Sources, Exposures, Toxicity, Metabolism, and Remediation of Airborne PCBs in Schools

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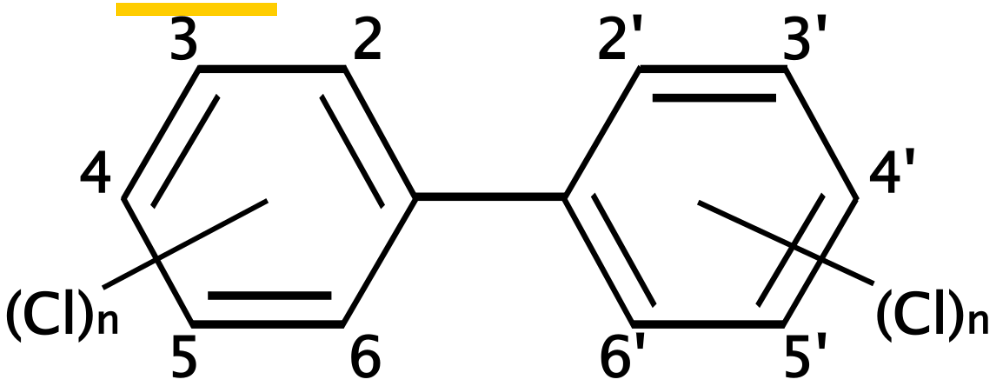
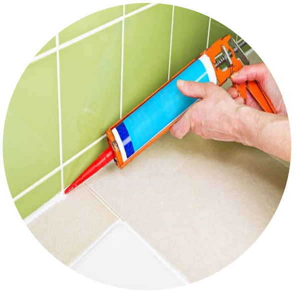
July 16, 2026

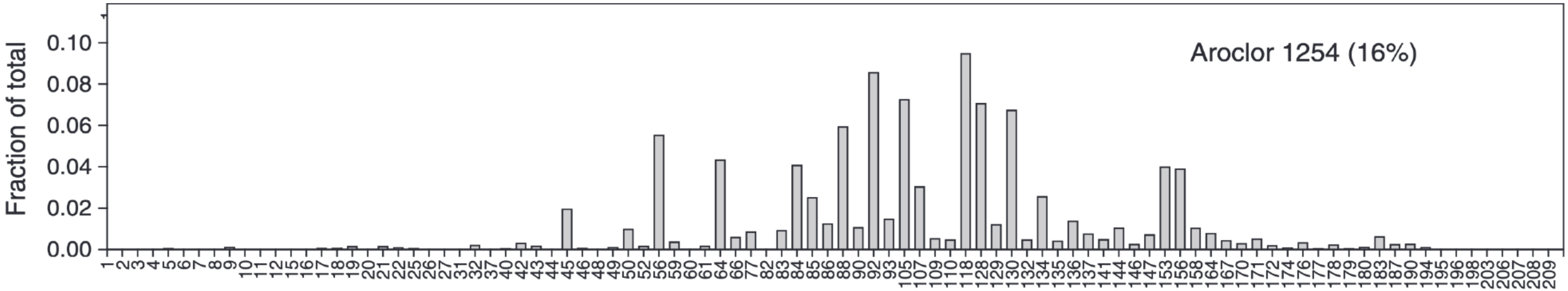
Polychlorinated biphenyls are a group of 209 distinct congeners

Polychlorinated Biphenyl (PCB)





PCBs areknown human carcinogens and associated with many non-cancer health impacts. Despite being banned in the 1970s, PCBs persist and are ubiquitous in the environment.



(Rodenburg, 2014)

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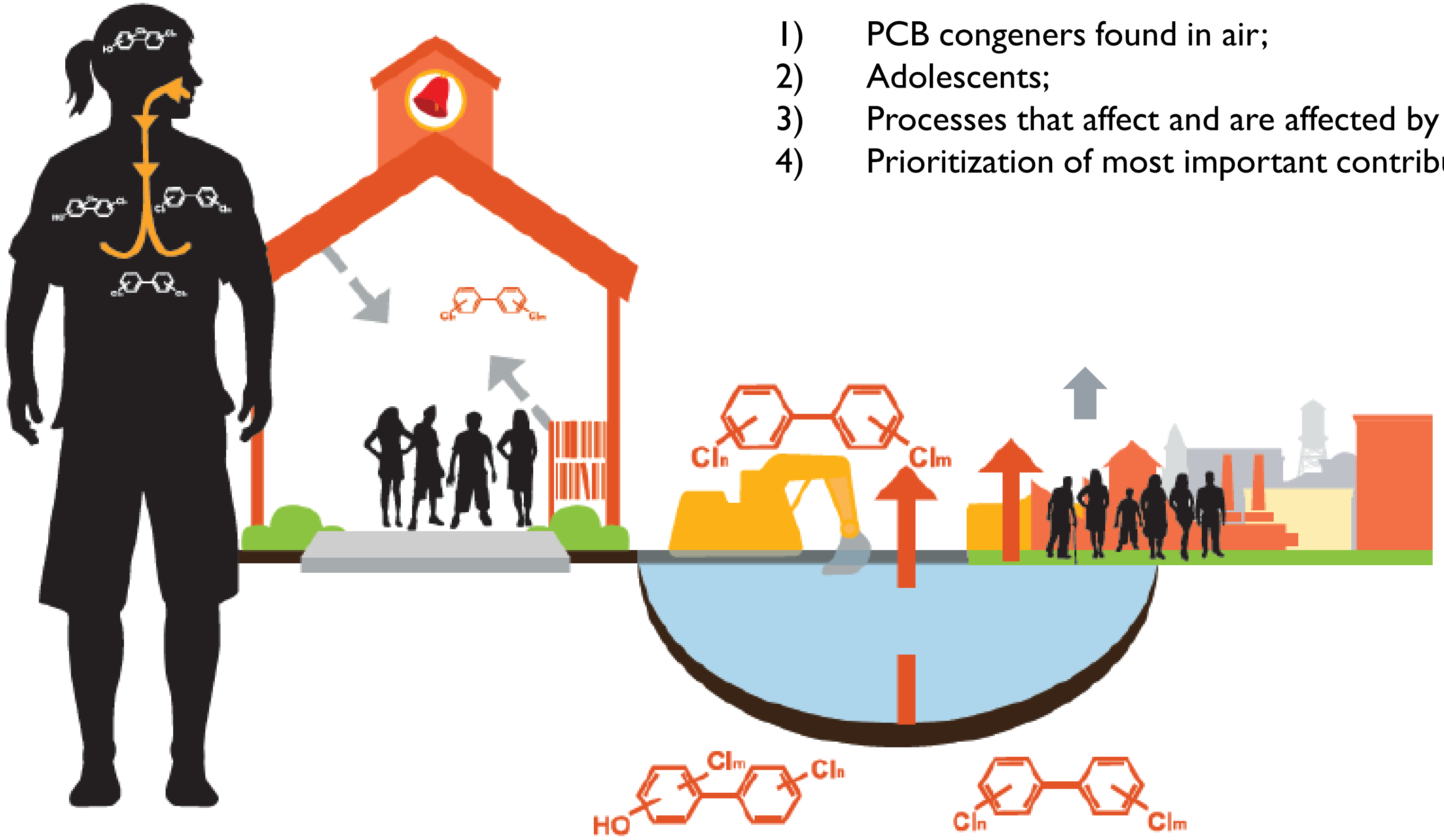
IOWA SUPERFUND RESEARCH PROGRAM



1) PCB congeners found in air;
2) Adolescents;
3) Processes that affect and are affected by the metabolism of PCBs; and
4) Prioritization of most important contributors to human health risk.

https://iowasuperfund.uiowa.edu/

THE IOWA SUPERFUND RESEARCH PROGRAM (ISRP) BY THE NUMBERS

- Established in 2006 to examine the sources, exposures and toxicity of polychlorinated biphenyls (PCBs)
- Published over 500 peer-reviewed studies
- Trained over 130 doctoral students and post-doctoral fellows
- Currently supports ~40 researchers from 4 Colleges, 10 departments, and 5 laboratories

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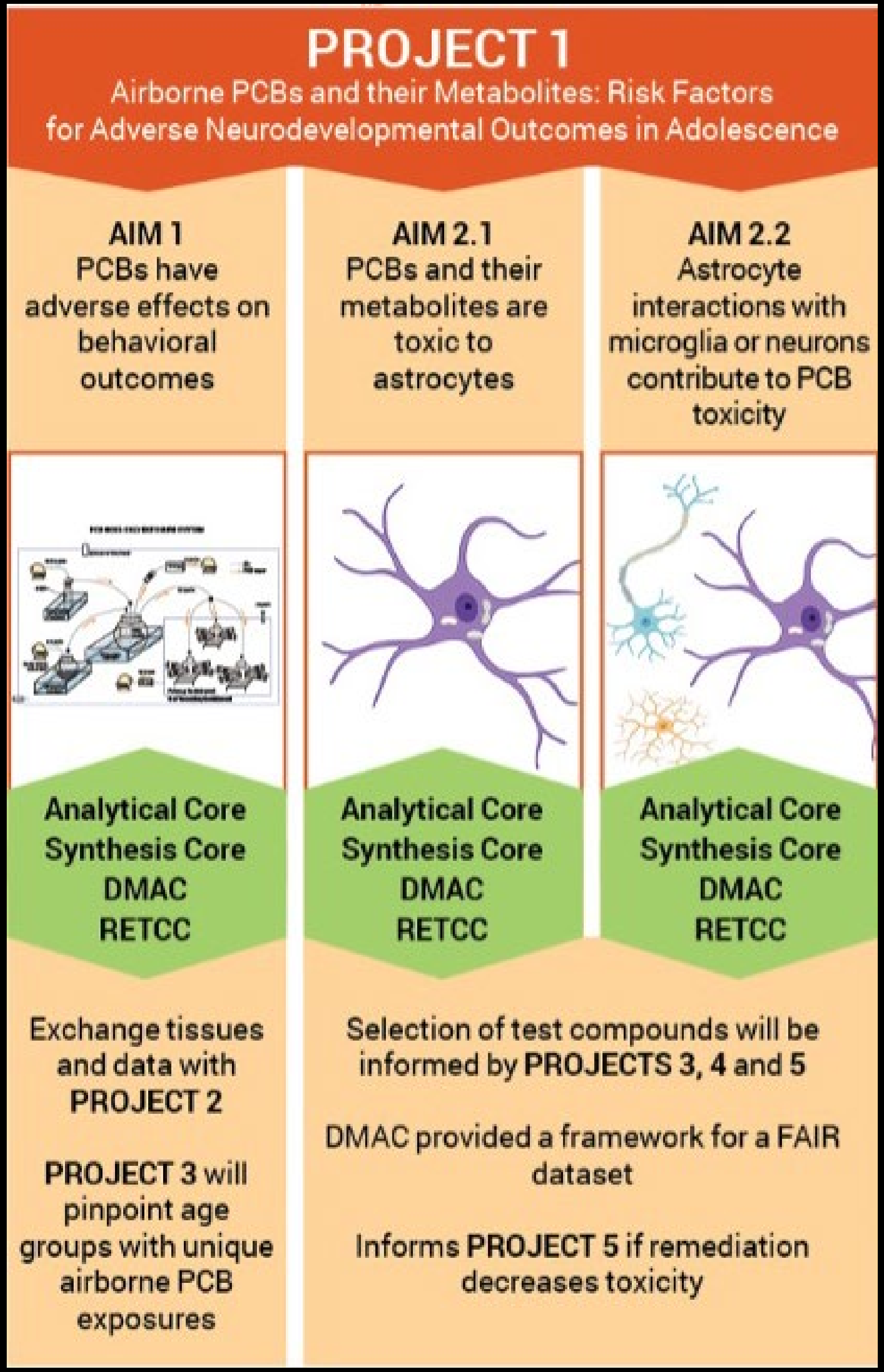
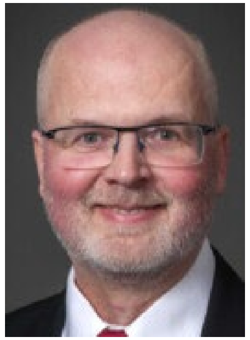
Project 1: Airborne PCBs and their metabolites: Risk Factors for Adverse Neurodevelopmental Outcomes in Adolescence

Lead: Dr. Hans Lehmler



Breakdown of PCBs create more toxic compounds



K.C. Donnelly Externship Award

toxics

MDPI

Article

Morphological, Behavioral, and Transcriptomic Profiling Reveals Developmental Toxicity of PCB Metabolites in Zebrafish

Nicole M. Breese [1,2], Lisa Truong [3], Xueshu Li [1], Robyn L. Tanguay [3] and Hans-Joachim Lehmler [1,2,*]

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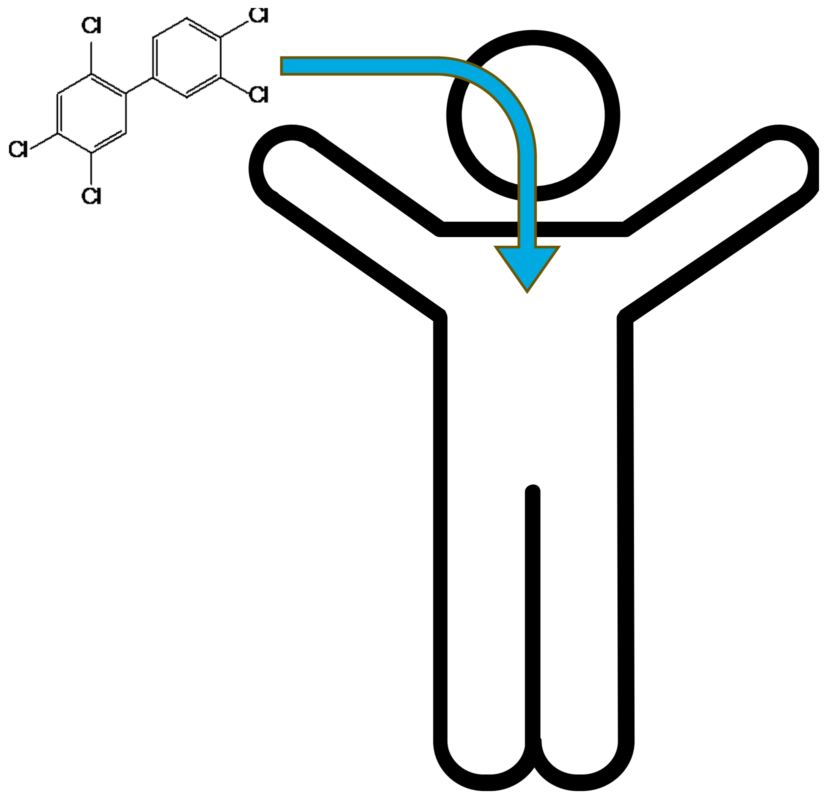
2 Interdisciplinary Graduate Program in Human Toxicology, The University of Iowa, Iowa City, IA 52242, USA
3 Sinnhuber Aquatic Research Laboratory, Department of Environmental and Molecular Toxicology, Oregon State University, Corvallis, OR 97331, USA; lisa.truong@oregonstate.edu (L.T.); robyn.tanguay@oregonstate.edu (R.L.T.)
* Correspondence: hans-joachim-lehmler@uiowa.edu; Tel.: +1-(319)-335-4310

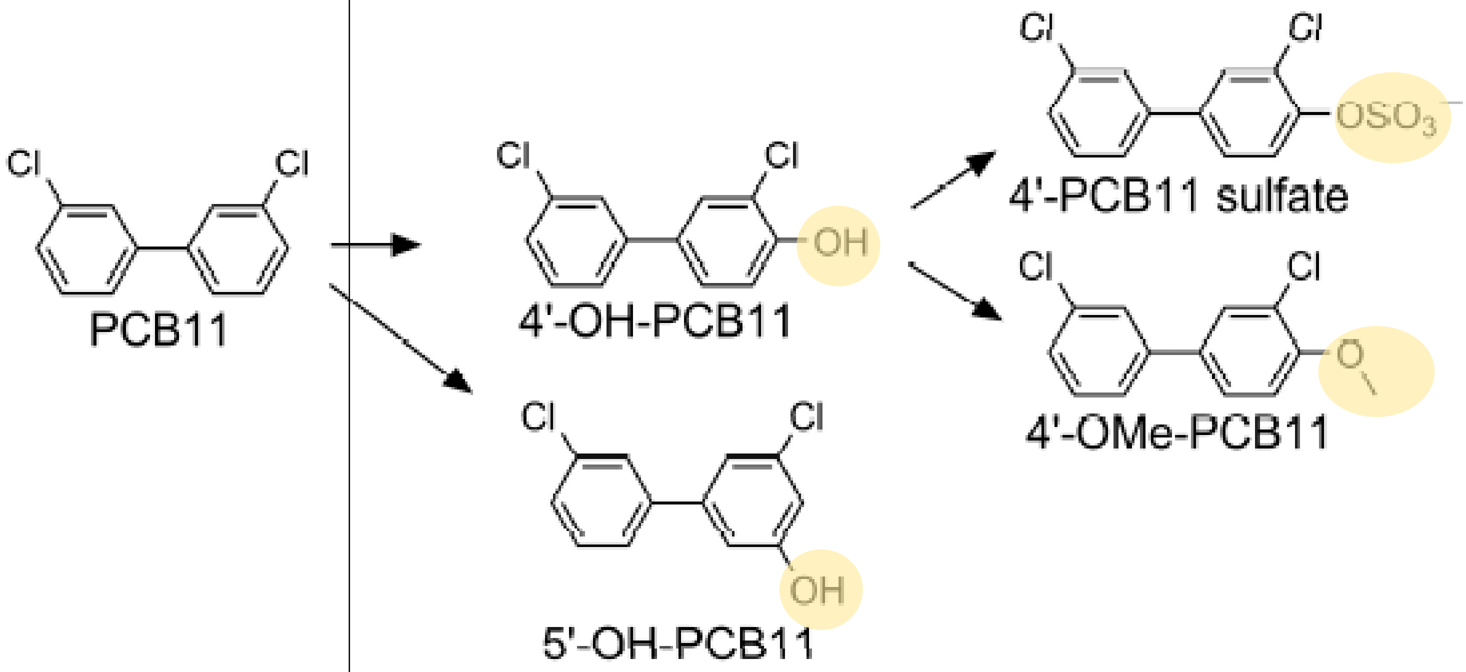
Abstract

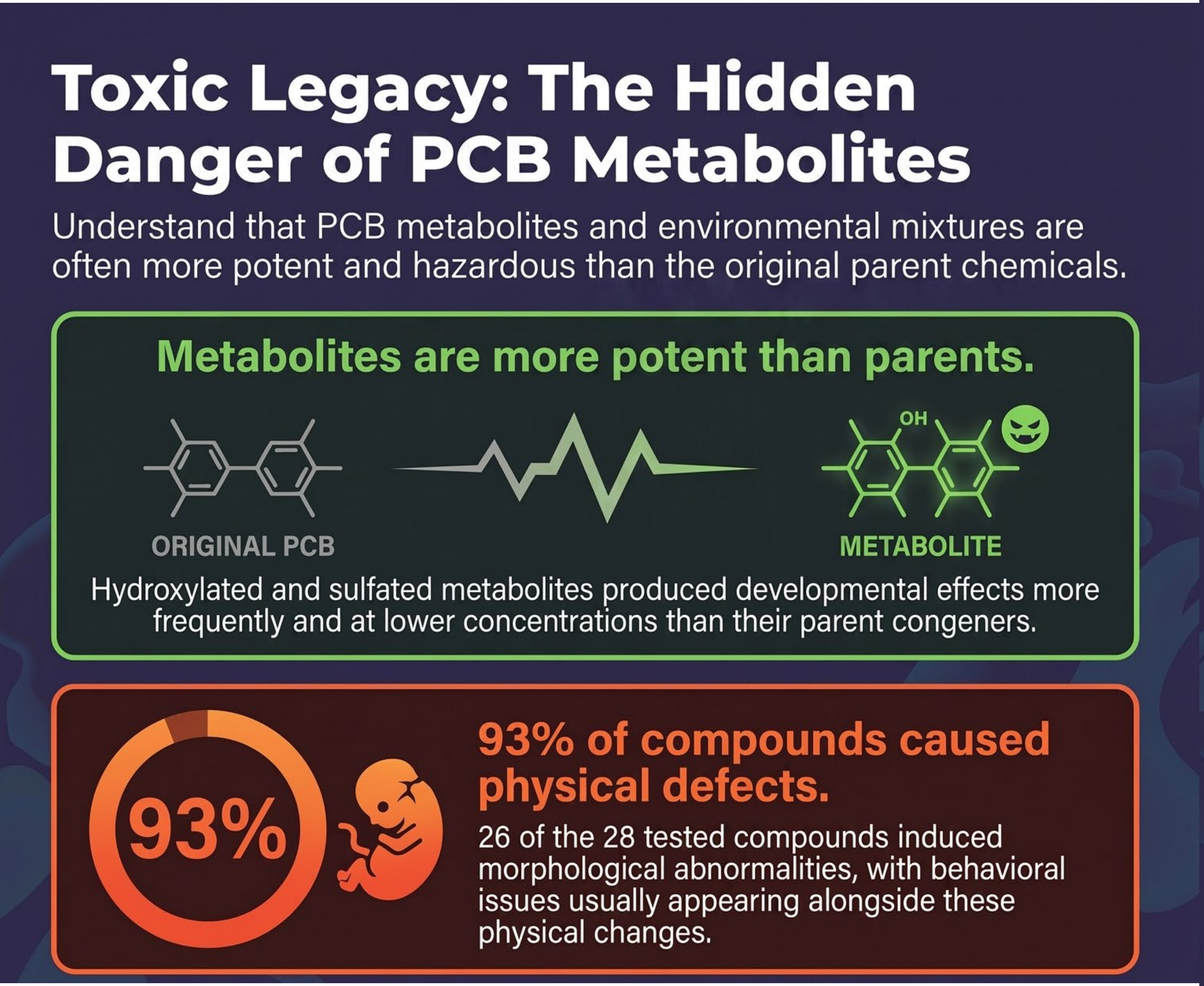
Polychlorinated biphenyls (PCBs) persist in the environment as complex mixtures and undergo extensive biotransformation, yet the developmental toxicity of PCB metabolites remains poorly defined. We evaluated developmental, neurobehavioral, and molecular effects of parent PCBs, hydroxylated, methoxylated, and sulfated metabolites, and environmentally relevant mixtures using embryonic zebrafish. This study employed a high-throughput screening approach using nominal exposure concentrations to enable

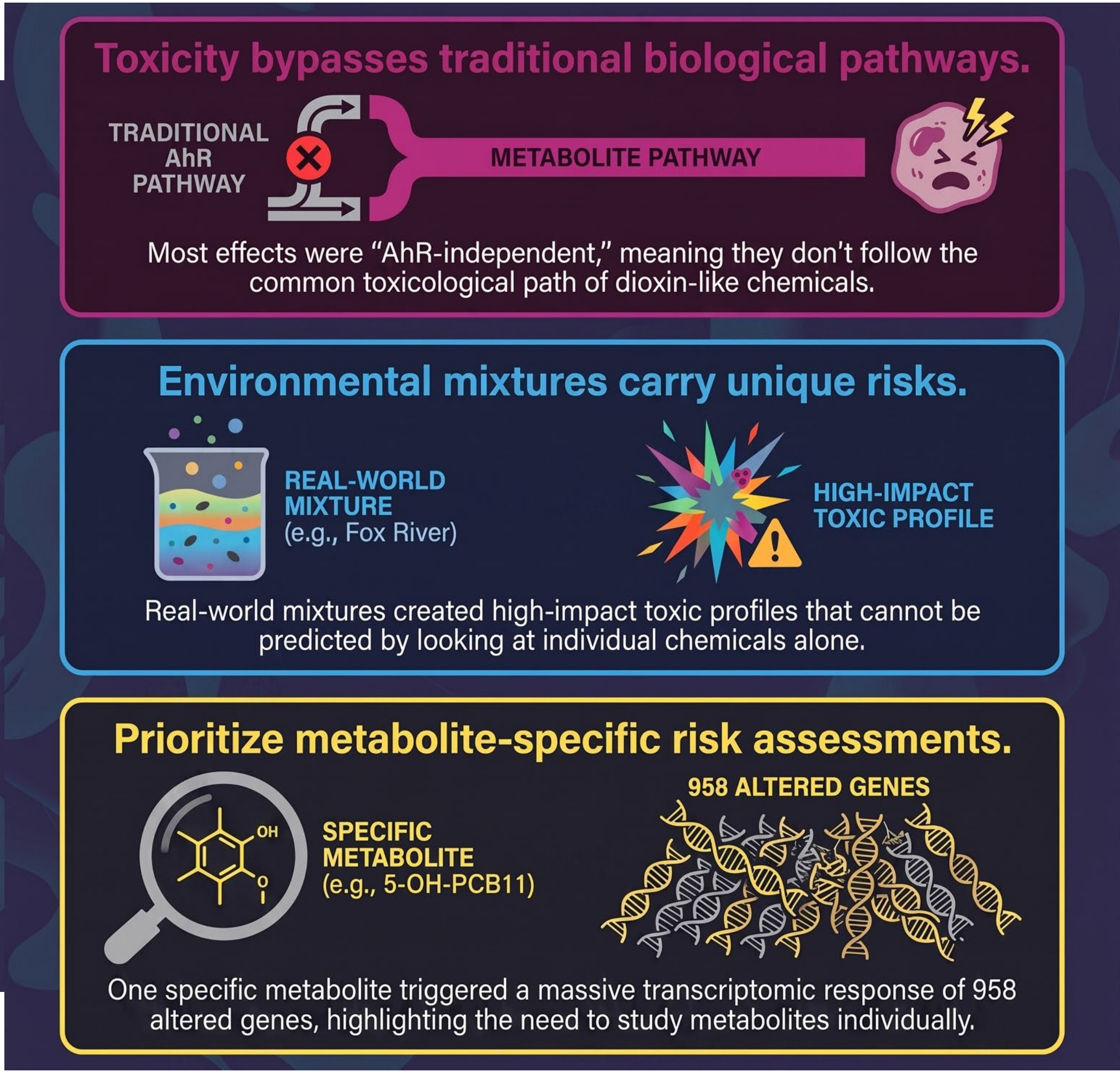
PCBs accumulate in the body and some get metabolized into PCB-metabolites



PCB Metabolites




Toxic Legacy: The Hidden Danger of PCB Metabolites
Understand that PCB metabolites and environmental mixtures are often more potent and hazardous than the original parent chemicals.
Metabolites are more potent than parents.
ORIGINAL PCB
OH
METABOLITE
Hydroxylated and sulfated metabolites produced developmental effects more frequently and at lower concentrations than their parent congeners.
93%
93% of compounds caused physical defects.
26 of the 28 tested compounds induced morphological abnormalities, with behavioral issues usually appearing alongside these physical changes.


Toxicity bypasses traditional biological pathways.
TRADITIONAL AhR PATHWAY
METABOLITE PATHWAY
Most effects were "AhR-independent," meaning they don't follow the common toxicological path of dioxin-like chemicals.
Environmental mixtures carry unique risks.
REAL-WORLD MIXTURE
(e.g., Fox River)
HIGH-IMPACT TOXIC PROFILE
Real-world mixtures created high-impact toxic profiles that cannot be predicted by looking at individual chemicals alone.
Prioritize metabolite-specific risk assessments.
OH
SPECIFIC METABOLITE
(e.g., 5-OH-PCB11)
958 ALTERED GENES
One specific metabolite triggered a massive transcriptomic response of 958 altered genes, highlighting the need to study metabolites individually.

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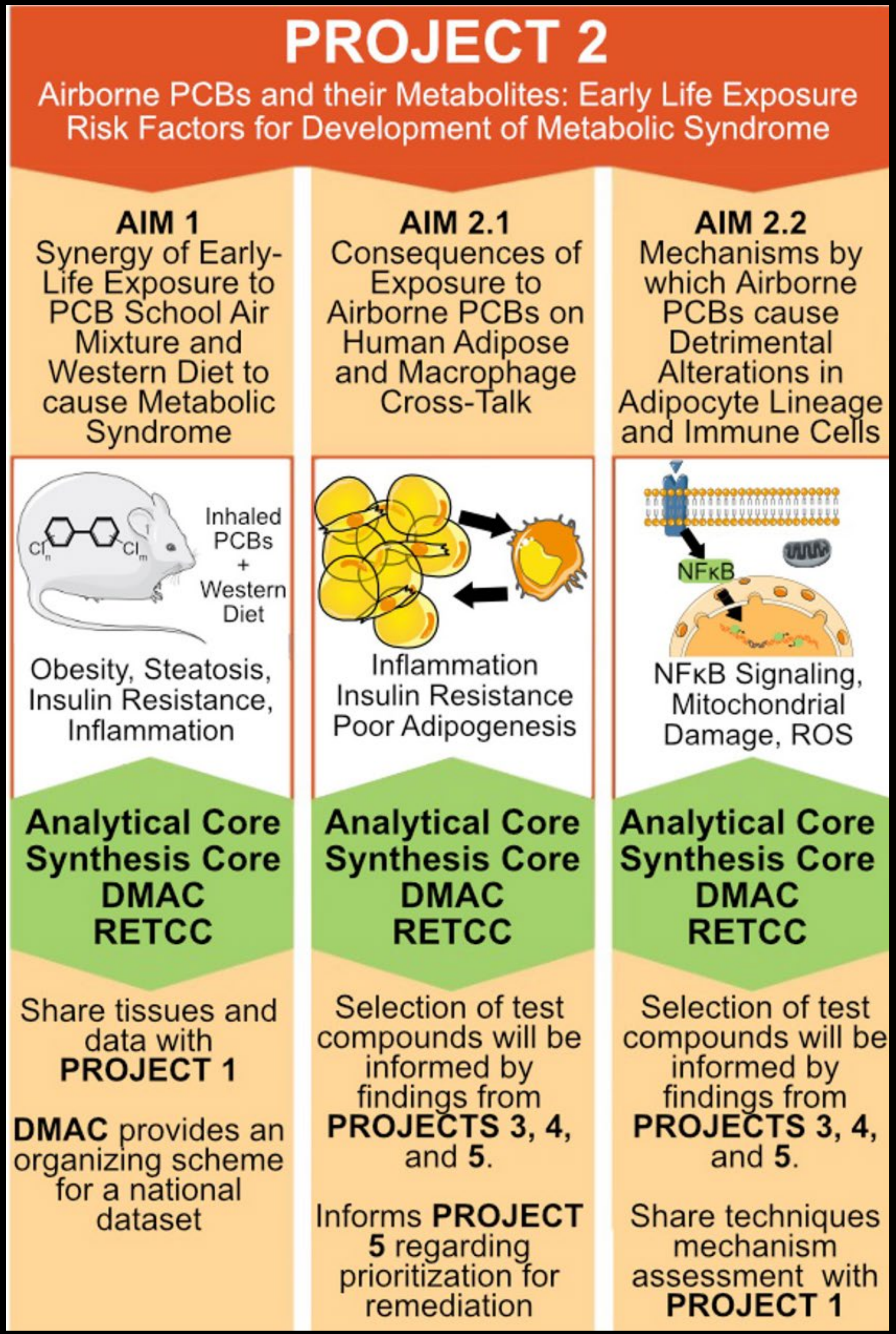
Project 2: Airborne PCBs and their metabolites: Early Life Exposure Risk Factors for Development of Metabolic Syndrome

Lead: Dr. Al Klingelhutz, Dr. James Ankrum



PCB Mixtures

Dec 2024 SRP Trainee
of the Month
NIEHS F30 Fellow

Journal of the Endocrine Society, 2026, **10**, bvaf205
https://doi.org/10.1210/jendso/bvaf205
Advance access publication 16 December 2025
Research Article

ENDOCRINE SOCIETY

OXFORD

Aroclor 1254 inhibits anti-inflammatory macrophage polarization through an AhR-dependent mechanism

Riley M. Behan-Bush,[1,2] Elizabeth Kilburg,[1] Jesse N. Liszewski,[1,2] Michael V. Schrodt,[1,2] Edward A. Sander,[1] Aloysius J. Klingelhutz,[2,3] and James A. Ankrum[1,2]

[1]Roy J. Carver Department of Biomedical Engineering, University of Iowa, Iowa City, IA 52242, USA
[2]Fraternal Order of Eagles Diabetes Research Center, University of Iowa, Iowa City, IA 52242, USA
[3]Department of Microbiology and Immunology, University of Iowa, Iowa City, IA 52242, USA

Correspondence: James A. Ankrum, PhD, University of Iowa, 3336 PBDB, 169 Newton Road, Iowa City, IA 52242, USA. Email: james-ankrum@uiowa.edu.

Abstract

Macrophages are critical regulators of tissue homeostasis and inflammation. During the development of chronic inflammatory diseases, tissue-resident macrophages often shift from an anti-inflammatory (M2) to a pro-inflammatory (M1) phenotype. Understanding the factors that drive this polarization shift is essential for elucidating the mechanisms underlying diseases such as cancer, cardiovascular disease, and metabolic syndrome. Environmental toxicants, including polychlorinated biphenyls (PCBs), may be key contributors to this dysregulation. Despite being banned in the United States for nearly 50 years, PCBs persist in the built and natural environment, with mixtures such as Aroclor 1254 still detected at concerning levels in schools and other public spaces. In this study, we investigated how Aroclor 1254 influences human monocyte-derived macrophage polarization. We found that exposure to Aroclor 1254 during differentiation skews naïve macrophages toward a pro-inflammatory phenotype, enhances LPS/IFNγ driven M1 polarization, and inhibits both IL-4 and dexamethasone induced M2

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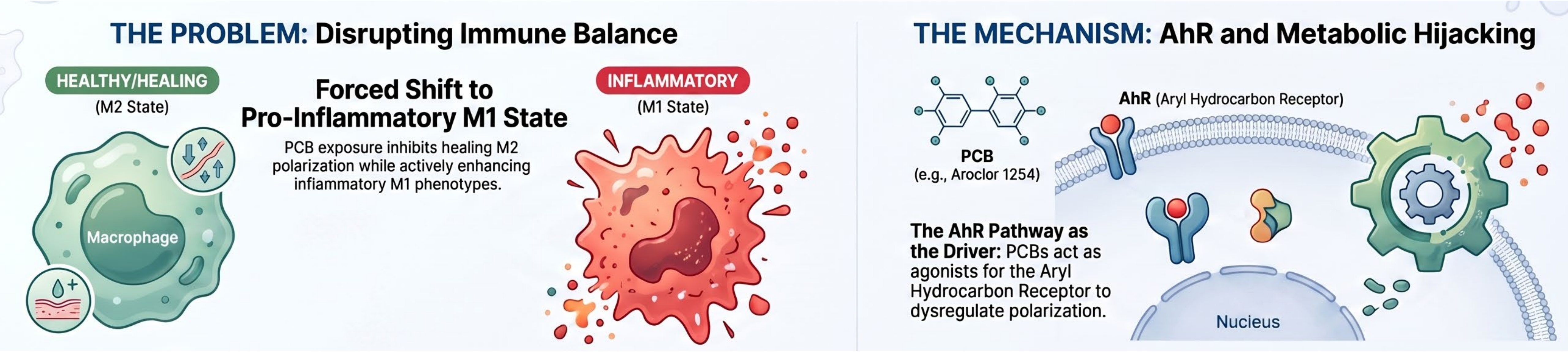
PCBs contribute to chronic inflammation which exacerbates numerous diseases



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Project 3: Emissions and Remediation of Airborne PCBs in Schools

Lead: Dr. Keri Hornbuckle

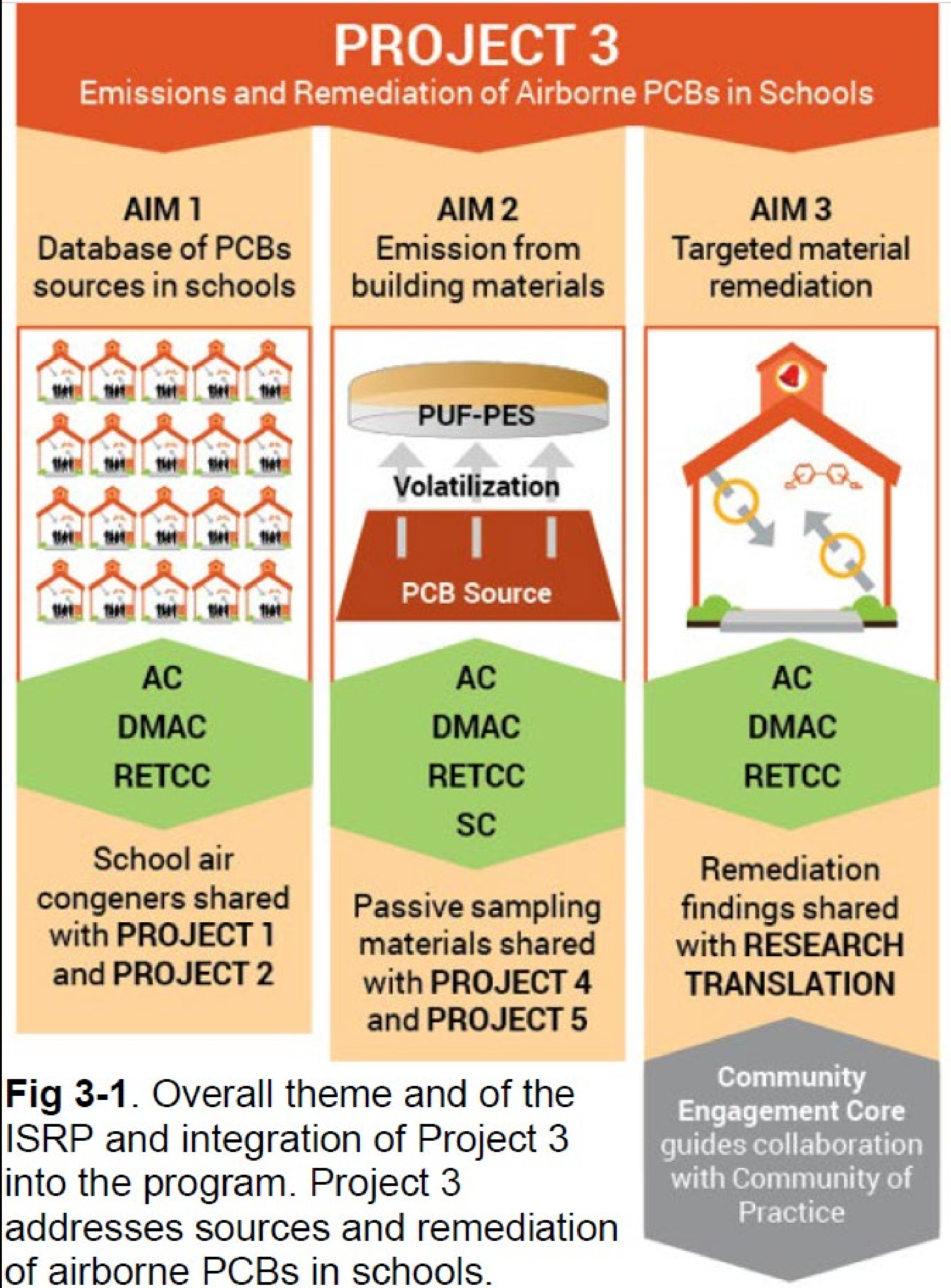

Fig 3-1. Overall theme and of the ISRP and integration of Project 3 into the program. Project 3 addresses sources and remediation of airborne PCBs in schools.

Jason Hua won the C. Ellen Gonter best research paper award through the American Chemical Society

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HEALTH

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Environmental Science & Technology

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Article

Widespread Emissions of Polychlorinated Biphenyls from Building Materials in Vermont Schools

Jason B. X. Hua, Rachel F. Marek, Michael P. Jones, Trevor D. Erb, Sarah C. Owen, and Keri C. Hornbuckle*

Cite This: *Environ. Sci. Technol.* 2026, 60, 4966–4977

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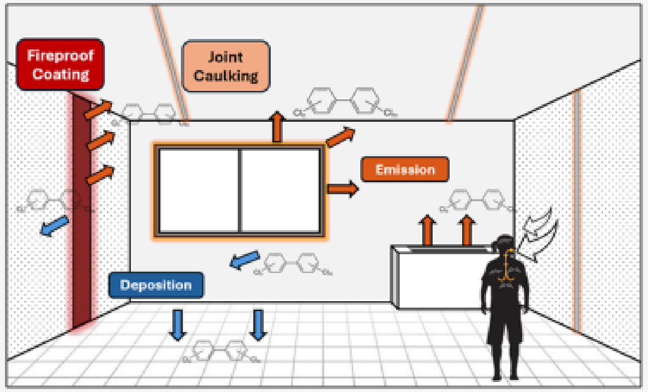
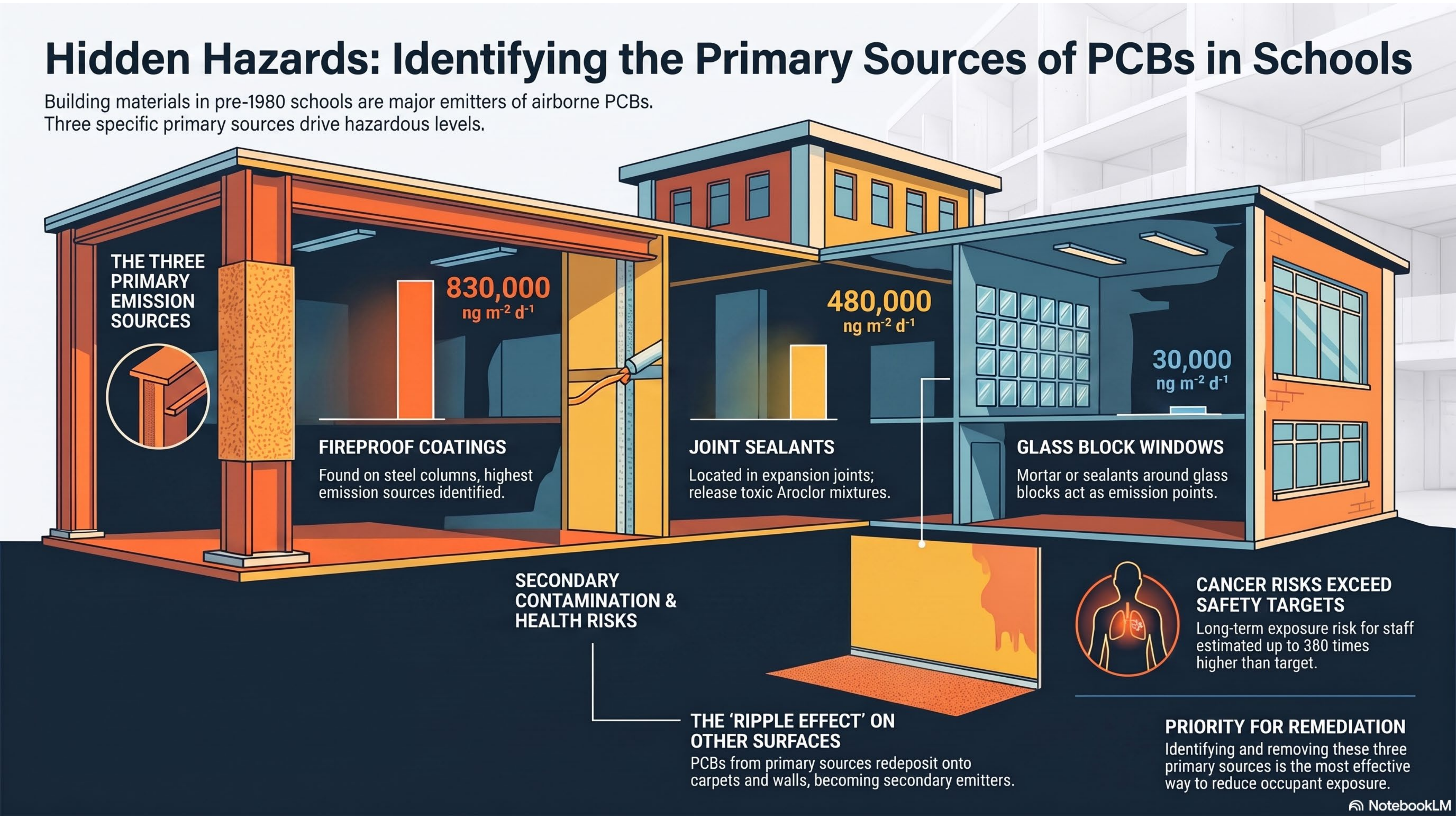
ABSTRACT: In collaboration with Vermont state and school officials, we conducted a research study to measure emissions of polychlorinated biphenyls (PCBs) from room surfaces in Vermont schools. Our study, the largest of its kind, investigated the sources of airborne PCBs in indoor school environments. Using simultaneous deployment of air samplers and emission samplers, we measured airborne PCBs in 16 schools and 98 school rooms constructed prior to 1980. There was a wide range in PCB air concentrations (1.7–5700 ng m^{-3}, n = 159) and surface emissions (33–830,000 ng m^{-2} d^{-1}, n = 182) across different schools as well as between rooms in the same school. We found that emissions of PCB congeners from walls, floors, ceiling and wall expansion joint caulking, and spray insulation explain the airborne PCB congener concentrations in many rooms. Our emission samplers identified three distinct types of building materials with emissions exceeding 30,000 ng m^{-2} d^{-1} including expansion joint sealant (up to 480,000 ng m^{-2} d^{-1}), glass block windows (up to 30,000 ng m^{-2} d^{-1}), and fireproof coating on steel columns (up to 830,000 ng m^{-2} d^{-1}). Consequently, school staff have an estimated excess lifetime cancer risk from both dioxin-like and nondioxin-like PCBs that ranges from 1.3×10^{-8} to 1.7×10^{-4} for central tendency exposure, and 2.8×10^{-8} to 3.8×10^{-4} for reasonable maximum exposure (State of Vermont's target cancer risk = 1×10^{-6}). Although production has been banned for decades, our study illustrates that PCBs continue to pose an exposure risk to occupants due to their long history of use in building materials. Our findings underscore the risks associated with the historic presence of PCB-containing building materials, offering critical insights for community efforts aimed at reducing exposure among children and school staff in thousands of schools across the country.



KEYWORDS: *PUF–PES, semivolatile organic compounds, persistent organic pollutants, PCBs, Aroclors, legacy compounds,*


Hidden Hazards: Identifying the Primary Sources of PCBs in Schools
Building materials in pre-1980 schools are major emitters of airborne PCBs.
Three specific primary sources drive hazardous levels.
THE THREE PRIMARY EMISSION SOURCES
830,000
ng m^{-2} d^{-1}
480,000
ng m^{-2} d^{-1}
30,000
ng m^{-2} d^{-1}
FIREPROOF COATINGS
Found on steel columns, highest emission sources identified.
JOINT SEALANTS
Located in expansion joints; release toxic Aroclor mixtures.
GLASS BLOCK WINDOWS
Mortar or sealants around glass blocks act as emission points.
SECONDARY CONTAMINATION & HEALTH RISKS
THE 'RIPPLE EFFECT' ON OTHER SURFACES
PCBs from primary sources redeposit onto carpets and walls, becoming secondary emitters.
CANCER RISKS EXCEED SAFETY TARGETS
Long-term exposure risk for staff estimated up to 380 times higher than target.
PRIORITY FOR REMEDIATION
Identifying and removing these three primary sources is the most effective way to reduce occupant exposure.
NotebookLM

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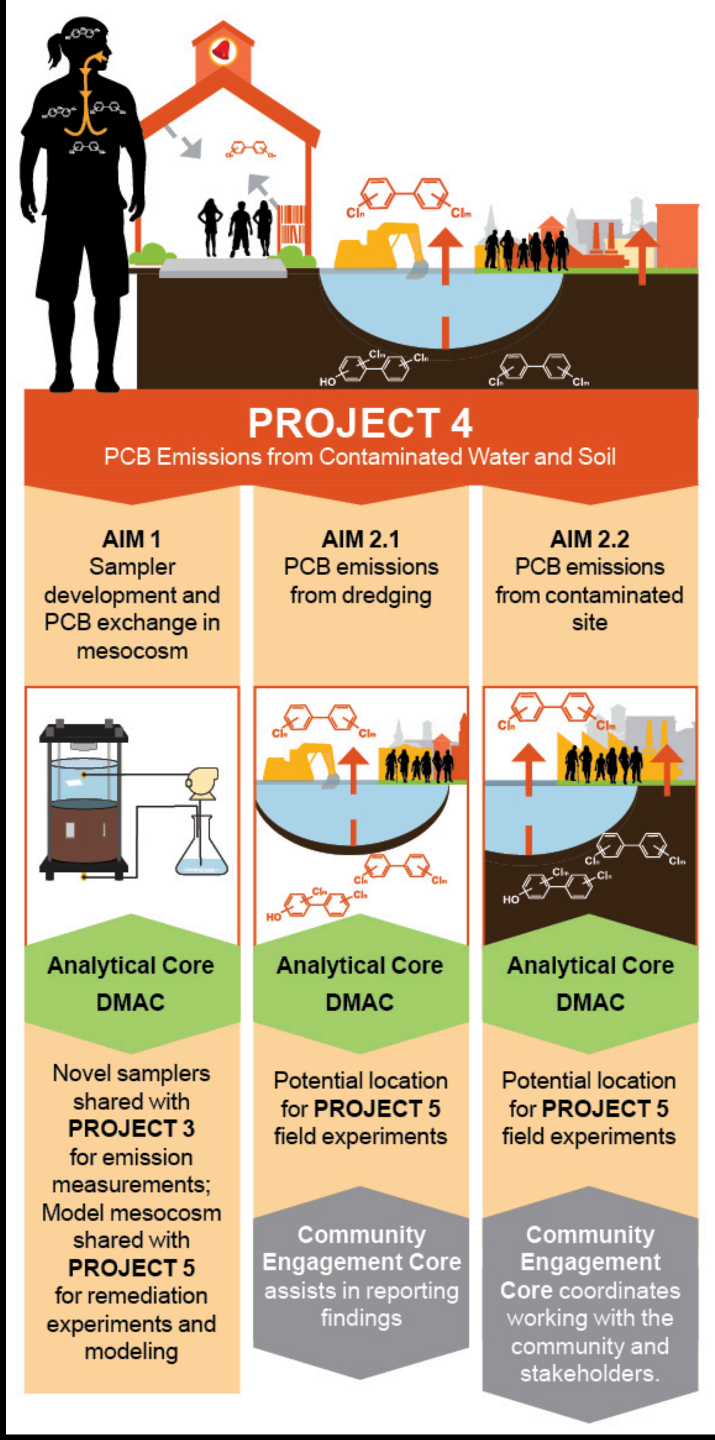
Project 4: PCB Emissions from Contaminated Water and Soil

Lead: Dr. Andres Martinez



Alexis Slade, awarded the President's Student Leadership Award for community engaged research

Dr. Andres Martinez

ACS ES&T Air

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Article

Airborne PCB Concentrations in Portland, Oregon: Emissions and Contributions from the Portland Harbor Superfund Site

Alexis R. Slade, Andres Martinez,* Martine E. Mathieu-Campbell, Cassie Cohen, Shannon Lea Watkins, and Keri C. Hornbuckle*

Cite This: *ACS EST Air* 2025, 2, 2922−2931

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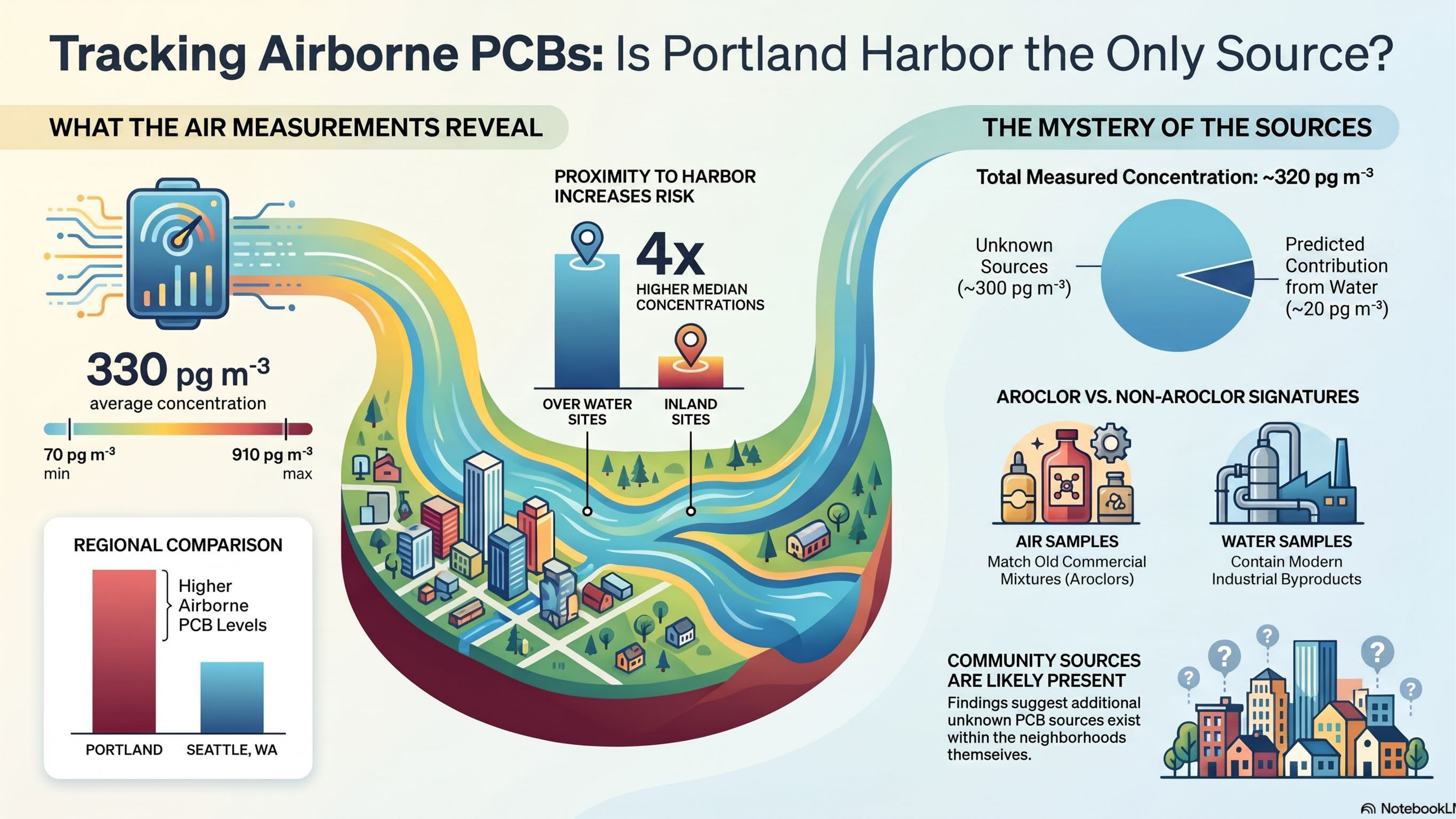
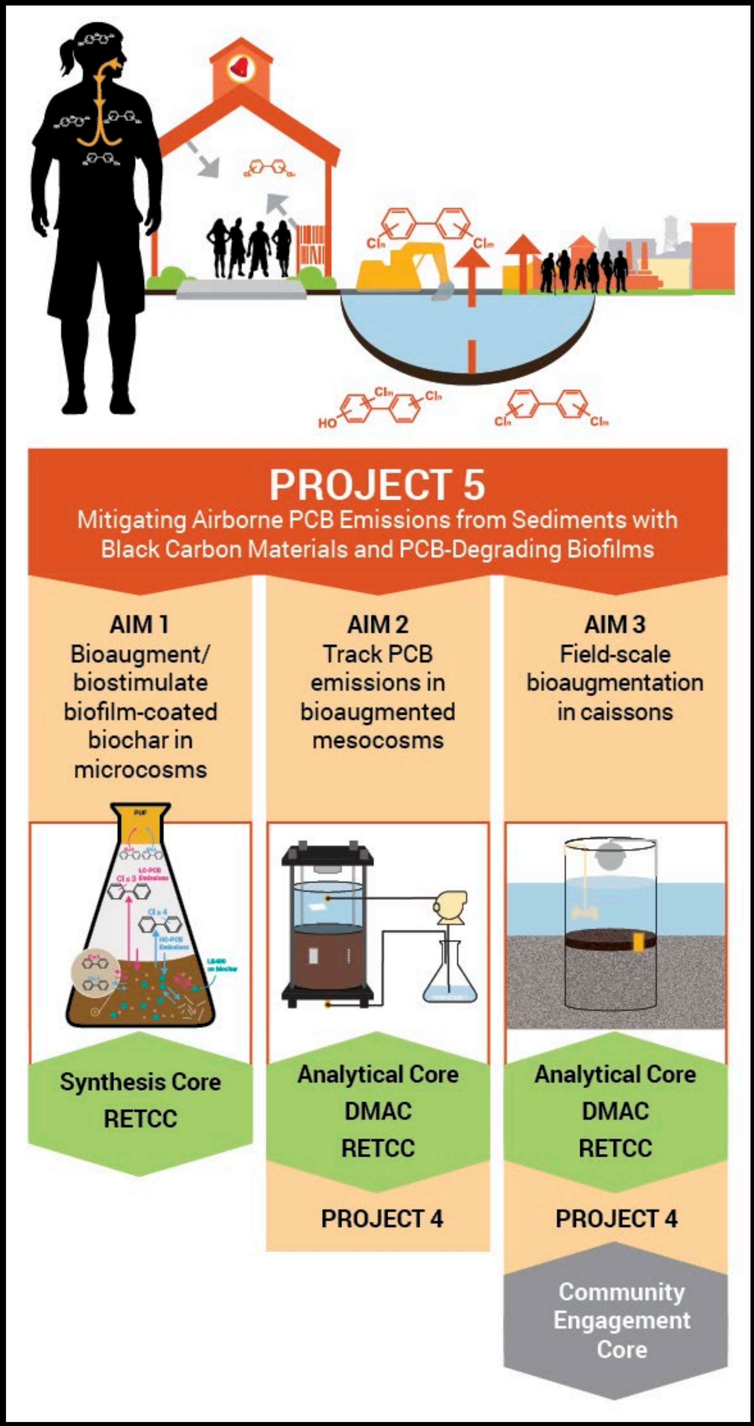
ABSTRACT: We investigated airborne concentrations of polychlorinated biphenyls (PCBs) near the Portland Harbor Superfund Site (PHSS), a historical and culturally significant location. In collaboration with residents, we measured airborne PCBs using polyurethane foam passive air samplers (PUF−PAS) deployed for 6 weeks. Additionally, we estimated PCB emissions based on the flux calculations from Portland Harbor (PH) water using PCB concentrations reported by the U.S. EPA to predict airborne PCB concentrations with an atmospheric dispersion model (AERMOD). Measured airborne total PCB concentrations ranged from 70 to 910 pg m^{-3} with a geometric mean of 330 pg m^{-3}, which is lower than concentrations observed in other known PCB-contaminated areas in the U.S. Air congener distributions resembled commercial Aroclor mixtures 1016 and 1242, and estimated PCB flux from the water averaged 450 ± 120 ng m^{-2} d^{-1}. Predicted airborne PCB concentrations ranged from 1 to 124 pg m^{-3}, with enrichment in non-Aroclor congeners when PH water is the sole source. However, all predicted concentrations were lower than measured values and exhibited different congener distributions, suggesting that PCB flux from PH water contributes only a minor portion (~2%) of Portland's airborne PCB burden, and that additional PCB sources exist within the community.


Tracking Airborne PCBs: Is Portland Harbor the Only Source?
WHAT THE AIR MEASUREMENTS REVEAL
330 pg m^{-3}
average concentration
70 pg m^{-3}
min
910 pg m^{-3}
max
REGIONAL COMPARISON
Higher Airborne PCB Levels
PORTLAND
SEATTLE, WA
PROXIMITY TO HARBOR INCREASES RISK
4x
HIGHER MEDIAN CONCENTRATIONS
OVER WATER SITES
INLAND SITES
THE MYSTERY OF THE SOURCES
Total Measured Concentration: ~320 pg m^{-3}
Unknown Sources (~300 pg m^{-3})
Predicted Contribution from Water (~20 pg m^{-3})
AROCLOR VS. NON-AROCLOR SIGNATURES
AIR SAMPLES
Match Old Commercial Mixtures (Aroclors)
WATER SAMPLES
Contain Modern Industrial Byproducts
COMMUNITY SOURCES ARE LIKELY PRESENT
Findings suggest additional unknown PCB sources exist within the neighborhoods themseives.
NotebookLM

IOWA

Project 5: Mitigating Airboren PCB Emissions from Sediments with Black Carbon Materials and PCB-Degrading Biofilms

Lead: Dr. Timoth Mattes



David Ramotowski, 3MT Winner

Prof. Tim Mattes

ACS ES&T Water

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Article

Paraburkholderia Xenovorans Strain LB400 Significantly Decreased Volatilization of Polychlorinated Biphenyls (PCBs) from Freshwater and Saline Sediments

David J. Ramotowski, Andres Martinez, Rachel F. Marek, Keri C. Hornbuckle, and Timothy E. Mattes*

Cite This: *ACS EST Water* 2025, 5, 5841−5851

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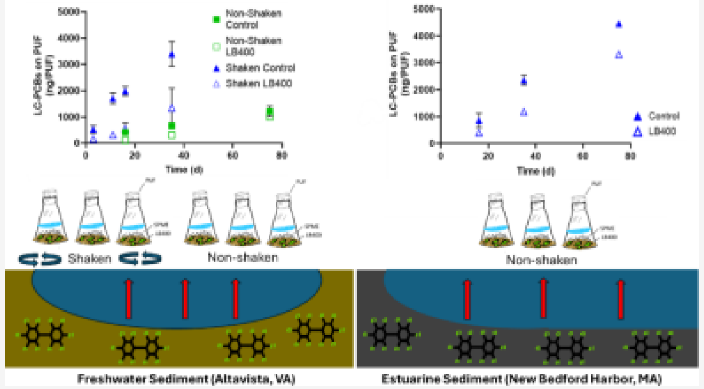
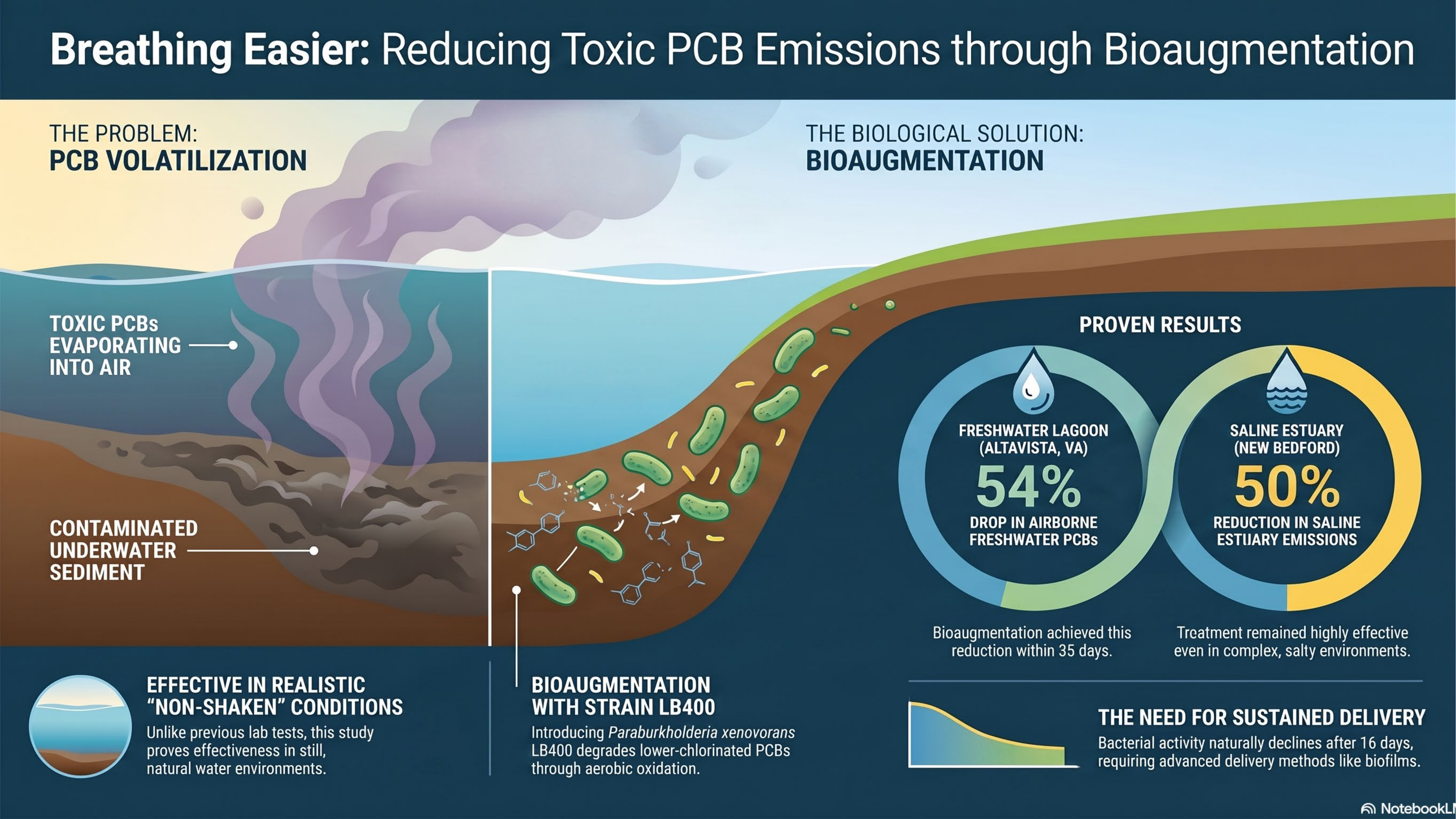
ABSTRACT: Airborne PCB emissions from contaminated sediments pose a public health risk and are frequently cited as a concern for communities located near PCB-contaminated bodies of water. We assessed the potential to decrease the emissions of lower-chlorinated (LC)-PCBs (<3 chlorines) through bioaugmentation with aerobic PCB-degrading *Paraburkholderia xenovorans* strain LB400 in laboratory microcosms using historically PCB-contaminated sediments from a wastewater lagoon (Altavista, VA; AVL) and an estuary (New Bedford Harbor, MA; NBH). We compared the impact of nonshaken vs shaken conditions on airborne PCBs in LB400-bioaugmented AVL sediment (51% LC-PCBs) to better replicate field conditions. After 35 days, airborne LC-PCBs decreased by 54% in nonshaken bioaugmented AVL sediments, compared to a 60% decrease in shaken bioaugmented sediments. Bioaugmenting LB400 into unshaken NBH sediments (44% LC-PCBs) significantly decreased airborne LC-PCBs by 50% over 35 days. Biphenyl dioxygenase gene (*bphA*) abundance decreased by several orders of magnitude after 16 days in all experiments, demonstrating a potential decrease in treatment effectiveness over time. These novel findings demonstrate that LB400 effectively degrades LC-PCBs with varying profiles over a range of environmentally relevant mixing scenarios. Further treatment delivery development has the potential to protect nearby communities from PCB exposure, decrease health risks, and improve quality of life.



KEYWORDS: *bioremediation, polychlorinated biphenyls, passive sampling, microcosms, sediment, Paraburkholderia xenovorans LB400,*


Breathing Easier: Reducing Toxic PCB Emissions through Bioaugmentation
THE PROBLEM:
PCB VOLATILIZATION
TOXIC PCBs EVAPORATING INTO AIR
CONTAMINATED UNDERWATER SEDIMENT
THE BIOLOGICAL SOLUTION:
BIOAUGMENTATION
PROVEN RESULTS
FRESHWATER LAGOON (ALTAVISTA, VA)
54%
DROP IN AIRBORNE FRESHWATER PCBs
SALINE ESTUARY (NEW BEDFORD)
50%
REDUCTION IN SALINE ESTUARY EMISSIONS
Bioaugmentation achieved this reduction within 35 days.
Treatment remained highly effective even in complex, salty environments.
EFFECTIVE IN REALISTIC “NON-SHAKEN” CONDITIONS
Unlike previous lab tests, this study proves effectiveness in still, natural water environments.
BIOAUGMENTATION WITH STRAIN LB400
Introducing *Paraburkholderia xenovorans* LB400 degrades lower-chlorinated PCBs through aerobic oxidation.
THE NEED FOR SUSTAINED DELIVERY
Bacterial activity naturally declines after 16 days, requiring advanced delivery methods like biofilms.
NotebookLM

COLLABORATORS AND SUPPORTERS

Vermont Department of Environmental Conservation (Patricia Coppolino, Eben Pendleton, Kristi Herzer, Richard Spiese, Kassandra Blanco, Shawn Donovan, Michael Nahmais)

Vermont Health (Sarah Owen, Danielle Thorkildsen, Andrea Kirk)

CDC: Centers for Disease Control and Prevention

Portland Harbor Community Coalition (Cassie Cohen)

Neighbors for Clean Air (Mary Peveto)

University of Iowa College of Engineering, College of Public Health, Graduate College, Vice President for Research

ISRP
IOWA SUPERFUND
RESEARCH PROGRAM

NIH National Institute of Environmental Health Sciences
Superfund Research Program

Grant Number P42ES013661