UC BERKELEY SUPERFUND RESEARCH PROGRAM
SCIENCE FOR A SAFER WORLD

Overview of the UC Berkeley Superfund Research Center: 2022-27

Martyn Smith, Director

Rachel Morello-Frosch, Projects 1 and 2, CEC

David Sedlak, Projects 3 and 4

SRP Progress in Research, Session III

May 12, 2023

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Goals of the UC Berkeley Center: Address 6 complex and intractable problems associated with hazardous sites and enhance access to safe drinking water

1. **Improve assessment of risks to pregnant women, the fetus and young children and protect against long-term impact** - *Quantify the effects of exposures*
2. **Protect disadvantaged communities from harmful exposures** - *Engage them in research and report-back (awareness and avoidance)*
3. **Understand the totality of chemicals to which communities are exposed** - *Use targeted & untargeted approaches to measure many chemicals*
4. **Account for interactions between mixtures of chemicals typically found at SRP sites** - *Use to improve both remediation and health impact assessment*
5. **Develop in situ remediation** - *Avoid depleting groundwater or costly transport of contaminated soil*
6. **Remediate highly-persistent halogenated chemicals resistant to typical approaches** - *Use new radical-based destruction methods*

SRP Mandates

- Risk
- Health Effect
- Detection
- Risk
- Remediation
- Remediation

CALIFORNIA WATER BOARDS
State Water Resources Control Board

HUMAN RIGHT TO water PORTAL
safe & clean. affordable. accessible.

NIH National Institute of Environmental Health Sciences
Superfund Research Program

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Projects – Biomedical

1. **Characterization of drinking water contaminants and perinatal health effects in disadvantaged communities**
   - ***GOALS:*** *Measure arsenic, nitrate, pesticides, hexavalent chromium, & PFAS in drinking water in domestic wells and community water system users in Tulare Lake Basin & Salinas Valley; Assess birth outcomes associated with arsenic and nitrate; Apply community-based participatory research and targeted and untargeted exposure analyses*

Rachel Morello-Frosch
UCB

Lara Cushing
UCLA

2. **Influence of exposure to a mixture of PFAS and metals on the developing immune system**
   - ***GOALS:*** *Examine effects of early-life exposures on immune function at birth (cytokine levels and lymphocyte proliferation) and age 7 (vaccine response – TDAP and MMR antibody titers) in mother-child pairs in Project Viva, a prospective birth cohort in MA; Examine the role of DNA methylation in vaccine response*

Joseph Lewnard
UCB

Andres Cardenas
Stanford

Emily Oken
Harvard

Projects – Engineering

3. In situ destruction of halogenated Superfund contaminants with biological radical reactions

- ***GOALS:*** *Use molecular biology, protein engineering, and high-throughput assays to identify aerobic and anaerobic microbial enzymatic-radical systems that can treat multiple classes of pollutants (PFAS and other highly halogenated compounds, PCBs, PBDEs, and chlorinated solvents)*

Lisa Alvarez-Cohen
UCB

4. In situ destruction of halogenated Superfund contaminants with persulfate-generated radicals

- ***GOALS:*** *Exploit novel radical species capable of dehalogenating recalcitrant contaminants (highly halogenated and hydrophobic contaminants resistant to oxidation - hexachlorobenzene, hexabromobenzene, PCBs, PBDEs, PFAS, and chlorinated solvents); Determine conditions that minimize the formation of toxic transformation products; Develop kinetic models that can be used by field engineers; Characterize transformation products*

David Sedlak
UCB

Martyn Smith
UCB

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Cores

Administration / Research Translation (RT) *– support assessment & action (e.g., develop/apply 'Key Characteristics' of various toxicant types with OEHHA/others); share findings broadly*


Martyn Smith

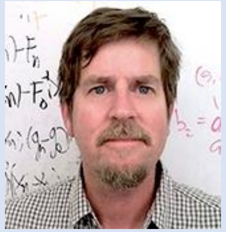

Lisa Alvarez-Cohen


Cliona McHale

Community Engagement Core: Advancing California's Human Right to Water through the Water Equity Science Shop (CEC-WESS) *– expand the Drinking Water Tool and develop digital tools*


Rachel Morello-Frosch

Data Management and Analysis (DMAC) *– support statistical and bioinformatic analysis and data sharing*


Alan Hubbard


Andres Cardenas (Stanford)

Research Experience & Training Coordination (RETCC) *– provide a forum for our trainees to holistically engage with the Center & stakeholders through inter-disciplinary research (IDR) and professional development, leadership & RT/CEC activities*


Cliona McHale

Project 1 and Community Engagement Core

Data- and community-driven research to advance clean drinking water access in CA

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COMMUNITY WATER CENTER
EL CENTRO COMUNITARIO POR EL AGUA

UCLA

OEHHA
SCIENCE FOR A HEALTHY CALIFORNIA

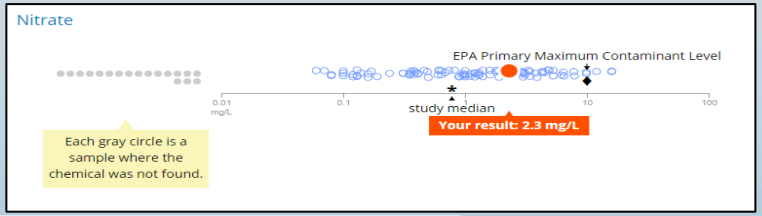
Water Equity Science Shop

Rushing Waters mural, Pacoima, CA | Lead artist: Levi Ponce | Photo: Justin Cram

Project 1: Community-engaged, discovery-driven methods to characterize drinking water contaminants in disadvantaged communities and their perinatal health effects

- Epidemiology: Assess perinatal effects of ubiquitous drinking water contaminant exposures among pregnant people in CA (2006-2020)

- Exposure Assessment: Characterize presence of regulated and novel unregulated chemicals in tap water using targeted and non-targeted methods.
    - Assess impacts of potential drinking water threats nearby (100 households)
- Results Communication: Facilitate public health action through individualized and aggregate report-back of results to participants in the tap water sampling study



Digital Report-back Interface (DERBI)

Fluoride in Drinking Water and Birth Outcomes

Water fluoridation as a public health achievement

Check for updates

Surgeon General's Perspectives

COMMUNITY WATER FLUORIDATION: ONE OF CDC'S "10 GREAT PUBLIC HEALTH ACHIEVEMENTS OF THE 20TH CENTURY"

Vivek H. Murthy, MD, MBA

Seventy years ago, nearly everyone in the United States had tooth decay. No one knew how to prevent it. It was not uncommon for 13-year-olds to have lost one or more permanent teeth to decay.[1] As recently as the late 1950s, about half of Americans older than 65 years of age lost all their natural teeth, which many replaced with dentures.[2]

In some areas of the United States, dentists observed that the enamel on many of their patients' teeth looked stained or mottled. However, these same teeth appeared to be protected from tooth decay. After some sleuthing, it was determined that fluoride in the local water supply was the reason for both phenomena. In 1945, as one of the first in a series of landmark studies, the city of Grand Rapids, Michigan, added

Vivek H. Murthy, MD, MBA
VADM, U.S. Public Health Service
Surgeon General

Studies suggest possible association between early-life fluoride consumption and neurodevelopment

Developmental Fluoride Neurotoxicity: A Systematic Review and Meta-Analysis

Anna L. Choi,[1] Guifan Sun,[2] Ying Zhang,[3] and Philippe Grandjean[1,4]

[1]Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA; [2]School of Public Health, China Medical University, Shenyang, China; [3]School of Stomatology, China Medical University, Shenyang, China; [4]Institute of Public Health, University of Southern Denmark, Odense, Denmark

Sex-Specific Neurotoxic Effects of Early-Life Exposure to Fluoride: a Review of the Epidemiologic and Animal Literature

Rivka Green[1] · Joshua Rubenstein[1] · Reynaldo Popoli[1] · Ronamae Capulong[1] · Christine Till[1]

National Toxicology Program
U.S. Department of Health and Human Services

DRAFT NTP MONOGRAPH ON THE

SYSTEMATIC REVIEW OF FLUORIDE EXPOSURE AND NEURODEVELOPMENTAL AND COGNITIVE HEALTH EFFECTS

September 6, 2019

scientific reports

Check for updates

OPEN **A systematic review and meta-analysis of the association between fluoride exposure and neurological disorders**

Giza Hellen Nonato Miranda[1], Maria Olímpia Paz Alvarenga[1], Maria Karolina Martins Ferreira[1], Bruna Puty[1], Leonardo Oliveira Bittencourt[1], Nathalia Carolina Fernandes Fagundes[2], Juliano Pelim Pessan[3], Marília Afonso Rabelo Buzalaf[4] & Rafael Rodrigues Lima[1]

Evaluate the expected change in birthweight, gestational age, and birthweight-for-gestational age z-scores if all water sources with fluoride levels above 0.7 (0.5) ppm were reduced to 0.7 (0.5) ppm.

Courtesy of Dana Goin

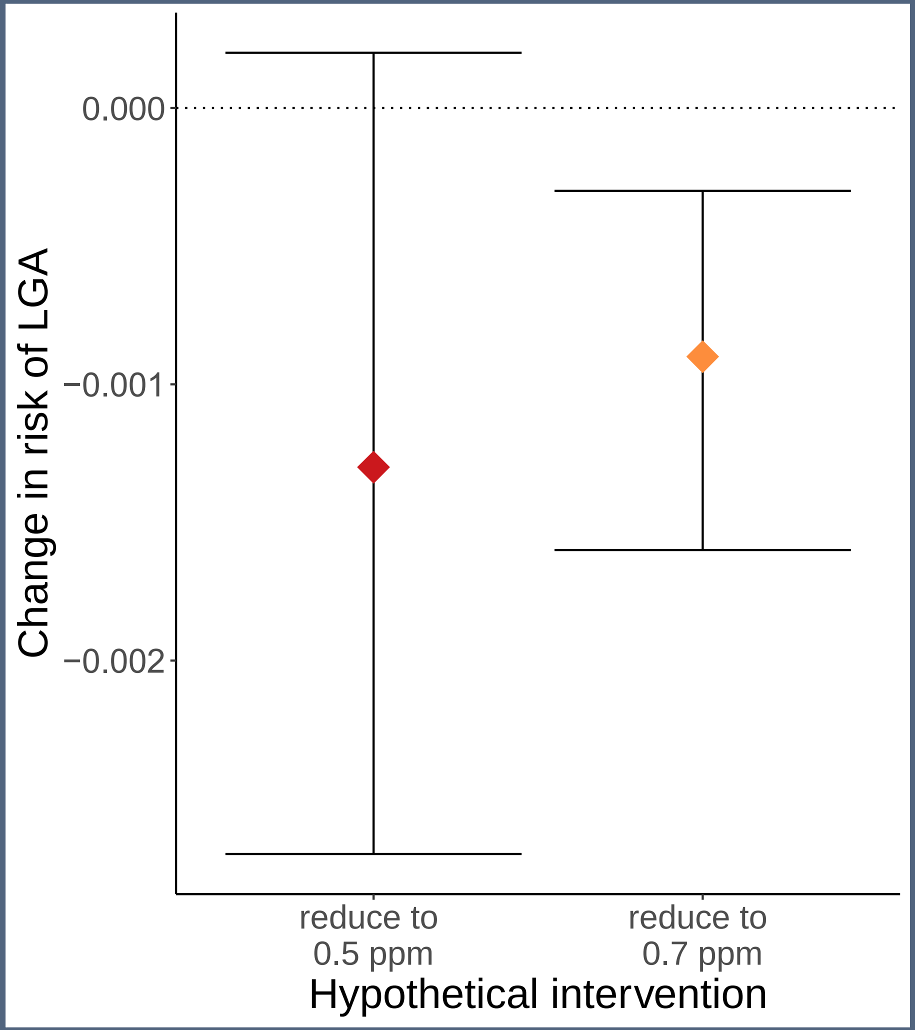
Study goals

- Evaluate the expected change in birthweight, gestational age, and birthweight-for-gestational age z-scores if all water sources with fluoride levels above 0.7 (0.5) ppm were reduced to 0.7 (0.5) ppm.
  - ✓0.7 ppm is level recommended by the US Public Health Service

Preliminary Results:

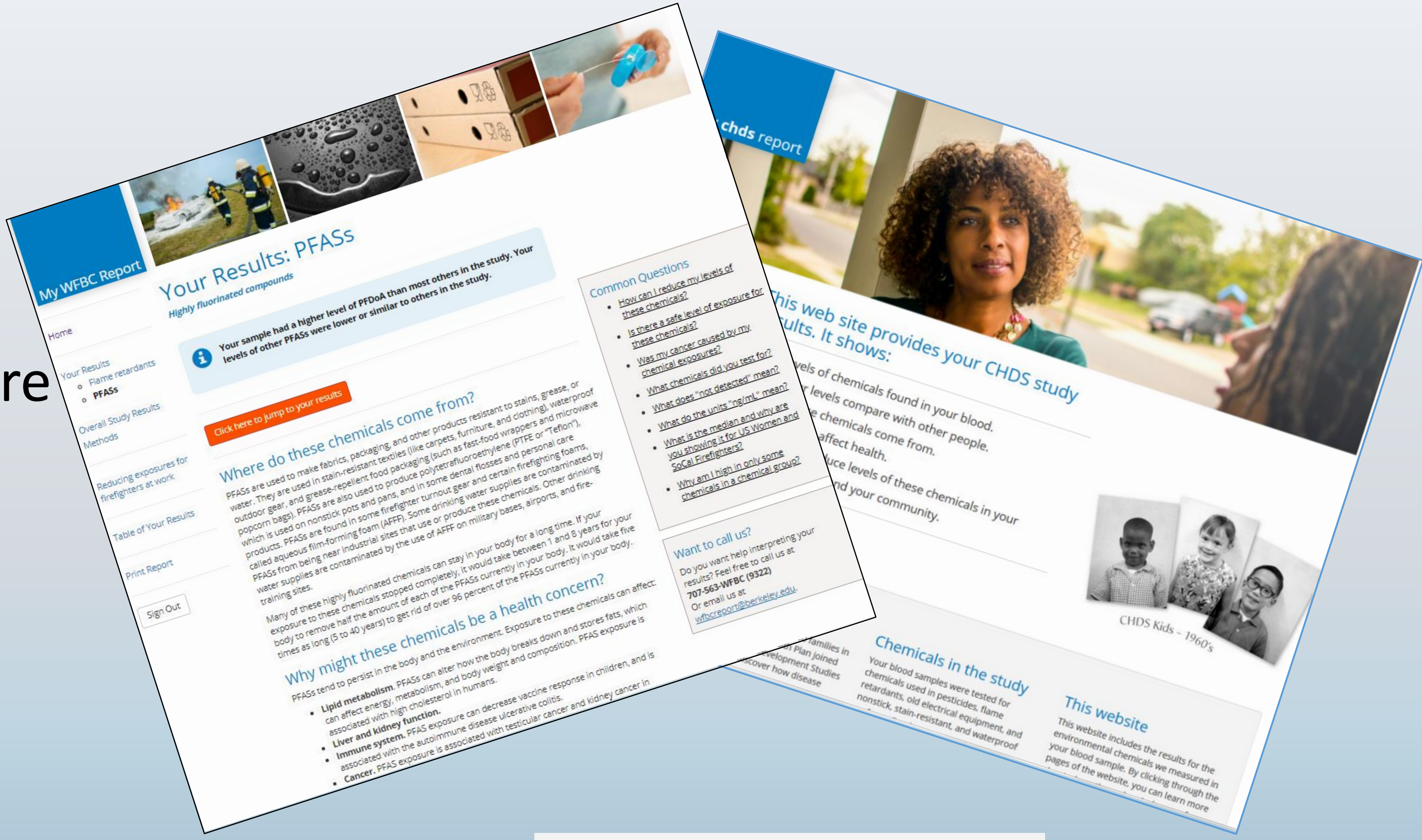
- Hypothetical interventions to reduce fluoride associated with small reduction in large-for-gestational age births
  - No association observed for birth weight or preterm birth outcomes

Courtesy of Dana Goin



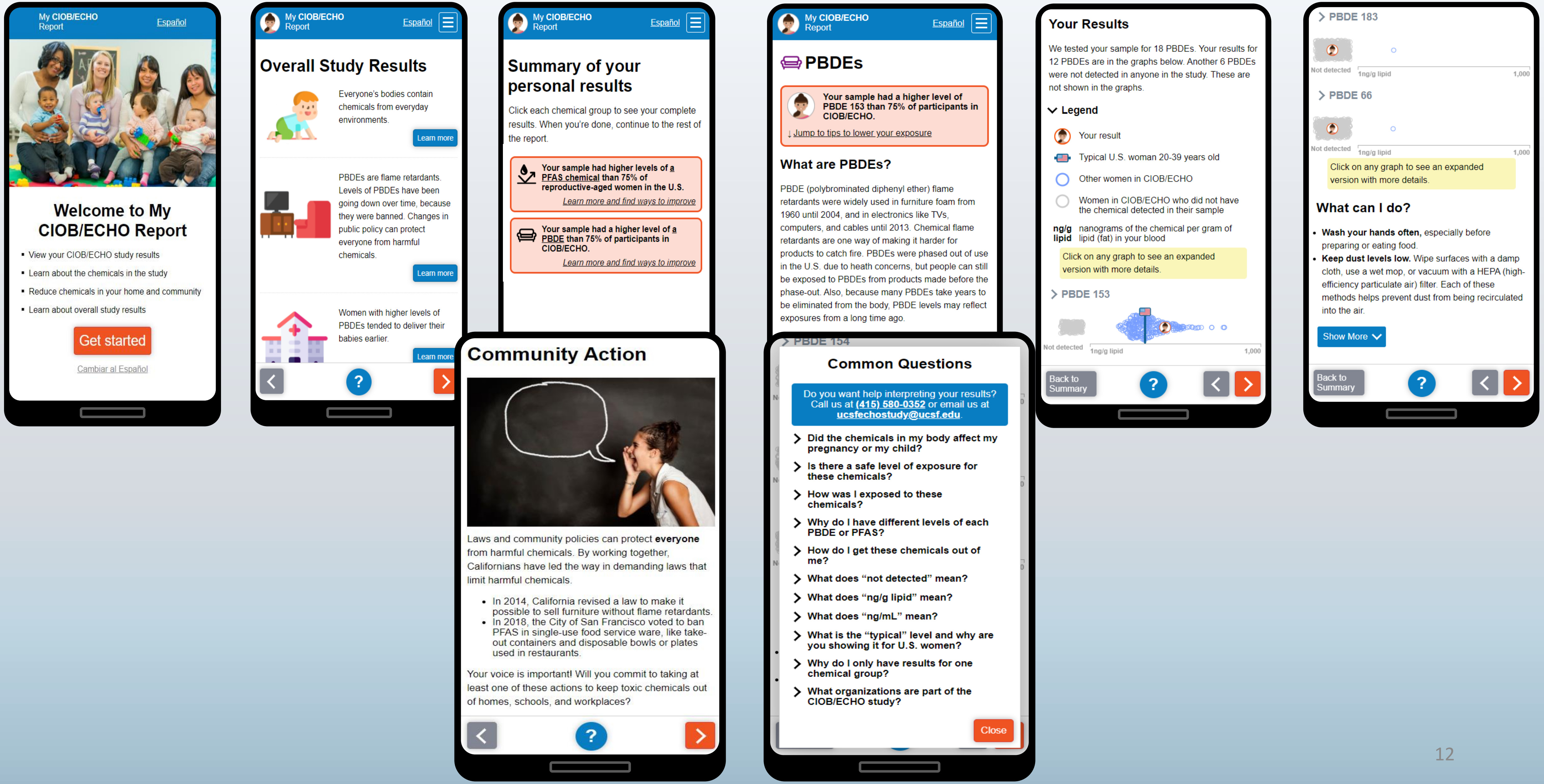
Return of Drinking Water Sample Results using Digital Exposure Report-Back Interface (DERBI)

A software framework for generating personalized exposure reports -- for computer, smartphone, print



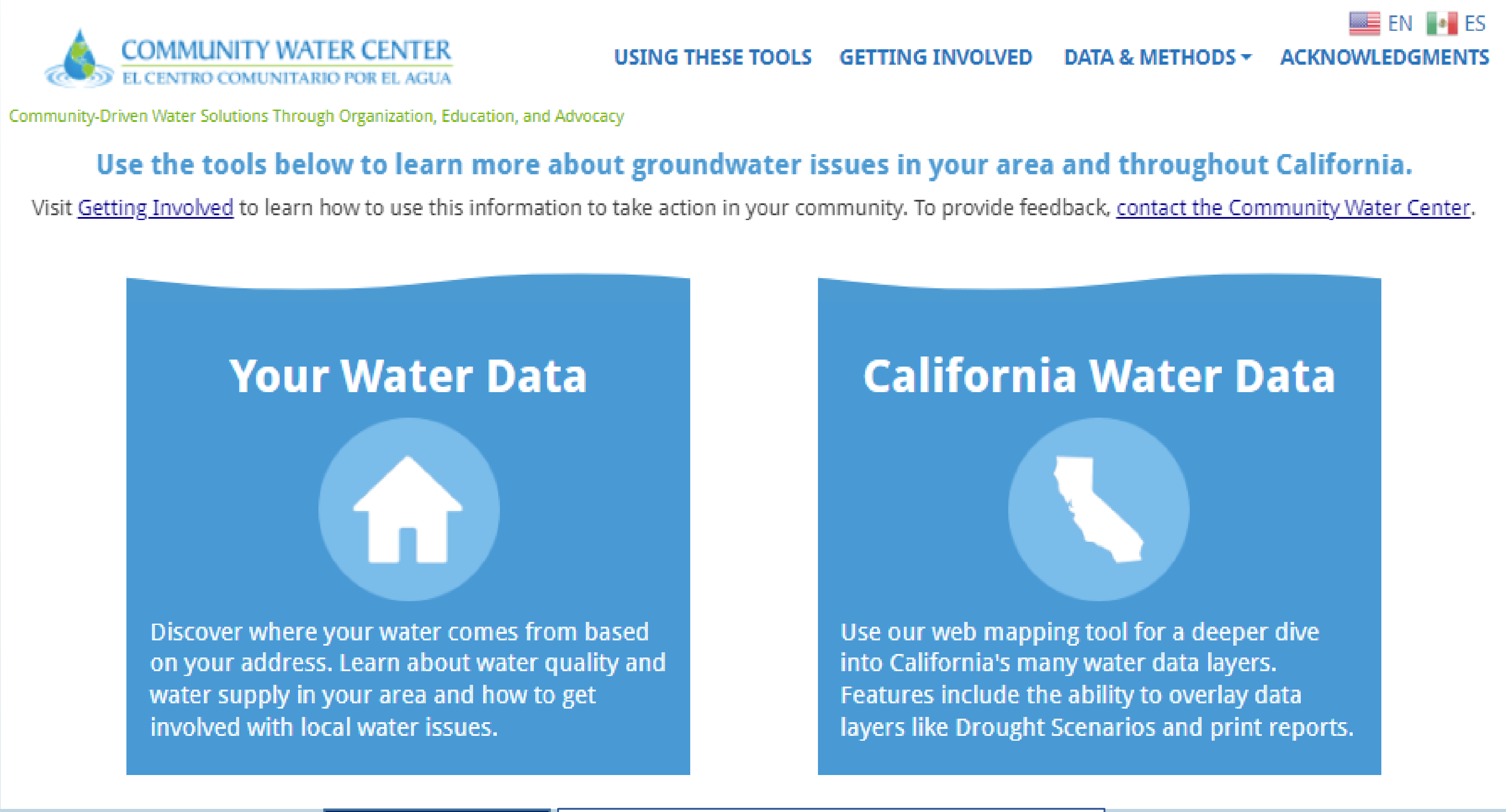
Boronow et al. 2017 EHP

Smartphone Reports *May* Expand Access



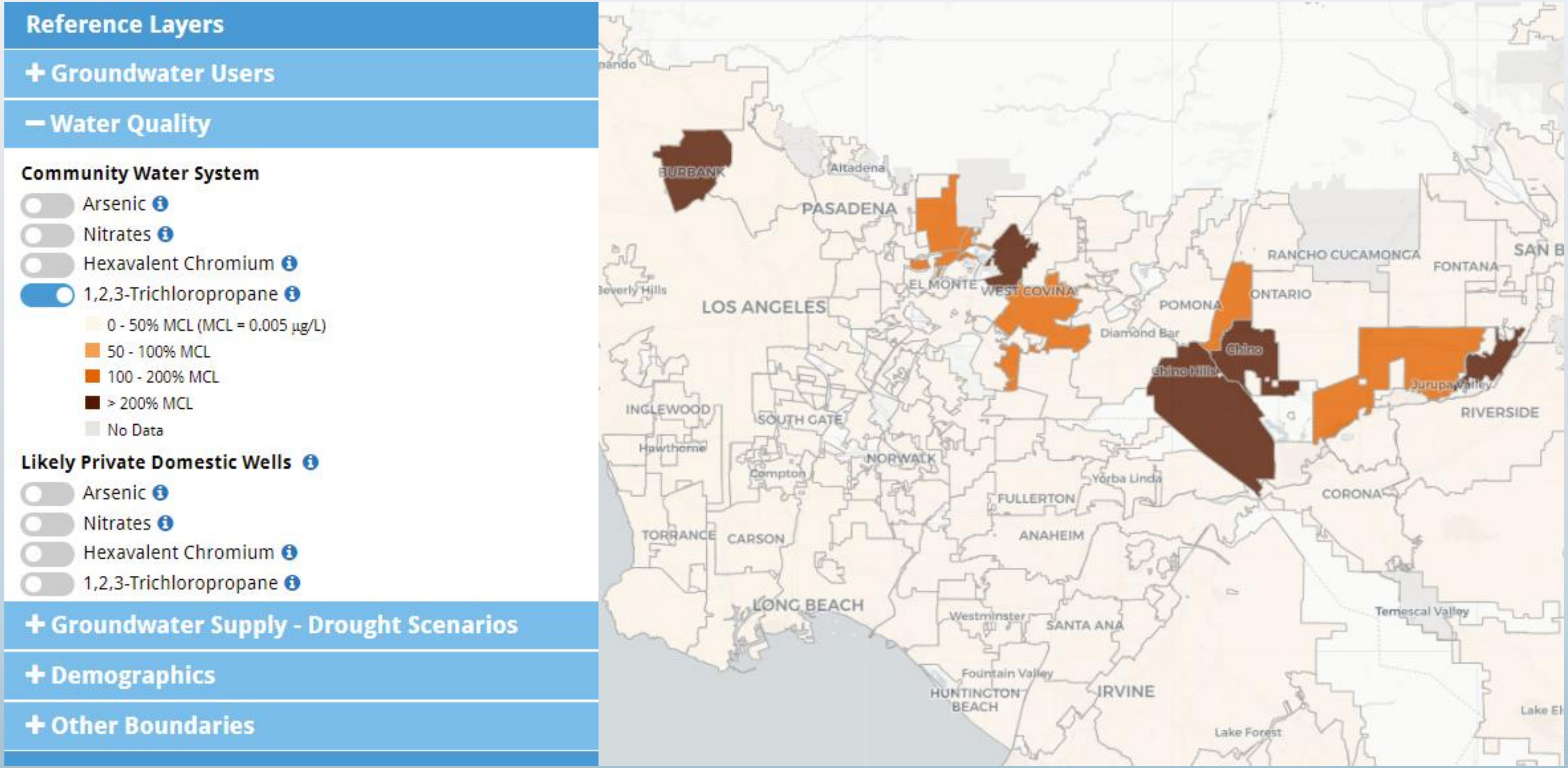
Community Engagement Core – Online Drinking Water Tool

drinkingwatertool.communitywatercenter.org



Drinking Water Tool

drinkingwatertool.communitywatercenter.org



Drinking Water Tool

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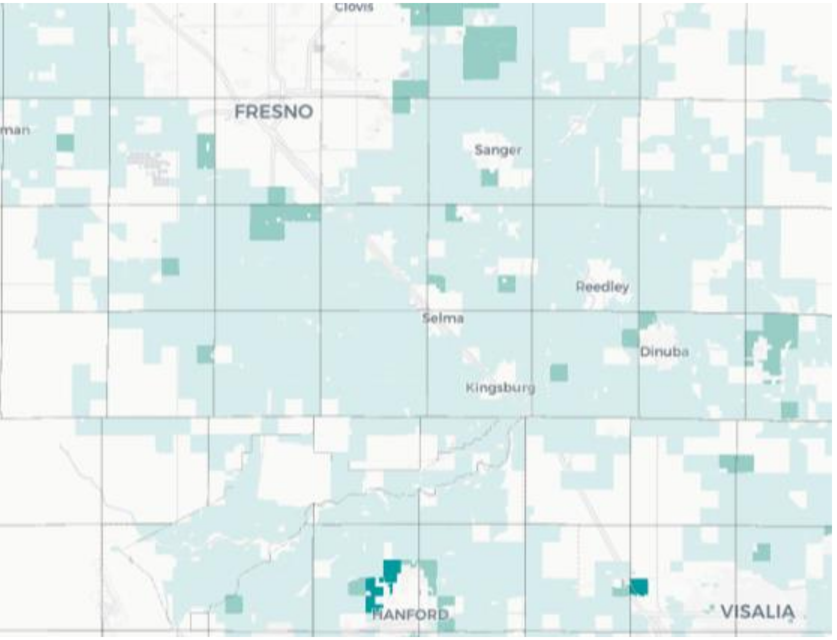
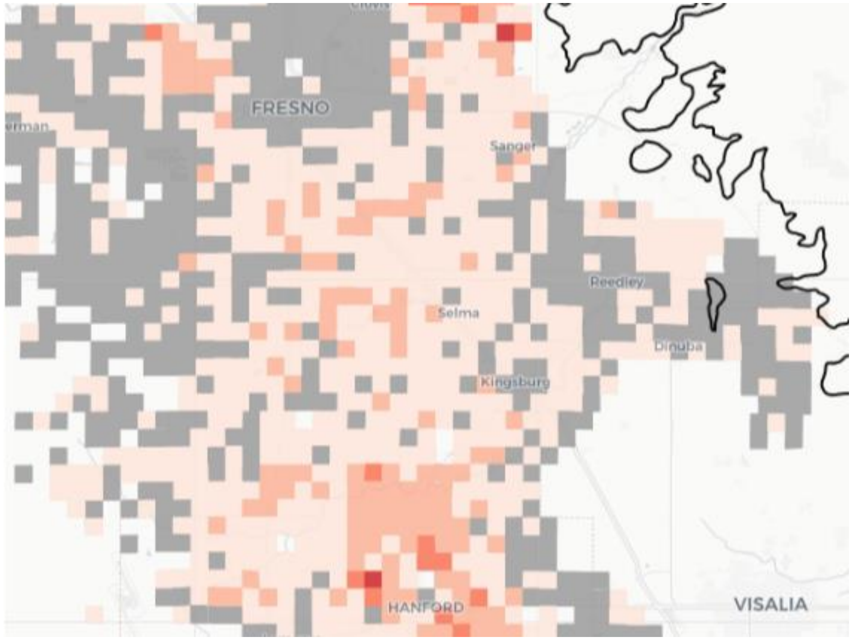


Likely Domestic Well Communities

Domestic Well Population

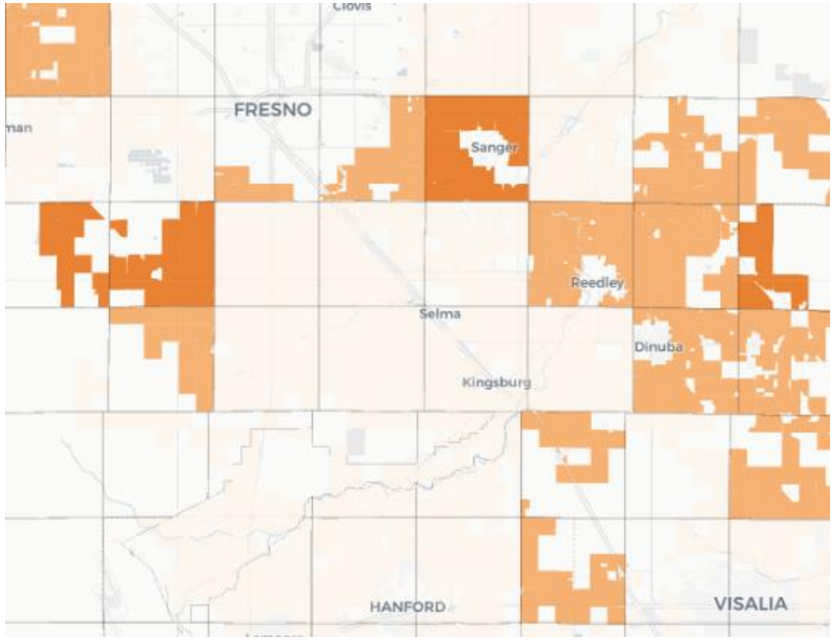
- Up to 250
- 251 - 1,500
- 1,500 - 4,250
- More than 4,250



Private Domestic Wells

Number of Impacted Domestic Wells

- 0
- 1 - 4
- 5 - 12
- 13 - 26
- More than 26



Likely Private Domestic Wells

Arsenic

Nitrates

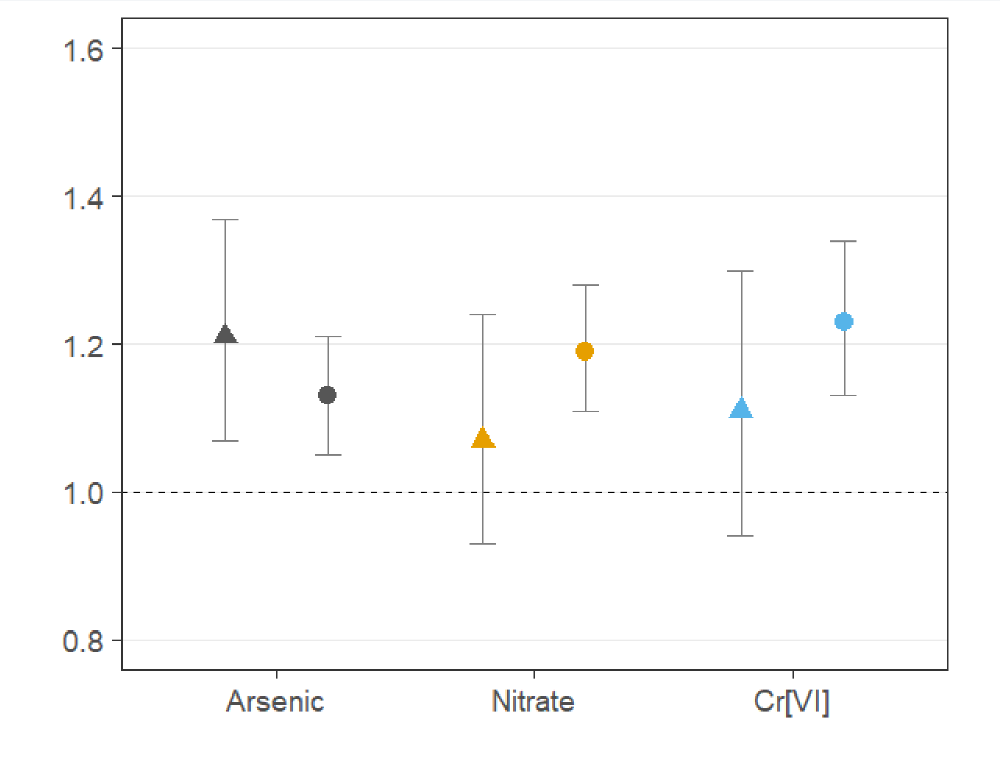
- 0 - 50% MCL (MCL = 10 mg/L)
- 50 - 100% MCL
- 100 - 200% MCL
- > 200% MCL
- No Data

Communities of color face higher risks of chemical contaminants ≥ 1/2 Maximum Contaminant Level (MCL)

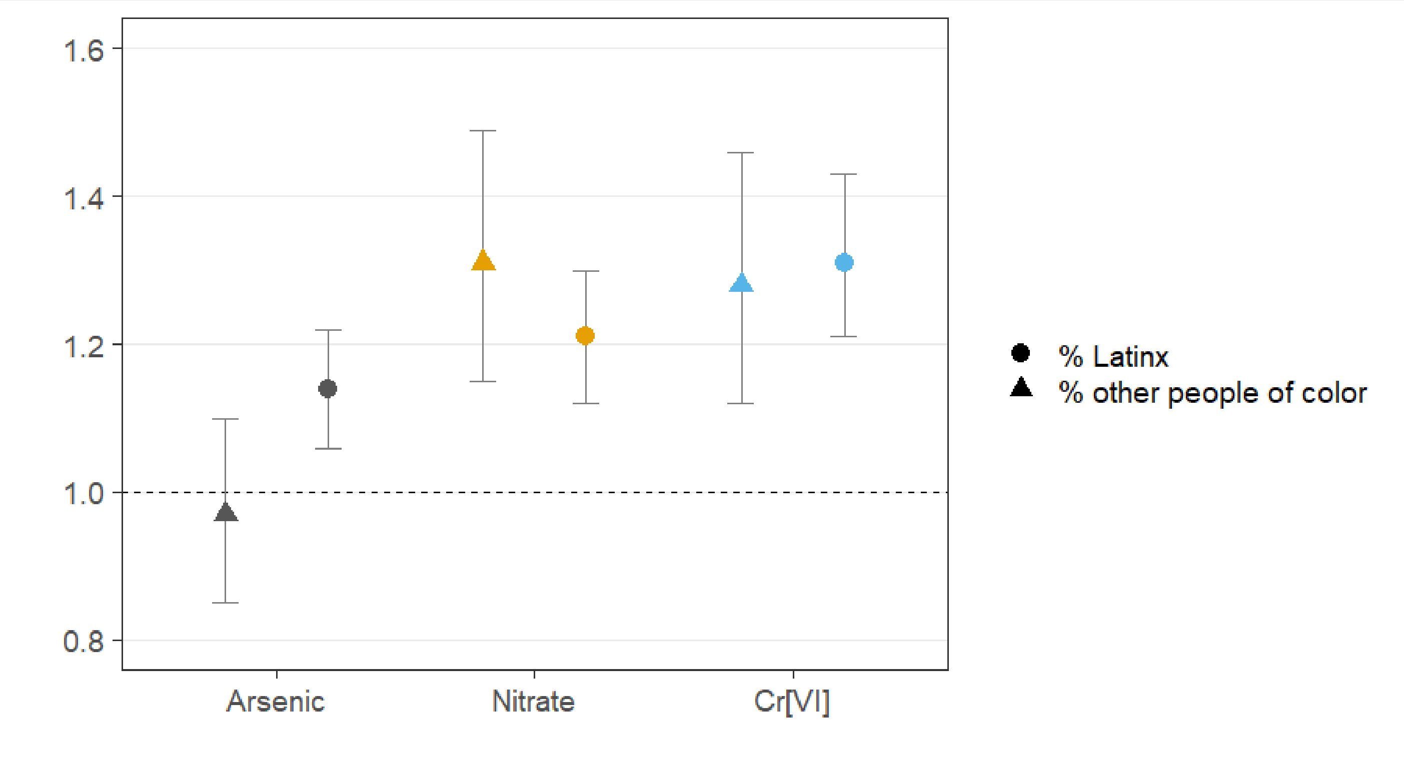
Prevalence ratios & 95% confidence intervals

Pace et al. (2022) AJPH

Domestic well areas (n = 1917)

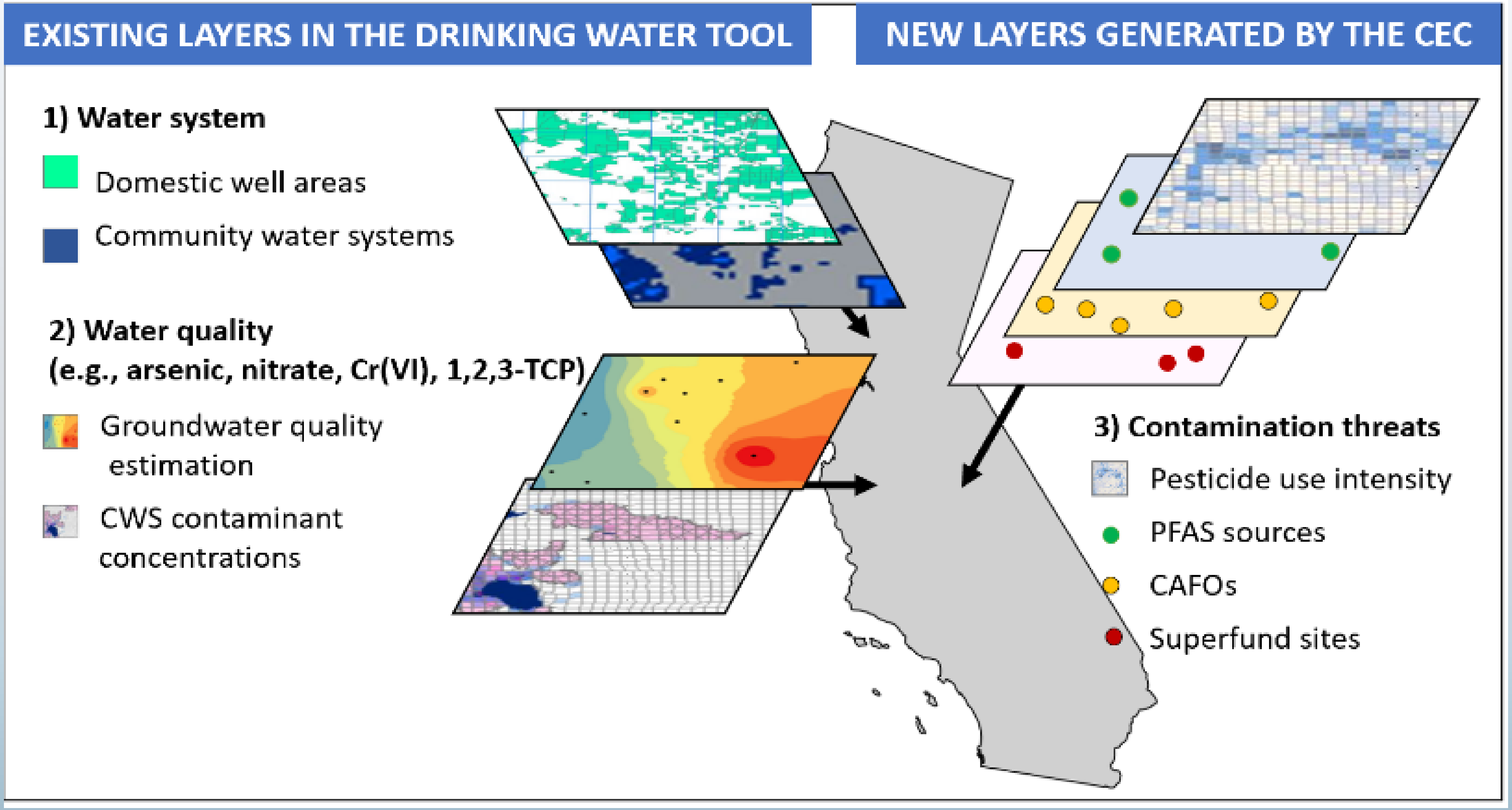


Community Water Systems (n = 2744)



MCL = 10 μg/L for all contaminants. Chromium does not have a current MCL; We used the most recent MCL for chromium (VI).
GAM models control for % renters, region, spatial autocorrelation, and (for community water systems) system size and ground vs. surface water source.

Expanding the Drinking Water Tool to incorporate additional drinking water threats



Project 2: Influence of pre- and postnatal exposure to a mixture of PFAS and metals on neonatal immune responses and childhood vaccine induced immunity

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Background

- Immune system development occurs during fetal development and early childhood

- Prenatal and early life environmental exposures may have health implications for developing offspring, including **developmental immunotoxicity**
  - Per- and polyfluoroalkyl substances (PFAS) and metals are two classes of chemicals **ubiquitously detected** in human populations and of pediatric concern

- Prior studies indicate that pre- and postnatal exposure to PFAS and certain metals hinder immune response to routine immunizations
  - More research needed on **timing of effects**, **mechanisms of altered immune effects**, and **impact of multiple exposures**

Table 1. Recommended child immunization schedule for the TDAP and MMR immunizations.

Vaccination	Age
Tetanus, Diphtheria and Pertussis (TDAP)	
1st dose	2 months
2nd dose	4 months
3rd dose	6 months
4th dose	15-18 months
5th dose	4-6 years
Measles, mumps, rubella (MMR)	
1st dose	12-15 months
2nd dose	4-6 years

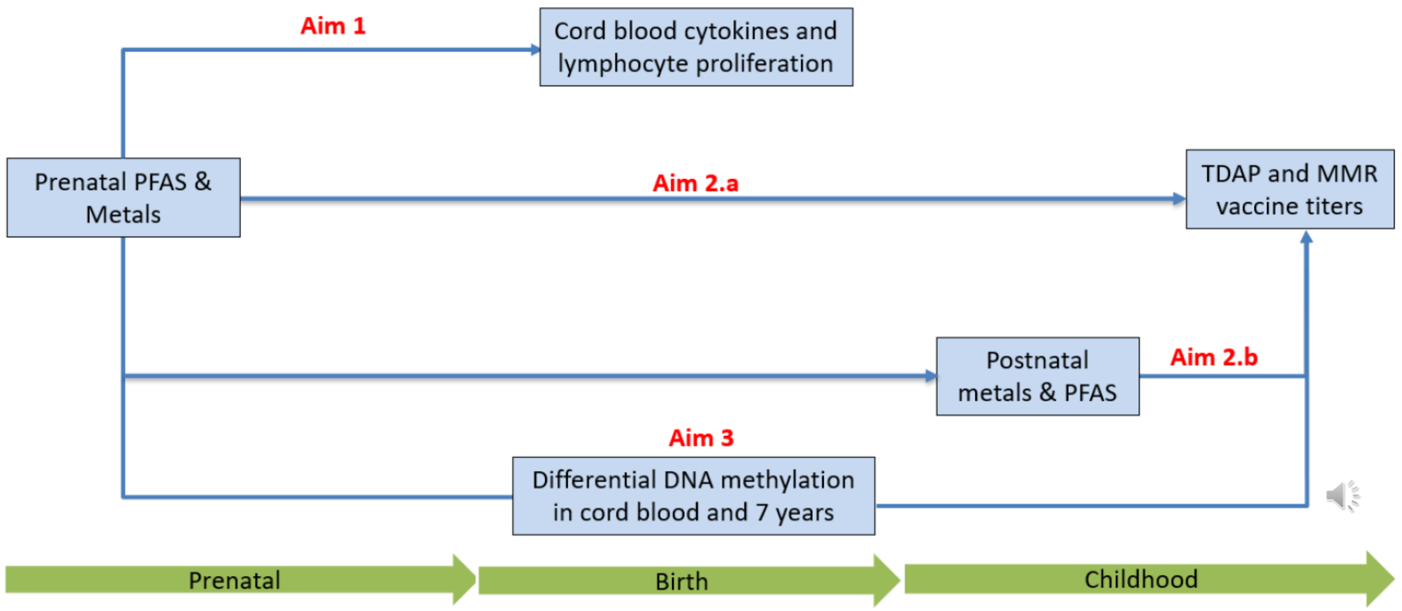
Study Design

- **Project Viva:** Project Viva; longitudinal pre-birth cohort in Eastern Massachusetts
- **Exposures:**
  - Prenatal plasma PFAS and blood metal concentrations (1st trimester of pregnancy)
  - Postnatal child metal levels (age 3 years) and child PFAS (age 7 years)
- **Outcomes:**
  - Cord blood cytokines and lymphocyte proliferation (birth)
  - TDAP and MMR vaccine titers (age 7 years)
- **Mediators:**
  - Cord blood leukocyte DNA methylation (birth and age 7 years)

Aims

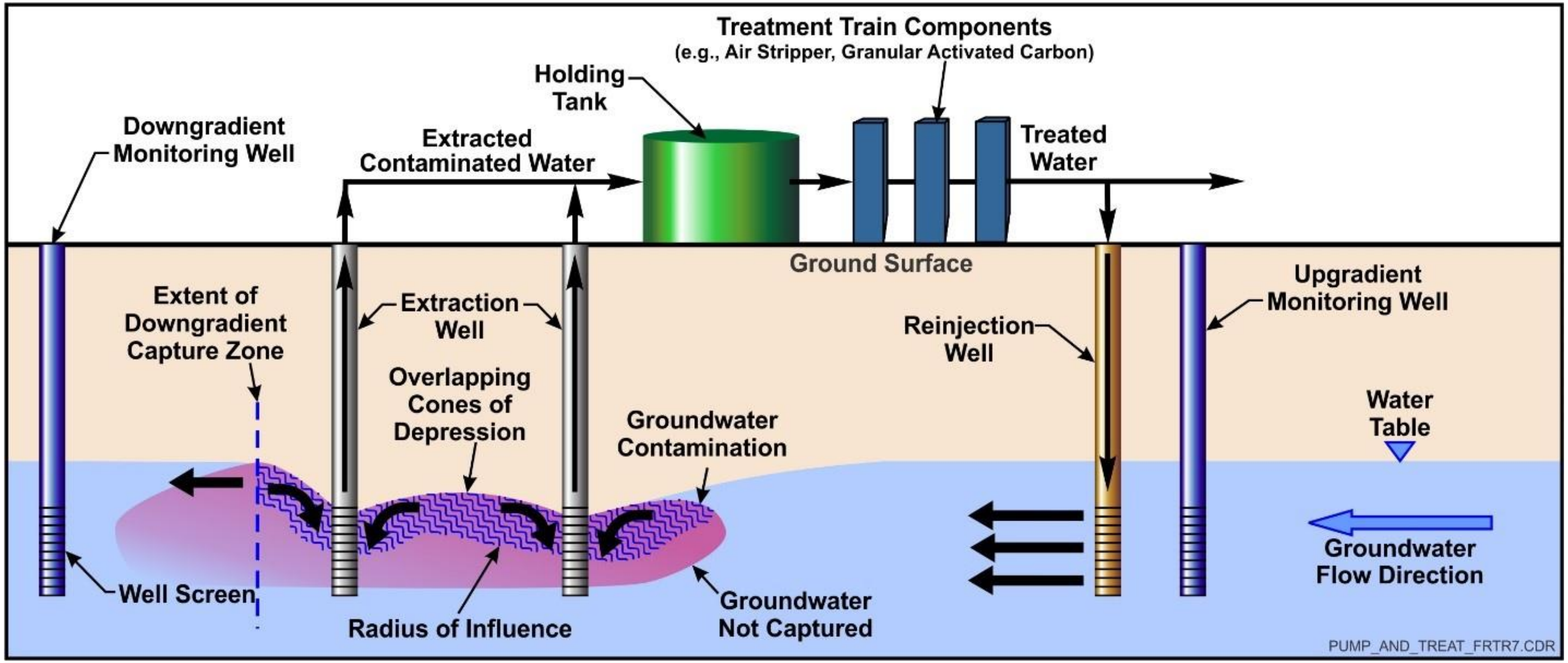
- **Aim 1:** Determine the extent to **which prenatal first trimester plasma PFAS and blood metal concentrations** are jointly associated as a mixture with **cytokines** (IL-13, IL-10, IL-6, INF-γ, and TNF-α) and **lymphocyte proliferation in cord blood**
- **Aim 2:** Quantify the extent to which **pre- and postnatal PFAS and metal mixtures** are associated with **anti-TDAP and anti-MMR antibody titers by mid-childhood**
- **Aim 3:** Test if **DNA methylation at birth** is associated with **anti-TDAP and anti-MMR titers in mid-childhood** and if DNA methylation of genes partly **mediates** the association between exposures and vaccine-derived immunity

Figure 1. Conceptual diagram for the study aims



A Brief History of Remediation

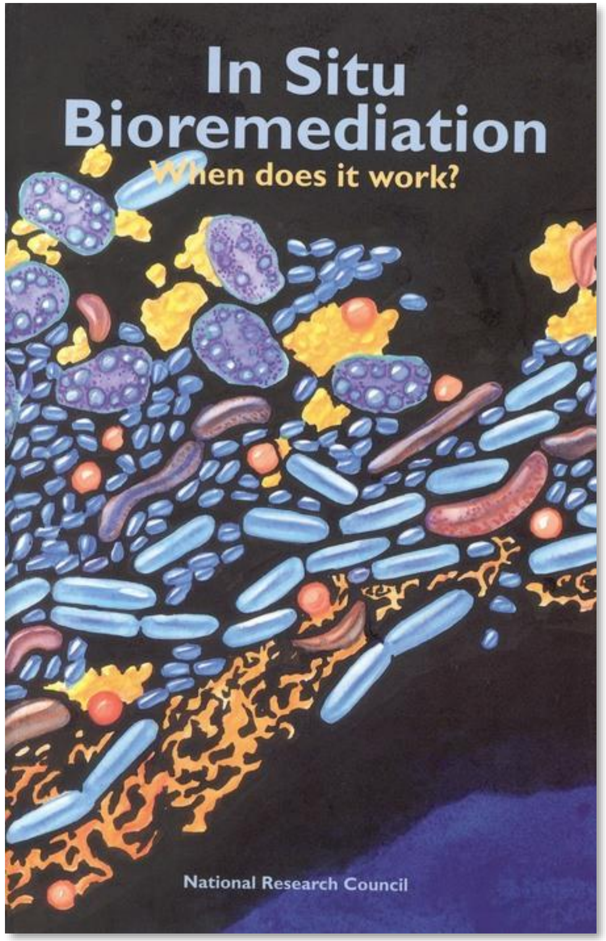
- 1970-1985: Pump and Treat Era



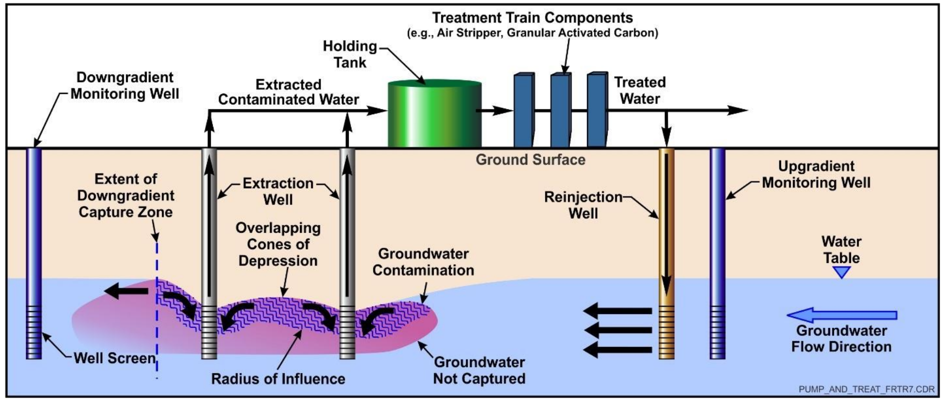
Federal Remediation Technologies Roundtable

A Brief History of Remediation

- 1970-1985: Pump and Treat Era
- 1985-2000: Bioremediation Era

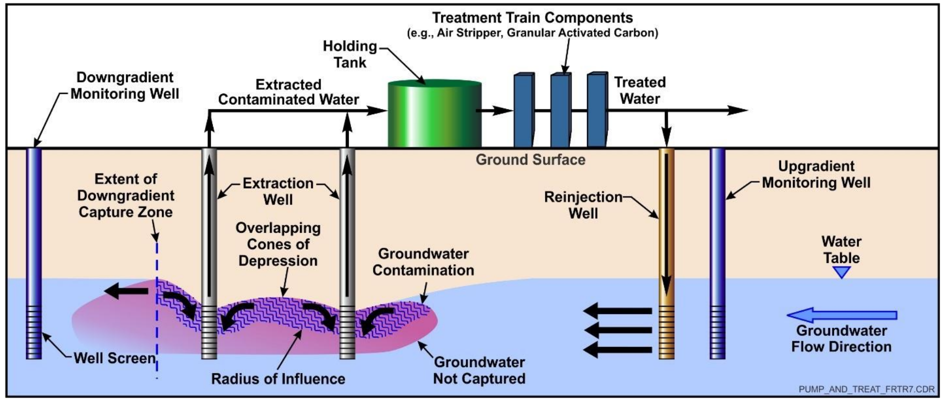


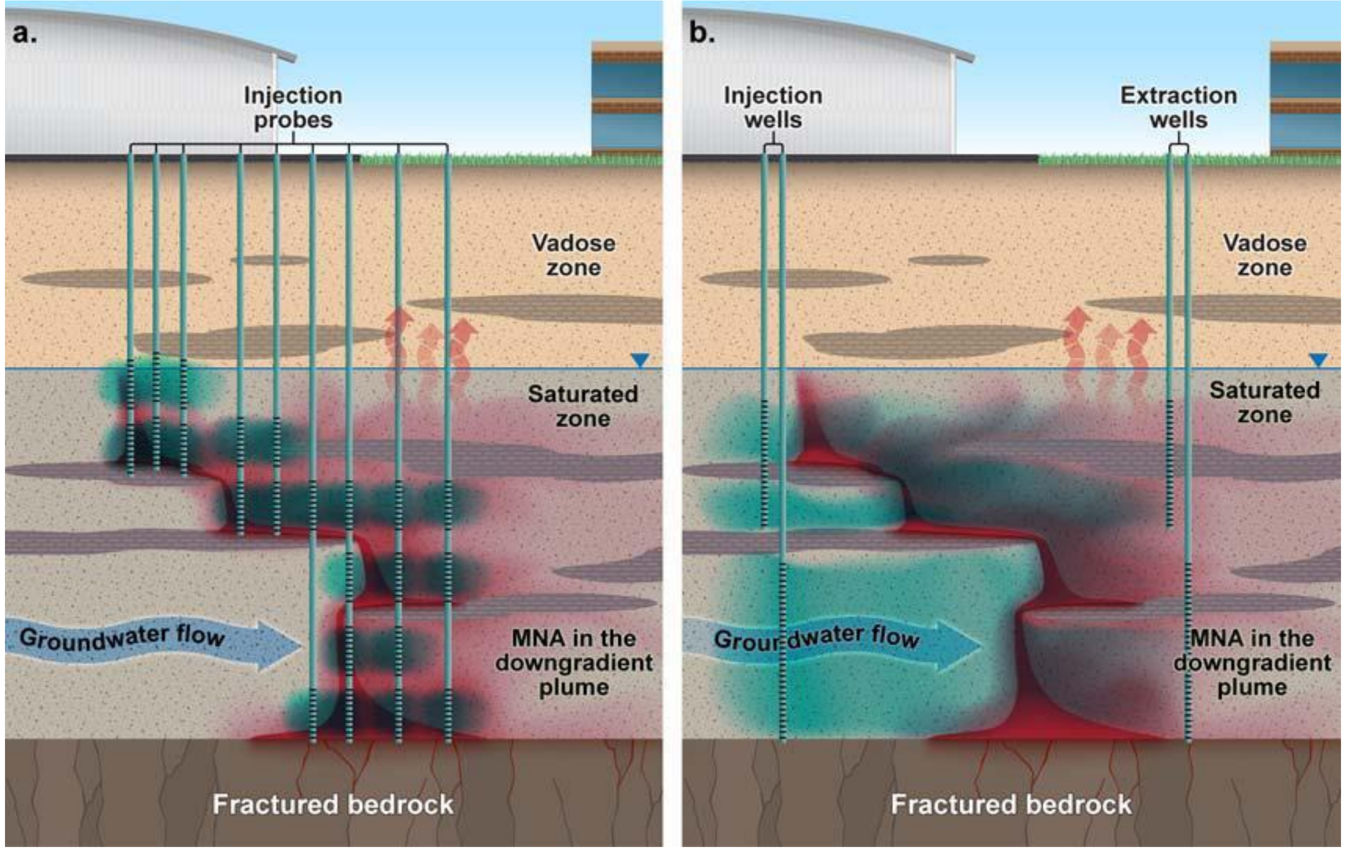
National Academies Press



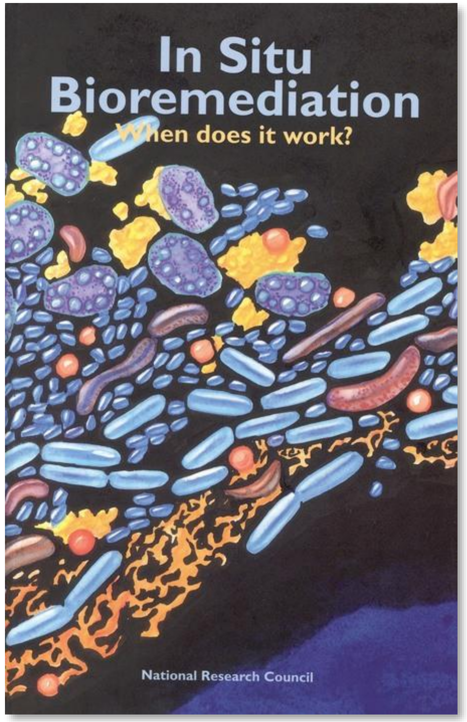
A Brief History of Remediation

- 1970-1985: Pump and Treat Era
- 1985-2000: Bioremediation Era
- 2000-2015: In Situ Chemical Treatment Era



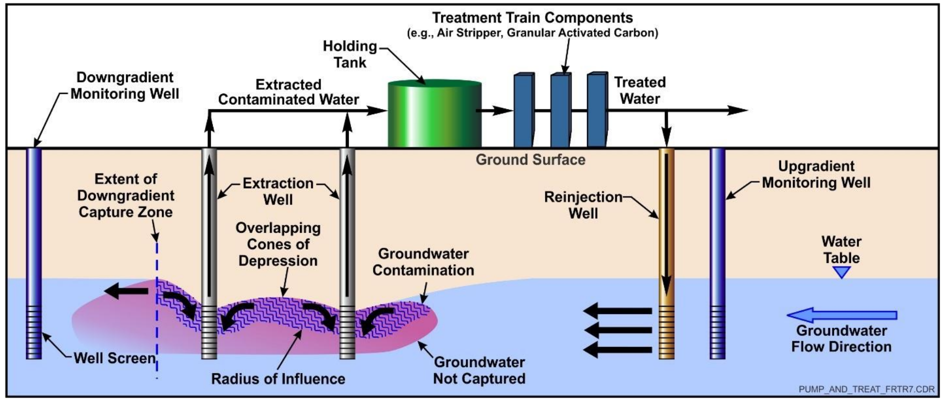


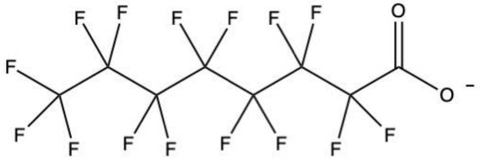
Envirowiki



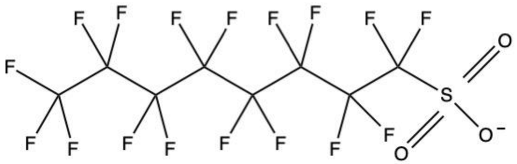
A Brief History of Remediation

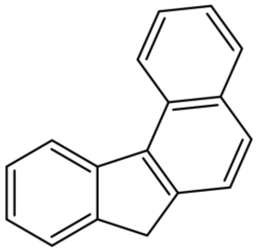
- 1970-1985: Pump and Treat Era
- 1985-2000: Bioremediation Era
- 2000-2015: In Situ Chemical Treatment Era
- 2015-2030: The Super-Recalcitrant Era



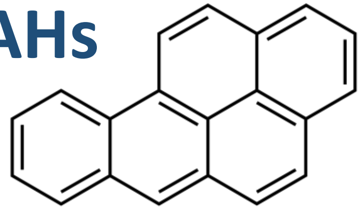


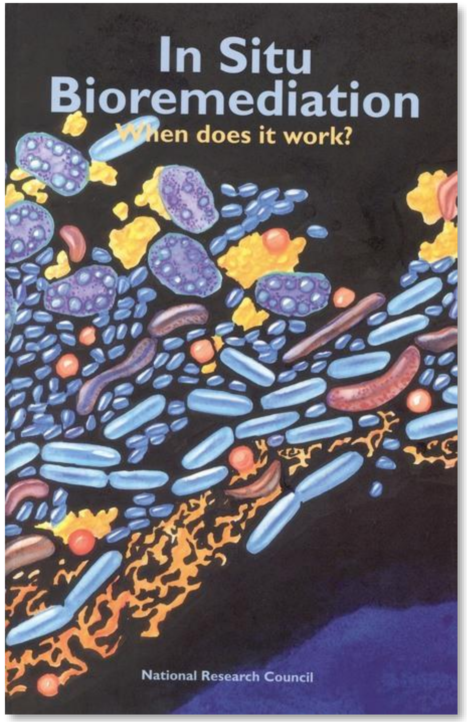
PFAS

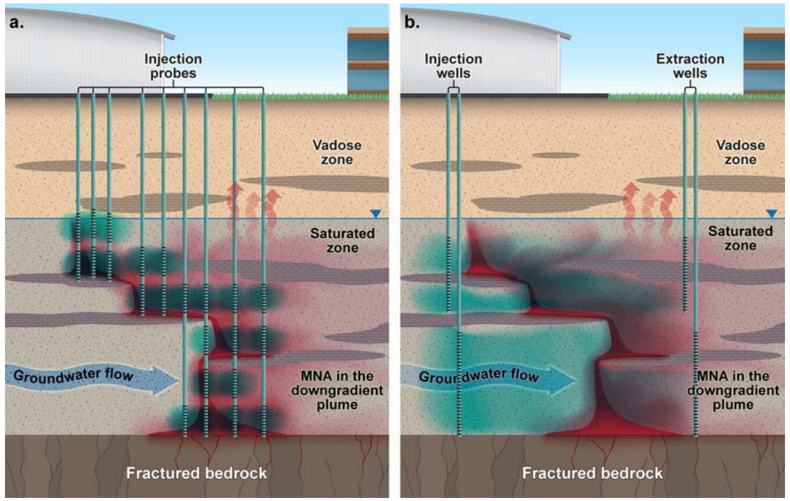




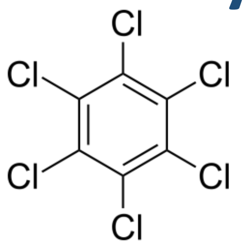
PAHs

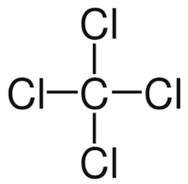


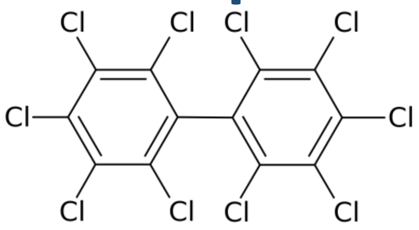




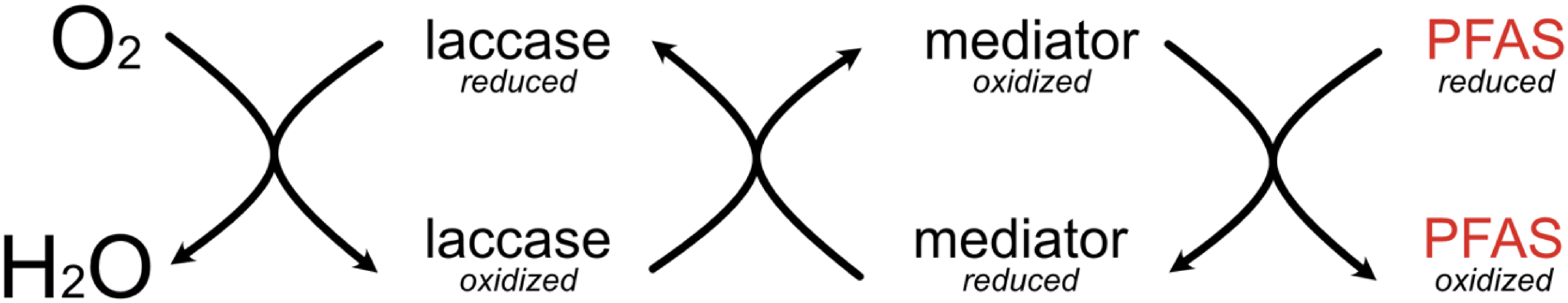
Fully Halogenated Compounds







Project 3: In Situ Destruction of Halogenated Superfund Contaminants with Biological Radical Reactions



Environmental Science & Technology LETTERS

pubs.acs.org/journal/estlcu

Letter

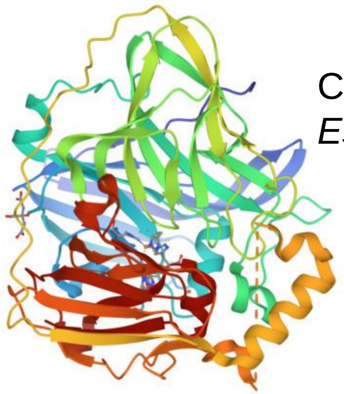
An Artifact of Perfluoroalkyl Acid (PFAA) Removal Attributed to Sorption Processes in a Laccase Mediator System

Sophia D. Steffens, Edmund H. Antell, Emily K. Cook, Guodong Rao, R. David Britt, David L. Sedlak, and Lisa Alvarez-Cohen*

Cite This: *Environ. Sci. Technol. Lett.* 2023, 10, 337–342

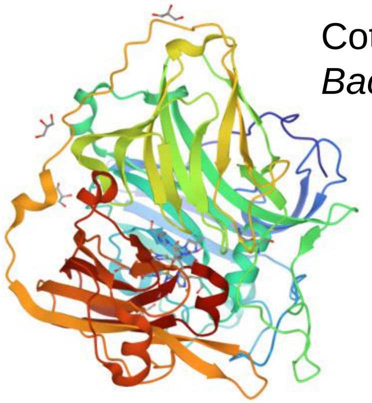
Read Online

Project 3: In Situ Destruction of Halogenated Superfund Contaminants with Biological Radical Reactions

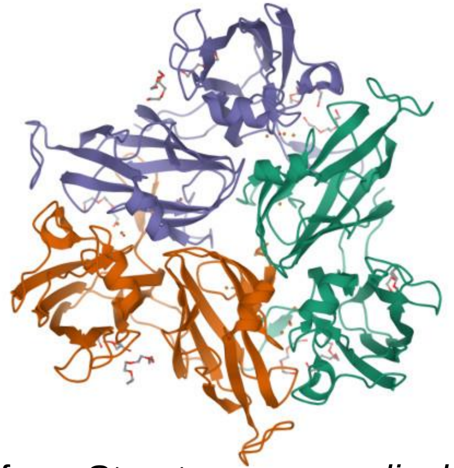


CueO from
Escherichia coli (2FQD)

Bacteria Laccase

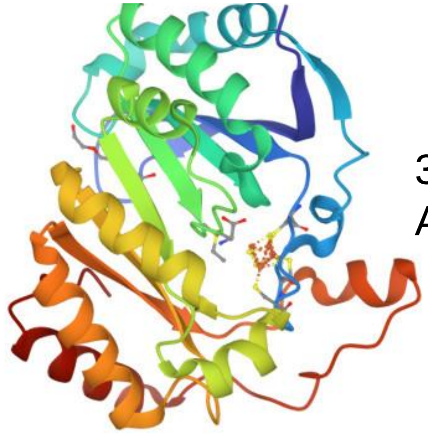


CotA from
Bacillus subtilis (1GSK)



SLAC from *Streptomyces coelicolor* (4GXF)

SAM/Glycyl Radical System



3C8F (*E. coli* PFL-AE)

Activating (radical SAM) enzyme

1H18 (*E. coli* PFL)

Glycyl radical enzyme

Project 4: In Situ halogenated Superfund Contaminants with Persulfate-Generated Radicals

$$SO_4^{\cdot -} + CH_3CH_2OH \rightarrow {}^{\cdot}CHCH_3OH + SO_4^{2-} + H^+$$

$$^{\cdot}CHCH_3OH + CCl_4 \rightarrow {}^{\cdot}CCl_3 + Cl^- + CH_3COH + H^+$$

Contents lists available at ScienceDirect

Water Research

journal homepage: www.elsevier.com/locate/watres

ELSEVIER

WATER RESEARCH

Contribution of alcohol radicals to contaminant degradation in quenching studies of persulfate activation process

Check for updates

Changyin Zhu [a, b], Fengxiao Zhu [a], Dionysios D. Dionysiou [c], Dongmei Zhou [a], Guodong Fang [a, *], Juan Gao [a, **]

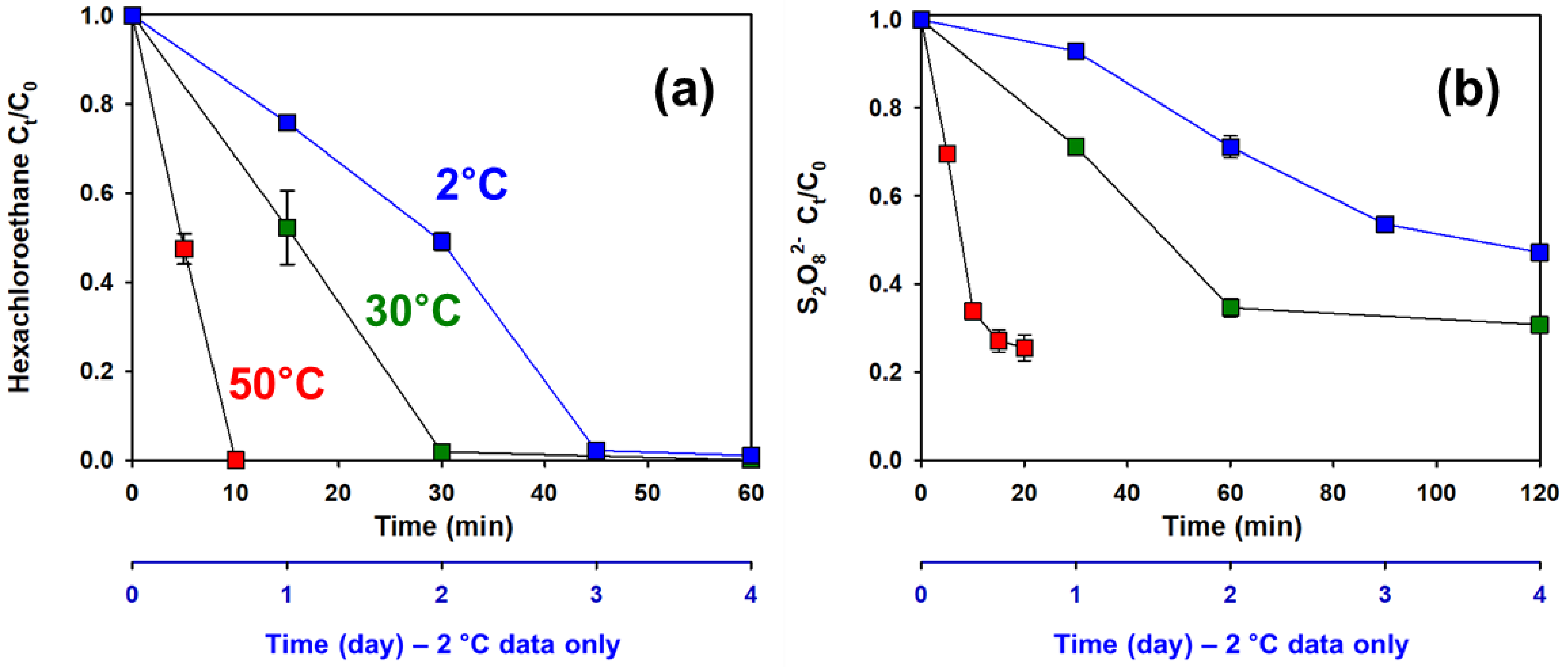
[a] Key Laboratory of Soil Environment and Pollution Remediation, Institute of Soil Science, Chinese Academy of Sciences, Nanjing 210008, PR China

[b] University of Chinese Academy of Sciences, Beijing 100049, PR China

[c] Environmental Engineering and Science Program, Department of Chemical and Environmental Engineering (ChEE), University of Cincinnati, Cincinnati, OH 45221-0071, USA

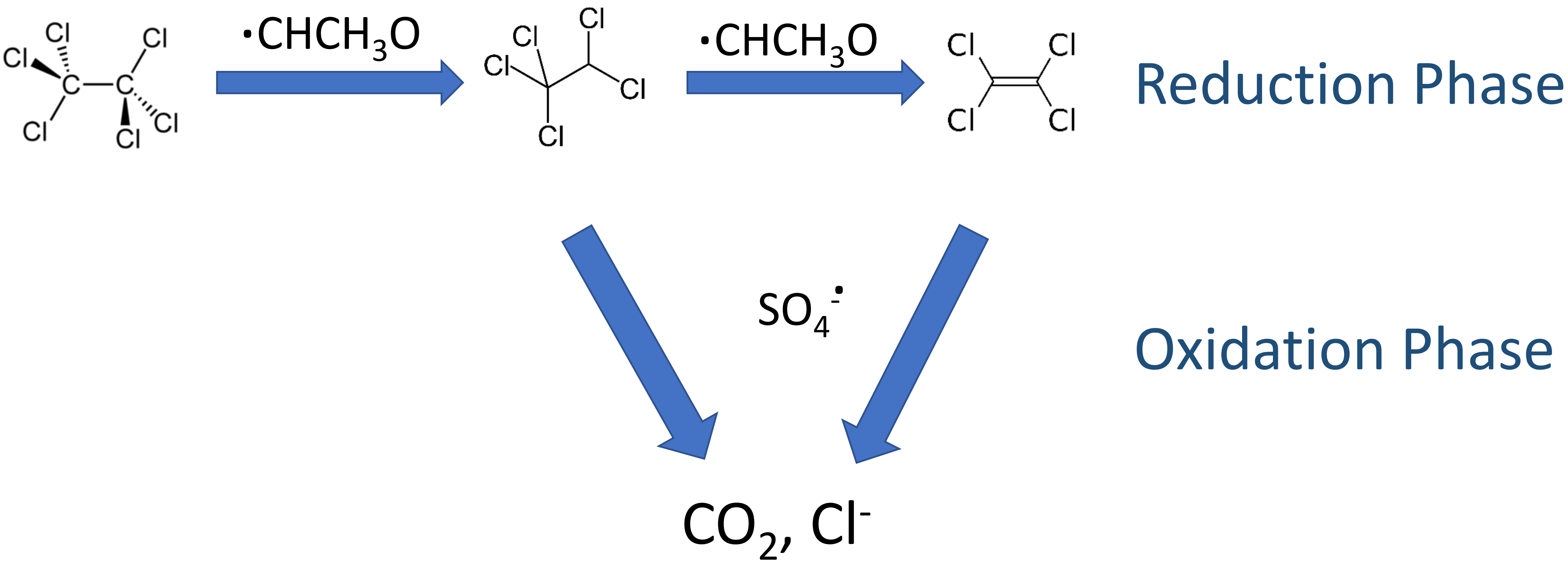
2018

Project 4: In Situ Destruction of Halogenated Superfund Contaminants with Biological Radical Reactions



Conditions: $[S_2O_8^{2-}]_0$=450 mM; $[\text{Ethanol}]_0$ = 1.8 M; $[O_2]_0$ = 220 to 275 µM; [Hexachloroethane] = 50 µM, $[Cl^-]_0$ = 1 mM; $[NO_3^-]_0$ = 0.1 mM; $[NO_2^-]_0$ = 0.01 mM; pH_0 = 1.4

Project 4: In Situ Destruction of Halogenated Superfund Contaminants with Biological Radical Reactions



All of the Above in the Super-Recalcitrant Era