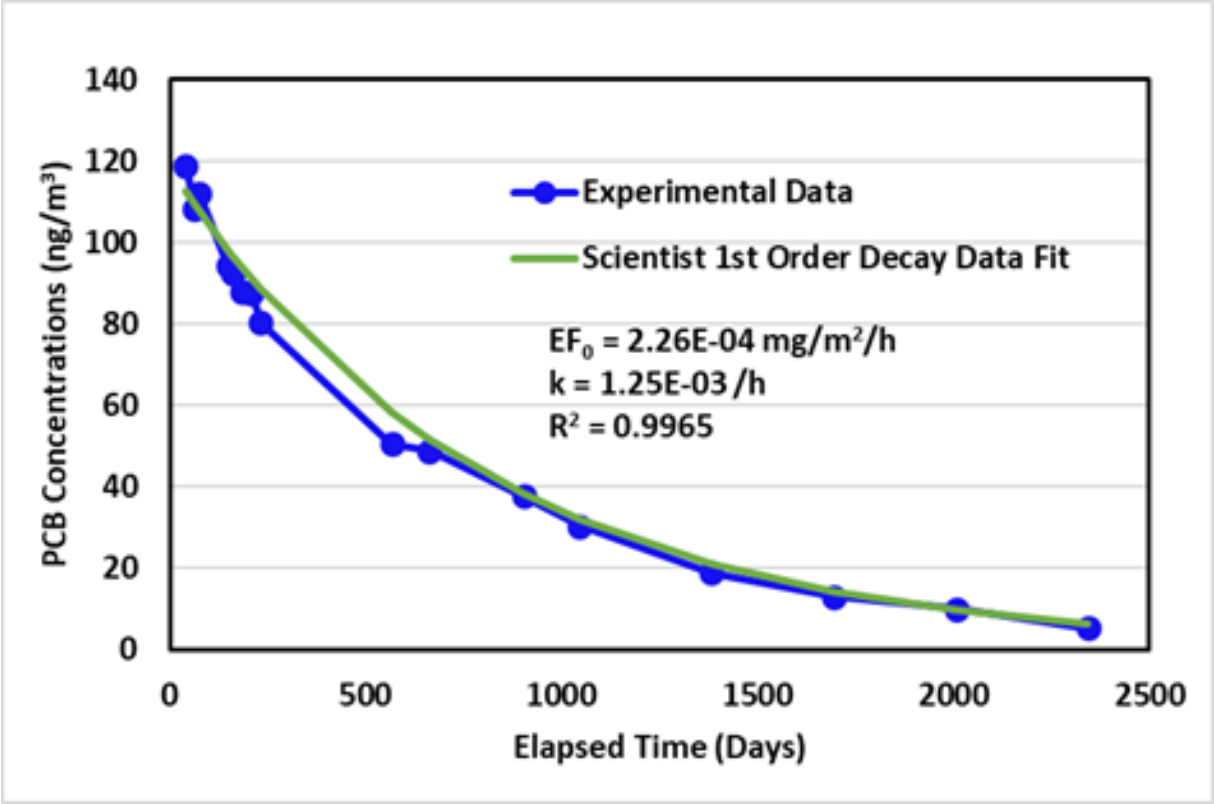


Figure 2. Least square fit of first order decay emission data from microchamber emission test T1 (L) and test T2 (R).

iPCB Emissions from Products

Table S6. Parameters Used for IAQX Simulation	
Parameter Name and Unit	Parameter Values
Initial emission factor EF_0, $mg/m^2/h$	3.84E-04 (from T1); 2.26E-04 (from T2)
1st order decay constant, k, /h	1.97E-03 (from T1); 1.25E-03 (from T2)
Initial concentration in the room/ mg/m^3	0
Room size, m^3	30
Air change rate, /h	0.5
Exposed sample surface area, m^2	0.3 (10 sheets) [a]
Sink	No
Sources remove time, h	1000
Simulation time, h	720 (30 days)
[a] The size of one foam sheet is 13.9 cm x 21.5 cm	

iPCB Emissions from Products

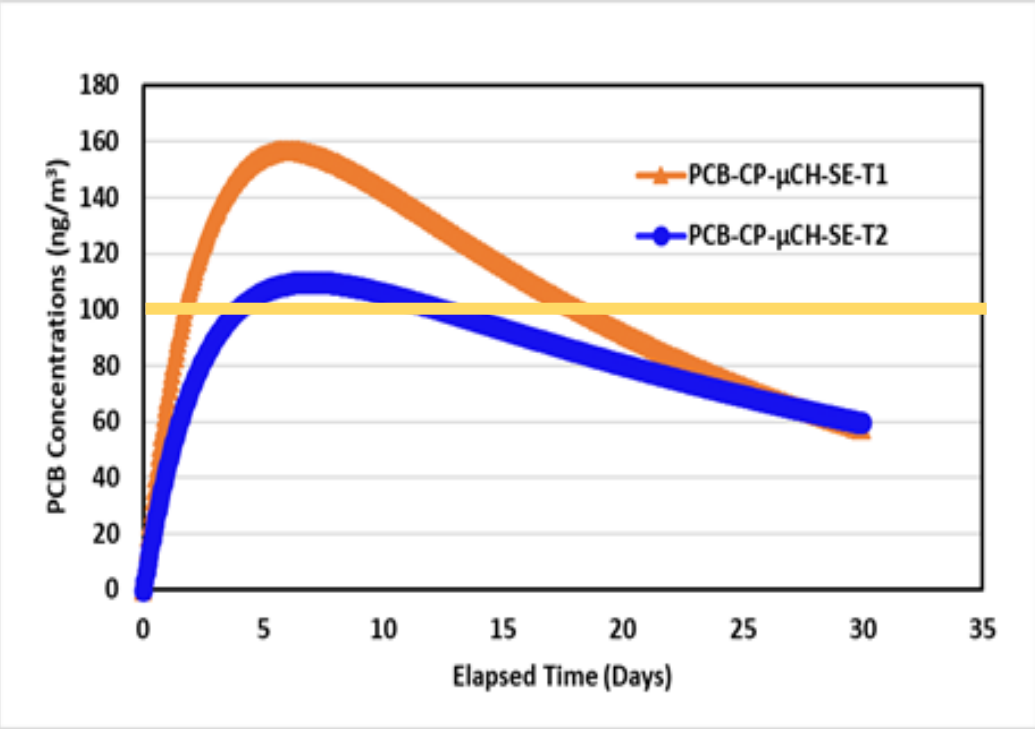


Figure 3. Gas-phase PCB-11 concentrations predicted in a 30 m^3 room with 10 foam sheets, 0.5 h^{-1} air change rate for over 30 days.

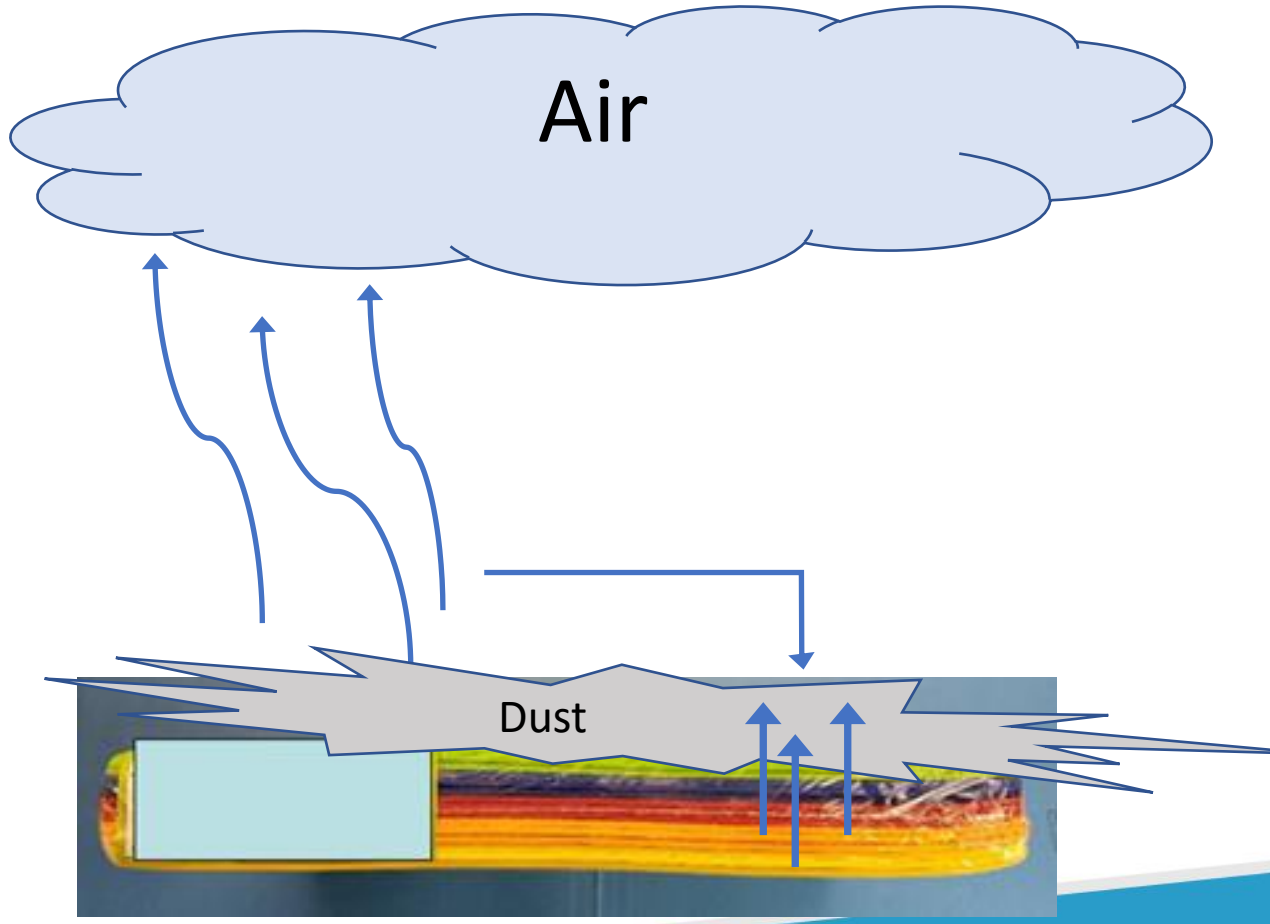
Exposure Levels for Evaluating PCBs in School Indoor Air (ng/m3)*

Age: 1-<2 yr	Age: 2-<3 yr	Age: 3-<6 yr	Age: 6-<12 yr elementary school	Age: 12-15< yr middle school	Age: 15-<19 yr high school	Age: 19+ yr adult
100	100	200	300	500	600	500

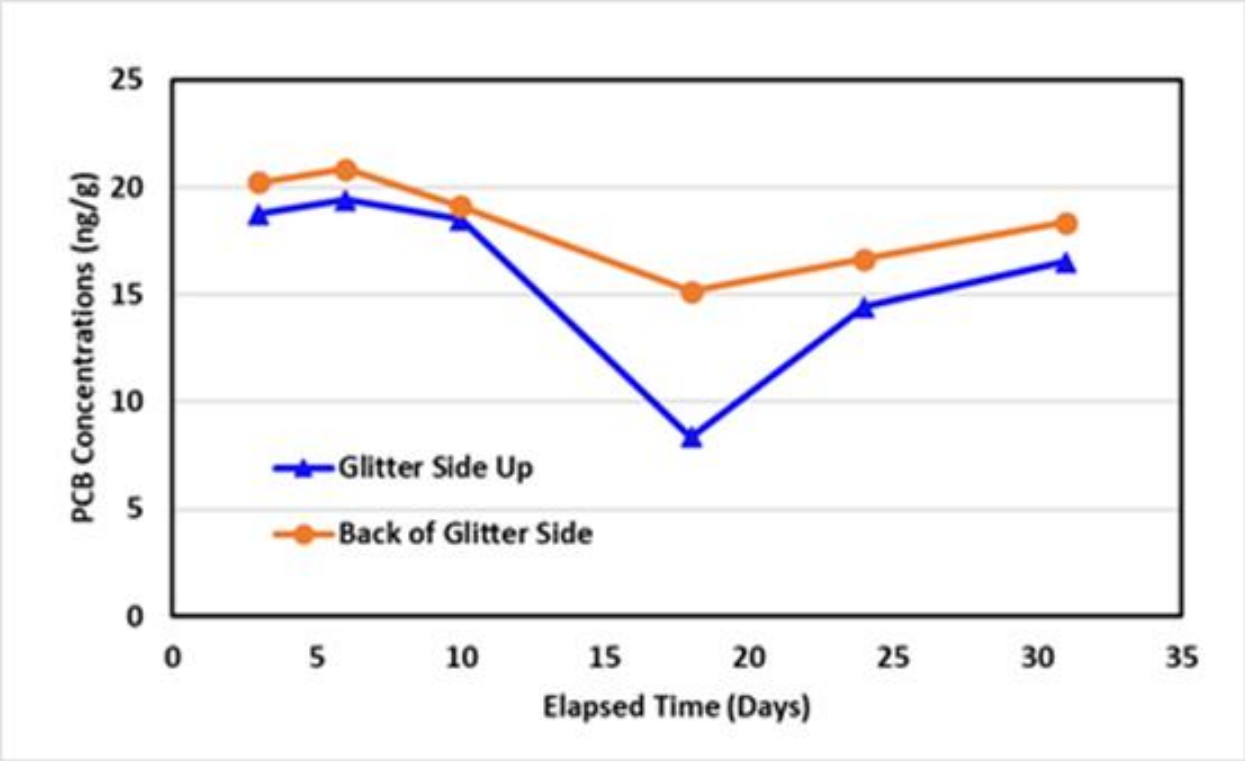
See: https://www.epa.gov/pcbs/exposure-levels-evaluating-polychlorinated-biphenyls-pcbs-indoor-school-air

iPCB Migration from Source to Dust

- Three Mass Transfer Processes Taking Place
  - Emissions of PCB-11 from the foam product covered with “clean” dust
  - PCB-11 migration from the foam source to dust via direct contact (dominant)
  - Sorption of PCB-11 from air into “clean” dust on the PCB-free release paper (negligible)



iPCB Migration from Source to Dust



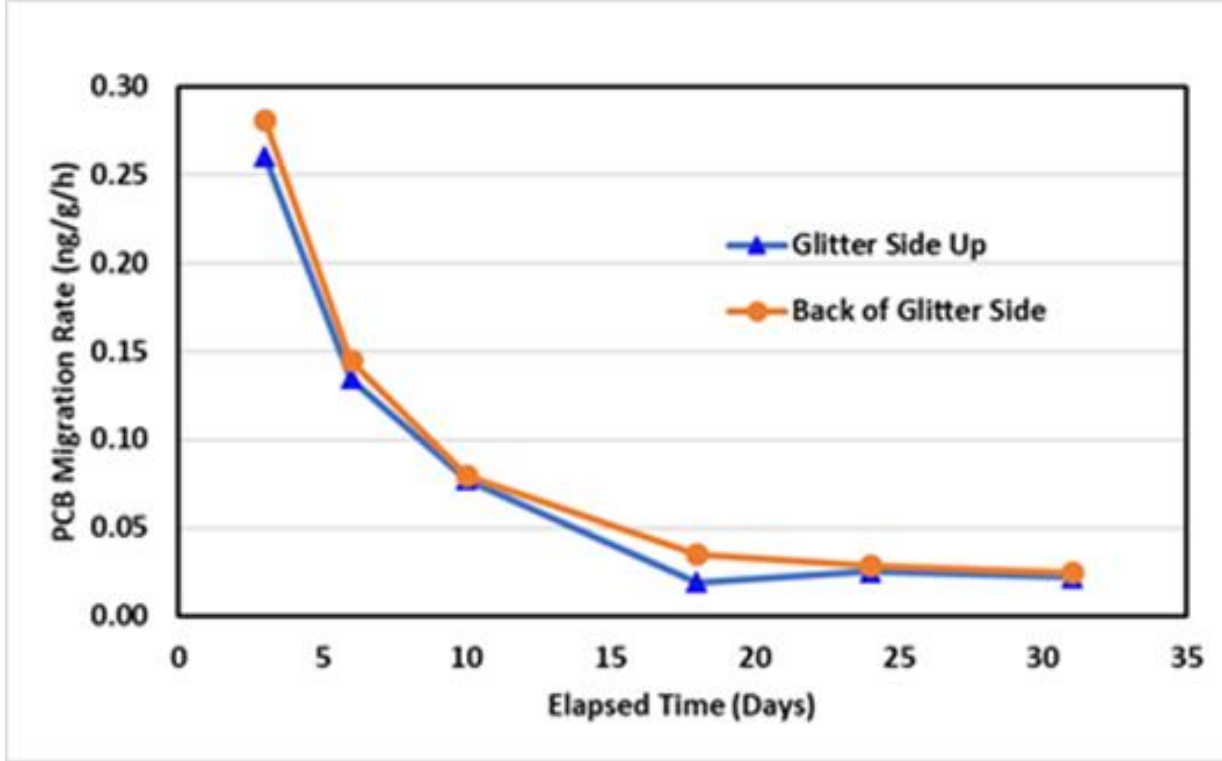


Figure 4. Migration concentration of PCB-11 from the CP-17 foam sheet to the house dust (left) and the migration rate (right).

Preliminary Exposure Estimation

- Exposure Routes Assessed
  - Inhalation of air
  - Dermal absorption from air
  - Ingestion of dust that absorbed PCBs from the air
  - Ingestion of dust contaminated by migration from the product
  - Dermal absorption of contaminated dust
- 3 Age Groups (when data is available)
  - Children 3 to <6 years
  - Children 6 to <11 years
  - Adults 16 to <21 years

Preliminary Exposure Estimation

- EPA's Exposure Factors Handbook 2011 Edition and Standard Route-Specific Algorithms and Experimental Data from this Research
  - Air inhalation $$\text{Intake}_{\text{inh}} = (\text{Conc}_{\text{air}} \times \text{InhRate} \times \text{ET} \times \text{ABS})/(\text{BW})$$
  - dermal absorption from air $$\text{Intake}_{\text{derm}} = (\text{Conc}_{\text{air}} \times \text{TransDermPerm} \times \text{BSA} \times \text{ET})/(\text{BW})$$
  - Ingestion of dust $$\text{Intake}_{\text{ing}} = (\text{Conc}_{\text{dust}} \times \text{IngRate} \times \text{ABS})/(\text{BW})$$
  - Ingestion of contaminated dust

$$\text{Intake}_{\text{dust\_ing}} = (\text{Mass}_{\text{dust\_contam}} \times \text{SA} \times \text{HtoM}_{\text{freq}} \times \text{HtoM}_{\text{eff}} \times \text{Frac} \times \text{ET} \times \text{Conc}_{\text{dust\_contam}} \times \text{ABS})/\text{BW}$$

  - Dermal absorption of contaminated dust

$$\text{Intake}_{\text{dust\_derm}} = (\text{Mass}_{\text{dust\_contam}} \times \text{Conc}_{\text{dust\_contam}} \times \text{SA} \times \text{ABS} \times \text{ET})/(\text{BW})$$

Preliminary Exposure Estimation

Table S7. Individual Parameters Used for Exposure Estimates				
Parameters	Age Group			Reference
	Child 3 to < 6 years	Child 6 to <11 years	Adult 16 to < 21 years	
InhRate m^3/day	10.1	12	16.3	1
BW, kg	18.6	31.8	71.6	2
TransDermPerm, m/h	0.13	0.13	0.13	3
IngRate, mg/day	60	30	30	4
BSA, m^2	0.76	1.08	1.84	5
$Mass_{dust\_contam}$, mg/m^2	0.011	0.011	NA [a]	5
SA, m^2/hands	0.037	0.051	0.083	5
$HtoM_{freq}$, 1/hr	15	7	2	6, 7(for adults)
$HtoM_{eff}$	0.2	0.2	0.2	8
Frac, 1/contact	0.13	0.13	0.13	8

[a.] Data not available.

Preliminary Exposure Estimation

Table 2. Estimated Intake of PCB-11 (ng/kg/day)			
Exposure Pathways		Age Groups	
	Child 3 to <6 years	Child 6 to <11 years	Adult 16 to <21 years
Inhalation from air	19.9	13.8	8.3
Dermal absorption from air	6.7	5.5	4.2
Ingestion of dust absorbed gas PCB	0.1[a] / 0. 01[b]	0.04[a] / 0.003[b]	0.02[a] /0.001[b]
Ingestion of contaminated dust	0.006	0.002	NA[c]
Dermal absorption of contaminated dust	1.1×10^{-7}	8.8×10^{-8}	NA[c]
Total	26. 7[a] / 26.6[b]	19.3[a] / 19.3[b]	12.5 [a,d]/12.5 [b,d]

[a.] Calculated based on Equation (5); [b.] Calculated based on measured data; [c.] Not calculated because of no data available for adults' $Mass_{dust\_contam}$; [d.] Calculation did not include ingestion or dermal absorption of contaminated dust.

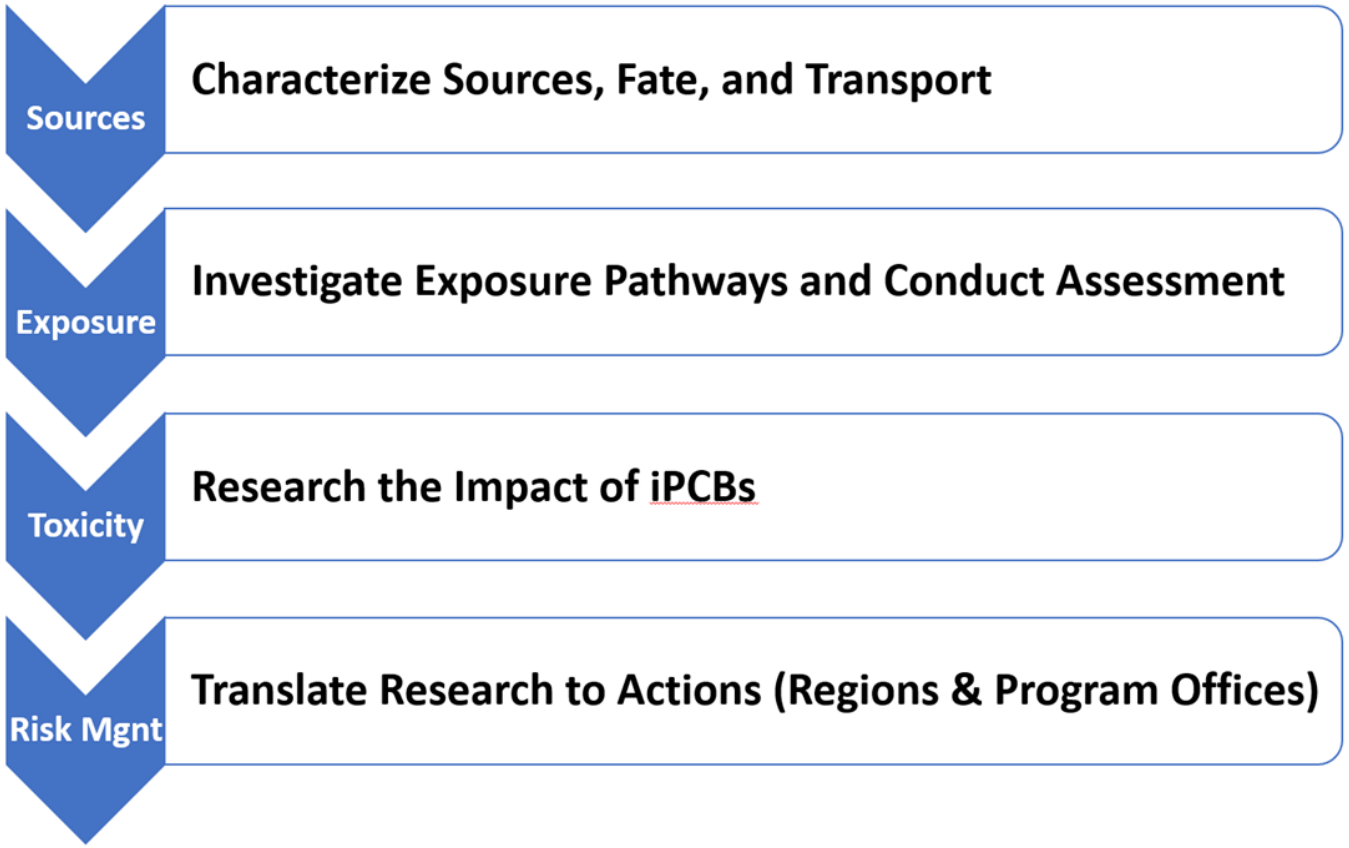
Preliminary Exposure Estimation

- Inhalation and dermal absorption from air are important intake pathways for the volatile iPCBs such as PCB-11.
- Our estimates were only based on one product releasing iPCBs into the room and only 10 sheets from that product.
- We might expect increased exposure to iPCBs from cumulative emissions from multiple products in a single room.

Implication

- iPCBs, e.g., PCB-11, in consumer products are present at a maximum concentration exceeding 800 ng/g.
- Multipathway exposure assessment is informative for discussions about potential migration from products into the environment.
- Understanding the fate, transport, and exposure pathways is a critical step for their cumulative risk assessment and in designing the ultimate mitigation solution.
- Data generated from this study will be valuable to contextualize the toxicity data for PCB-11 generated by the NTP, once it is released.

Future Work


Sources
Characterize Sources, Fate, and Transport
Exposure
Investigate Exposure Pathways and Conduct Assessment
Toxicity
Research the Impact of iPCBs
Risk Mgnt
Translate Research to Actions (Regions & Program Offices)

Thank You!

Image from the U.S. EPA Facility in Research Triangle Park, NC