Yale Superfund Research Center: Emerging Water Contaminants: Investigating and Mitigating Exposures and Health Risks

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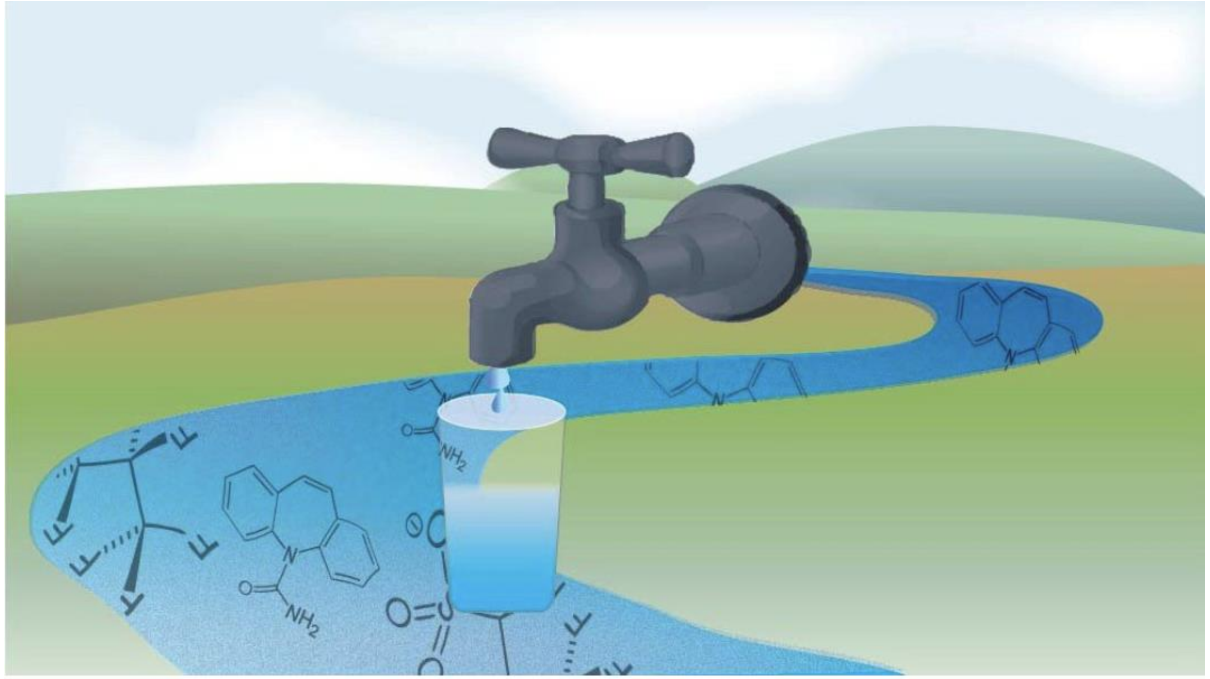
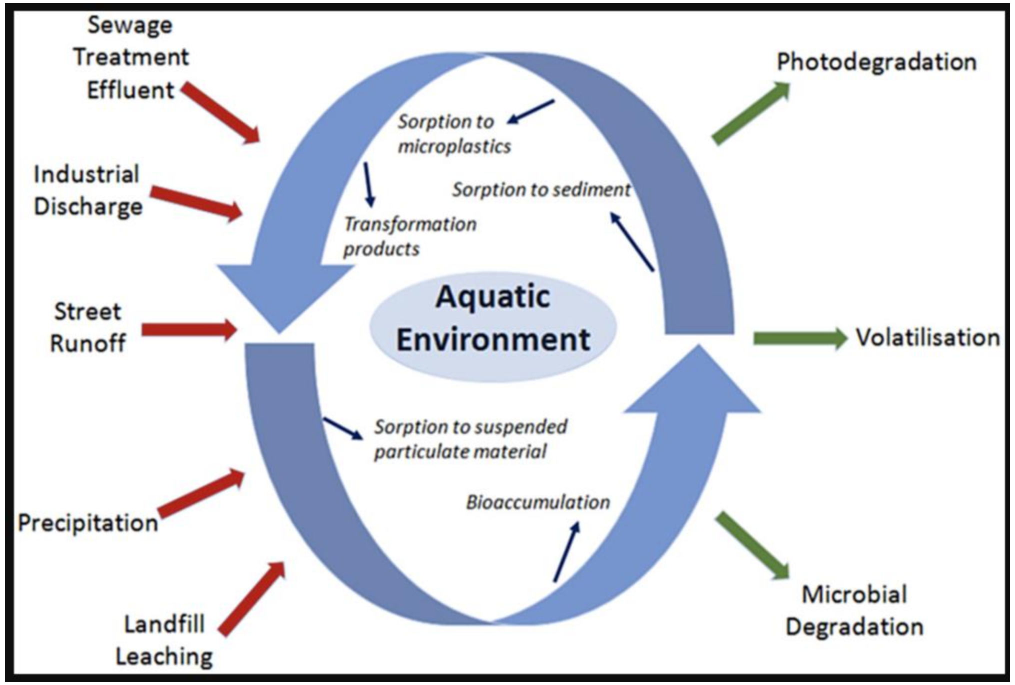
Water Contaminants of Emerging Concern

- Chemicals that have been detected in global drinking water supplies at trace levels and for which the risk to human health is not yet known or completely evaluated.
- They include industrial chemicals and endocrine disrupting compounds, pharmaceuticals, personal care products, and pesticides.





The Overall Objective of YSRTP

Improve public health protection from emerging contaminants in drinking water by applying advanced research techniques and communication strategies to the detection, toxicological evaluation, exposure assessment, mitigation, and community outreach involving these contaminants.

1,4-Dioxane (1,4-DX) is a carcinogen in public drinking water that is unregulated throughout most of the USA and Europe.

The barriers to effective policy and regulation make 1,4-DX a key focus for solving the problems of emerging contaminants in drinking water.

We focus on 1,4 dioxane because

(i) It appears in water at Superfund sites due to current and former industrial uses and environmental release.

(ii) It is on the ATSDR Substance Priority List.

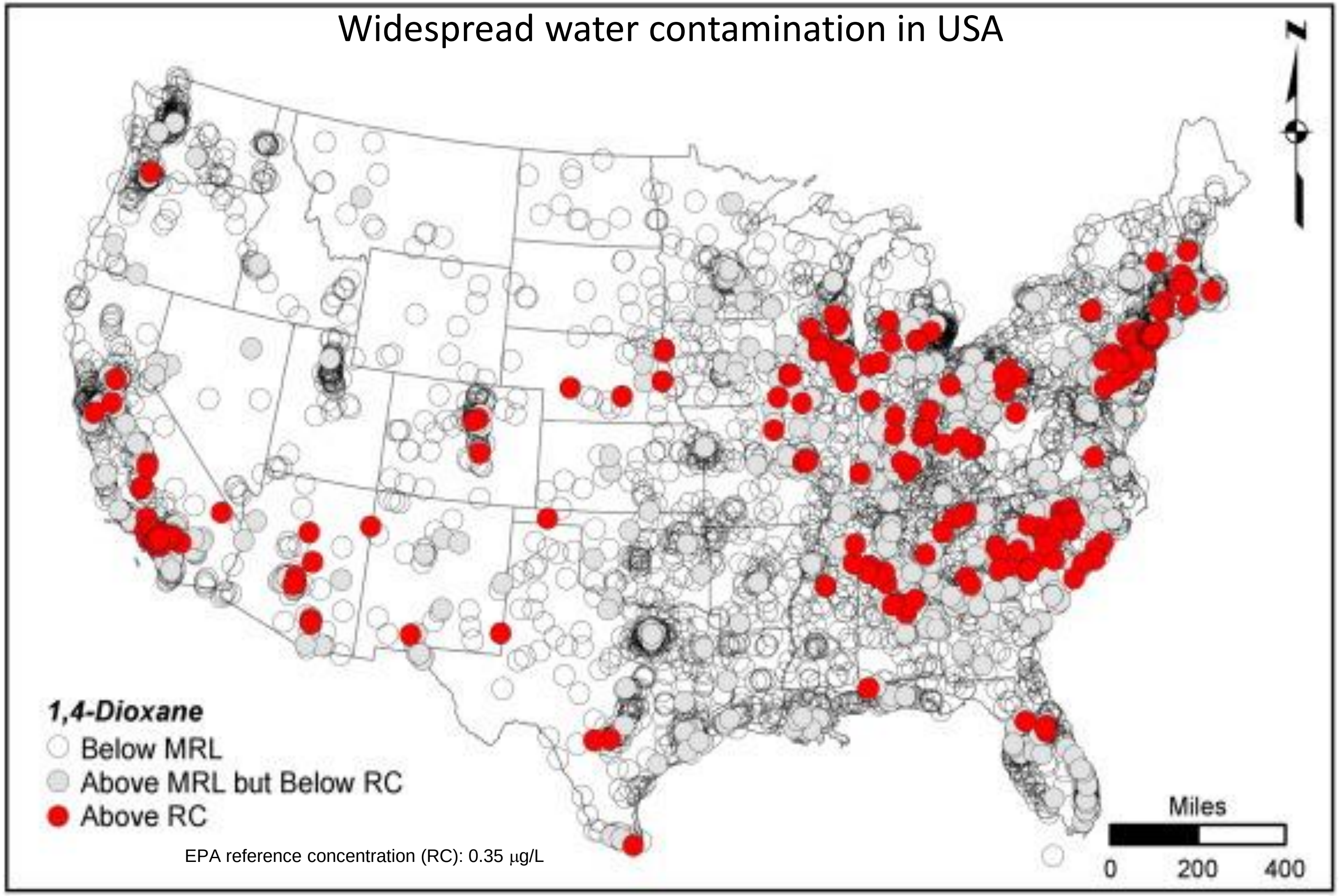
(iii) It was prioritized by the US Environmental Protection Agency (USEPA) for third unregulated monitoring rule (UCMR-3) testing in 2013-2015.

(iv) It co-exists in Superfund sites with 1,1,1-trichloroethane, 1,1-dichloroethane, and 1,1,1-trichloroethylene.

Of the 28 chemicals tested in UCMR-3, 1,4-DX was the second most frequently detected above a risk-based reference concentration (6.9% tested public supplies).

1,4-Dioxane in USA (UCRM3)

Widespread water contamination in USA



Sci Total Environ. 2017 Oct 15;596-597:236-245

1,4-Dioxane and its co-contaminants

Integrated Environmental Assessment and Management — Volume 8, Number 4—pp. 731–737

Co-Occurrence of 1,4-Dioxane with Trichloroethylene in Chlorinated Solvent Groundwater Plumes at US Air Force Installations: Fact or Fiction

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(Submitted 22 November 2011; Returned for Revision 23 January 2012; Accepted 16 March 2012)

Environmental Management

ABSTRACT

Increasing regulatory attention to 1,4-dioxane has prompted the United States Air Force (USAF) to evaluate potential environmental liabilities, primarily associated with legacy contamination, at an enterprise scale. Although accurately quantifying environmental liability is operationally difficult given limited historic environmental monitoring data, 1,4-dioxane is a known constituent (i.e., stabilizer) of chlorinated solvents, in particular 1,1,1-trichloroethane (TCA). Evidence regarding the co-occurrence of 1,4-dioxane and trichloroethylene (TCE), however, has been heavily debated. In fact, the prevailing opinion is that 1,4-dioxane was not a constituent of past TCE formulations and, therefore, these 2 contaminants would not likely co-occur in the same groundwater plume. Because historic handling, storage, and disposal practices of chlorinated solvents have resulted in widespread groundwater contamination at USAF installations, significant potential exists for unidentified 1,4-dioxane contamination. Therefore, the objective of this investigation is to determine the extent to which 1,4-dioxane co-occurs with TCE compared to TCA, and if these chemicals are co-contaminants, whether or not there is significant correlation using available monitoring data. To accomplish these objectives, the USAF Environmental Restoration Program Information Management System (ERPIMS) was queried for all relevant records for groundwater monitoring wells (GMWs) with 1,4-dioxane, TCA, and TCE, on which both categorical and quantitative analyses were carried out. Overall, ERPIMS contained 5788 GMWs from 49 installations with records for 1,4-dioxane, TCE, and TCA analytes. 1,4-Dioxane was observed in 17.4% of the GMWs with detections for 93.7% of all 1,4-dioxane detections, verifying that 1,4-dioxane is seldom found independent of chlorinated solvent contamination. Surprisingly, 64.4% of all 1,4-dioxane detections were associated with TCE independently. Given the extensive data set, these results conclusively demonstrate for the first time that 1,4-dioxane is a relatively common groundwater co-contaminant with TCE. Trend analysis demonstrated a positive log-linear relationship where median 1,4-dioxane levels increased between approximately 6% and approximately 20% of the increase in TCE levels. In conclusion, this data mining exercise suggests that 1,4-dioxane has a probability of co-occurrence of approximately 17% with either TCE and/or TCA. Given the challenges imposed by remediation of 1,4-dioxane and the pending promulgation of a federal regulatory standard, environmental project managers should use the information presented in this article for prioritization of future characterization efforts to respond to the emerging issue. Importantly, site investigations should consider 1,4-dioxane a potential co-contaminant of TCE in groundwater plumes. Integr Environ Assess Manag 2012;8:731–737. © 2012 SETAC

Keywords: 1,4-Dioxane 1,1,1-Trichloroethane Trichloroethylene Groundwater Co-occurrence

INTRODUCTION

The United States Air Force (USAF) Emerging Issues Program has recently considered 1,4-dioxane as an emerging contaminant. Although relatively little is known about the occurrence, fate, and transport of 1,4-dioxane in the environment (Mohr 2001, Mohr and Jacobs 2005; DiGuiseppi and Whitesides 2007), numerous toxicity studies suggest that 1,4-dioxane has the potential to negatively impact human health (Stickney et al. 2003; ATSDR 2007; USEPA 2010). The United States Environmental Protection Agency's (USEPA) Integrated Risk Information System (IRIS) has recently developed oral noncancer and revised cancer toxicity assessments (USEPA 2010), which will likely be used to develop a federal maximum contaminant level (MCL) for drinking water and regulatory screening levels for groundwater and soil. Some states and other regulatory entities currently regulate 1,4-dioxane levels in environmental media (Mohr 2001; USEPA 2006; ATSDR 2007). Increasing regulatory attention has prompted the USAF to evaluate potential environmental liabilities posed by 1,4-dioxane contamination at an enterprise scale.

Because of its solvent and stabilizing properties, many commercial products contain (or contained) 1,4-dioxane. Existing household products that contain 1,4-dioxane as a solvent include, but are not limited to, lacquers, paints, varnishes, resins, oils, waxes, dyes, and adhesives (USEPA 1995; Mohr 2001). Additionally, 1,4-dioxane is found currently in a wide range of industrial products including insecticides, fumigants, aircraft deicing fluids, and antifreeze (Mohr 2001; Surprenant 2002). Although recent production

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ELSEVIER

1,4-Dioxane pollution at contaminated groundwater sites in western Germany and its distribution within a TCE plume

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HIGHLIGHTS

- 1,4-Dioxane was evaluated in German groundwater and was detected at all sites tested.
- Max. concentrations of 1,4-dioxane exceed the 0.1 μg/L assessment value at each site.
- Highest concentration of 1,4-dioxane was detected in a VCH plume (152 μg/L).
- Depth distribution of 1,4-dioxane exhibited strong correlation with TCE.

GRAPHICAL ABSTRACT

ARTICLE INFO

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Germany
Distribution pattern
Landfill leachate

ABSTRACT

An effective and sensitive method for the analysis of 1,4-dioxane in water has been available since 2008 (EPA 522). This method is increasingly being applied to investigate the distribution of 1,4-dioxane in the aquatic environment. However, there is a need for more information about the possible occurrence of 1,4-dioxane in groundwater in Europe in general, and in Germany in particular, where virtually no data have been collected so far. The possible contamination of groundwater with 1,4-dioxane is of relevance to Germany because up to 70% of Germany's drinking water is obtained from groundwater and about 17% from river bank filtrate, which contains variable proportions of groundwater. The aim of the present study is to investigate selected and representative groundwater sites in Germany that have suspected occurrences of 1,4-dioxane. Five of the sites are well known for their volatile chlorinated hydrocarbon contamination, two sites have representative landfill leachate characteristics, and one site is negatively impacted by a detergent manufacturing plant. The presence of 1,4-dioxane was observed at each of these sites. Measured maximum concentration values ranged from 0.15 μg/L to 152 μg/L. An aquifer containing a trichloroethylene (TCE) plume with 1,4-dioxane as a co-contaminant was investigated in more detail. A perfect match was found between the concentrations of 1,4-dioxane and TCE in the vertical and horizontal distribution profiles. The results indicate the necessity for investigating groundwater contamination by 1,4-dioxane at sites with known 1,1,1-trichloroethane (TCA) and TCE contaminations, in landfill leachates, and at sites of detergent production.

1,4-Dioxane: Another forever chemical plagues drinking-water utilities

Highly miscible in water, the likely carcinogen is challenging to remove

by *Cheryl Hogue*

November 8, 2020 | A version of this story appeared in **Volume 98, Issue 43**

https://cen.acs.org/environment/pollution/14-Dioxane-Another-forever-chemical/98/i43

Credit: Shutterstock

1,4-Dioxane is an unwanted by-product occurring in small amounts in shampoos, detergents, and cleaning products. It has also contaminated some communities' drinking water.

WATER RELEASES

The top three US dischargers of 1,4-dioxane into rivers or public sewage systems in 2019 were from pharmaceutical and plastics plants, according to data filed with the Environmental Protection Agency.

Indorama Ventures

- Plastics
- Decatur, Alabama
- 10,453 kg
- To sewage system, then the Tennessee River

APG Polytech, a subsidiary of Taiwan-based Far Eastern New Century

- Plastics
- Apple Grove, West Virginia
- 8,922 kg
- To the Ohio River

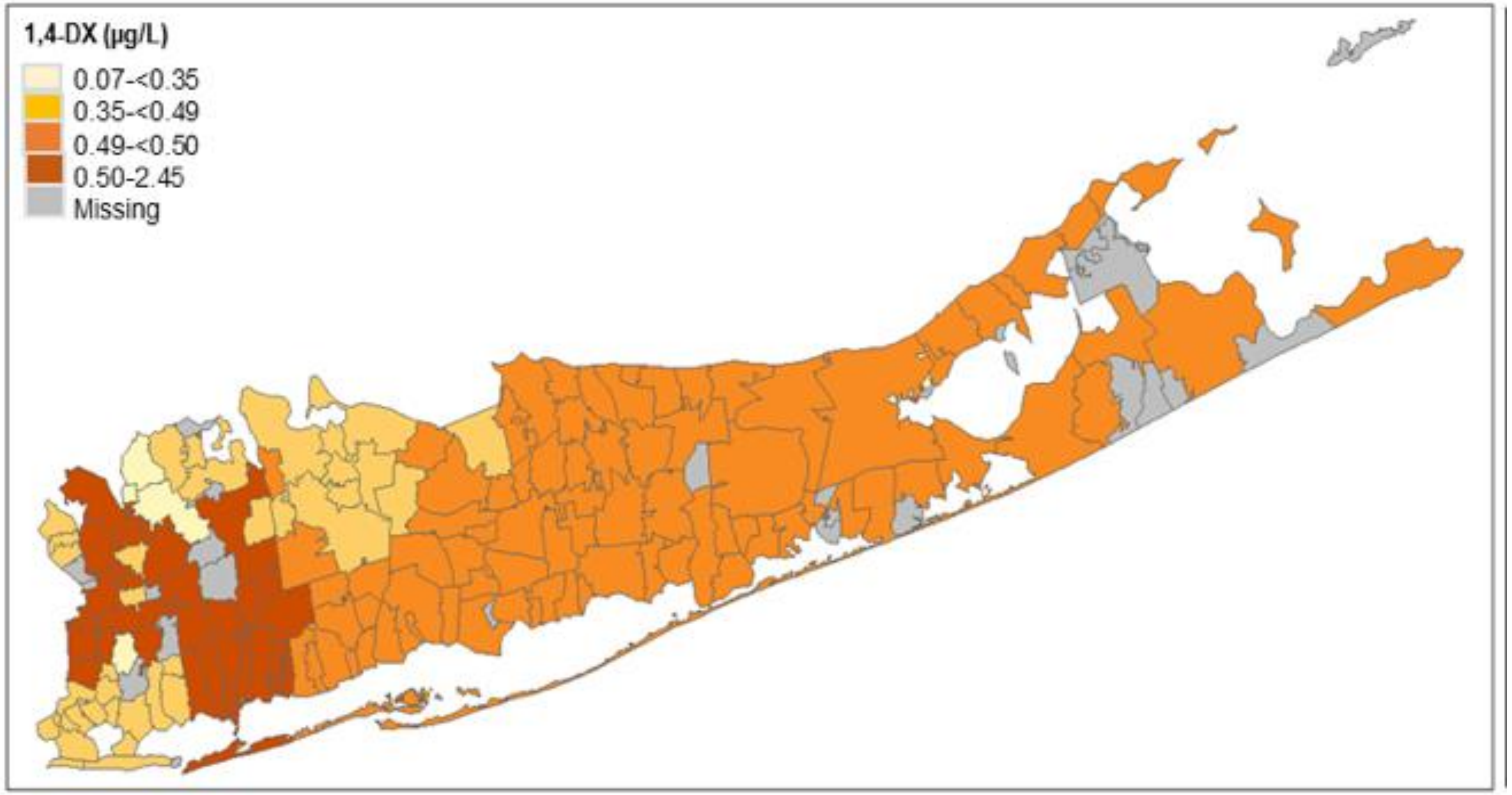
DAK Americas, a subsidiary of Mexico-based Alpek

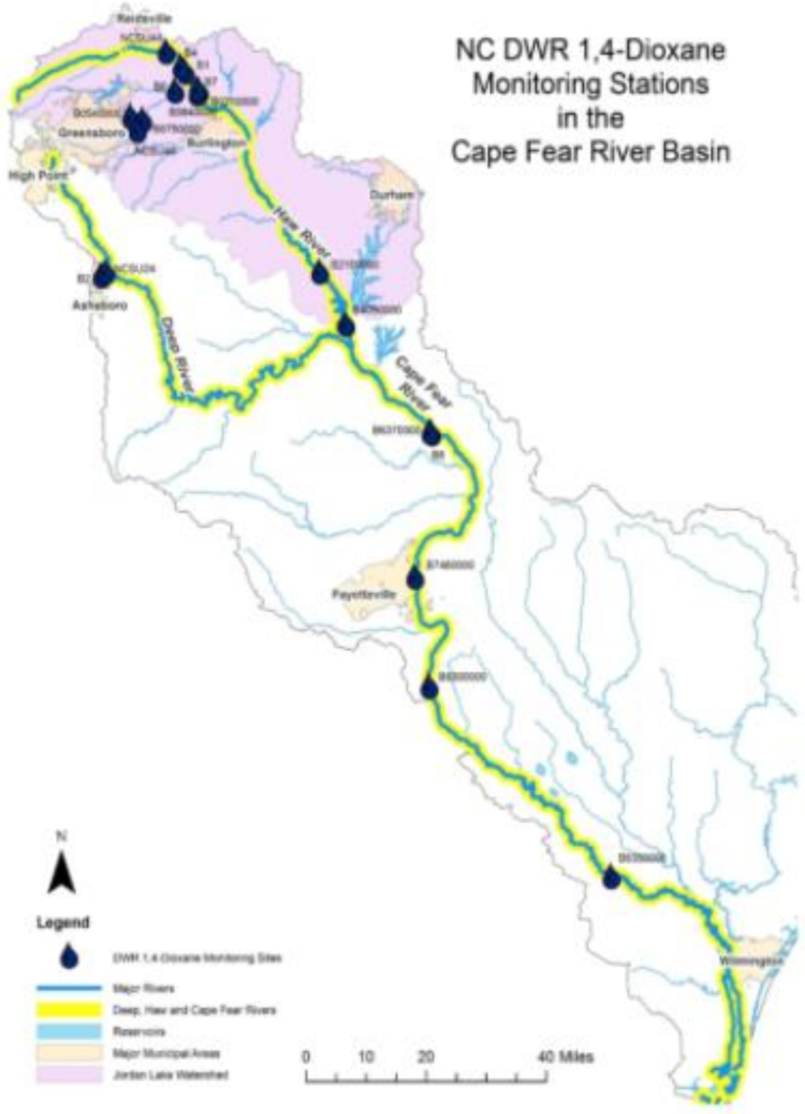
- Plastics
- Moncks Corner, South Carolina
- 8,057 kg
- To the Cooper River

Source: US EPA Toxics Release Inventory, 2019.

Note: The largest environmental release of 1,4-dioxane in 2019 was reported from Huntsman International's Houston plant. This facility sent 197,713 kg of 1,4-dioxane for disposal in an underground injection well.

Long Island NY and North Carolina





Ann Harbor, Michigan

1,4-dioxane groundwater pollution eventually could cause vapors in some Ann Arbor basements

Michigan Radio | By Lester Graham
Published December 1, 2022 at 2:49 PM EST

Scio Residents For Safe Water /

A graphic representation of the dioxane plume under Ann Arbor

A newly published study suggests a plume of contaminated groundwater could eventually get into home basements in parts of Ann Arbor.

The research by University of Michigan scientists suggests that a current plume of the chemical 1,4-dioxane in groundwater will get closer to the surface.

ELSEVIER

Available online at www.sciencedirect.com
ScienceDirect

Current Opinion in
Environmental Science & Health

Atmosphere of wet basements as a novel route for potential residential exposure to 1,4-dioxane vapor

Robert E. Bailey[1,2] and Rita Loch-Caruso[2,3]

Abstract
Detection of 1,4-dioxane has been reported in shallow groundwater in neighborhoods of the city of Ann Arbor, Michigan. Michigan has a voluntary 1,4-dioxane shallow groundwater screening level based on its potential for vapor intrusion. Calculations show that if 1,4-dioxane-contaminated water were to enter a basement and evaporate, potentially unhealthy concentrations of 1,4-dioxane could arise in homes with damp basements under certain conditions. Potential residential risk is suggested if: 1) shallow groundwater is within 3 m of the surface, 2) groundwater 1,4-dioxane concentration exceeds 150 μg/L, and 3) a basement has higher humidity than the upper floors. Different from vapor intrusion, this suggests that liquid water intrusion with subsequent volatilization within a structure may be a novel exposure pathway for 1,4-dioxane.

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Corresponding author: Bailey, Robert E. (bob.bailey734@gmail.com)

Current Opinion in Environmental Science & Health 2022, **30**:100406

This review comes from a themed issue on **Environmental Toxicology 2022: 1,4 dioxane**

Edited by **Vasilis Vasiliou**

For complete overview of the section, please refer to the article collection - Environmental Toxicology 2022: 1,4 dioxane

https://doi.org/10.1016/j.coesh.2022.100406

Keywords
1,4-Dioxane pollution, Shallow groundwater, Protective air concentration, Vapor intrusion, Volatilization, Indoor air pollution.

and move with the water underground. It is miscible with water and does not readily volatilize from water [3]. Nonetheless, if liquid water contaminated with 1,4-dioxane were to enter a residence, then there is the potential for a hazardous vapor concentration from volatilization inside the residence even if groundwater concentrations present low vapor intrusion risk.

In this article, we describe calculations that illustrate the difference in risk potential from contaminated groundwater for evaporation of liquid water containing 1,4-dioxane in a basement compared with vapor intrusion. This project was initiated to explore a basis for evaluating the potential risk from 1,4-dioxane in shallow groundwater in residential areas using the city of Ann Arbor, Michigan, as an example.

Site description

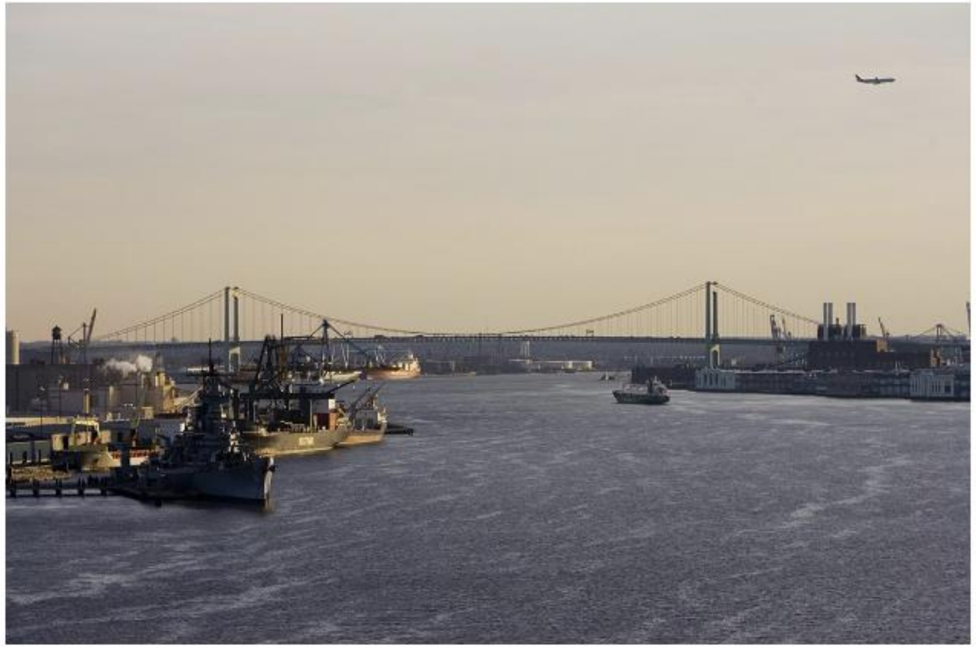
Wastewater management practices from 1966 to 1986 at Gelman Sciences, Inc. allowed 1,4-dioxane to contaminate groundwater [4*]. The resulting contamination plume, defined by concentrations above 1 μg/L, has spread laterally to an estimated area approximately 1.5 km wide by 7 km long (10 km^2). The eastern portion of this groundwater plume is shown on the map in Figure 1 (top panel).

The underlying geology of this area is approximately 50–90 m of unconsolidated glacial deposits above relatively impermeable Mississippian Coldwater Shale [5,6,7**]. Hydrogeological analysis delineating the extent of 1,4-dioxane contamination has revealed a complex series of interconnected aquifers as illustrated in the cross-sectional representation in Figure 1 (bottom panel) [2]. The cross section shows that land elevation slopes down from the west to the east, toward the Huron River (not shown), with decreasing distance between the land surface and the water table.

ENERGY & ENVIRONMENT

How a toxic chemical ended up in the drinking water supply for 13 million people

Officials found a gap in state and federal regulations that allowed an unsafe chemical to end up in an essential water supply.



The Delaware River incident highlights the extent to which drinking water suppliers are often on the hook for cleaning up other people's problems. | Matt Rourke/AP Photo

By RY RIVARD
01/23/2022 07:00 AM EST

TRENTON, N.J. — New Jersey's largest drinking water supplier discovered a toxic chemical in the river where it gets water for hundreds of thousands of customers, setting off a major search for polluters that led back to a Pennsylvania wastewater treatment plant and a South Jersey company.

1,4 Dioxane in New Jersey

AG Platkin, NJDEP, and Division of Consumer Affairs Announce 1,4-Dioxane Contamination Lawsuit

State's Complaint Seeks Compensation for Natural Resource Damages and Consumer Fraud

For Immediate Release: March 23, 2023

Office of the Attorney General
– Matthew J. Platkin, *Attorney General*
NJ Department of Environmental Protection
– Shawn M. LaTourette, *Commissioner*

For Further Information:

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Tara Oliver
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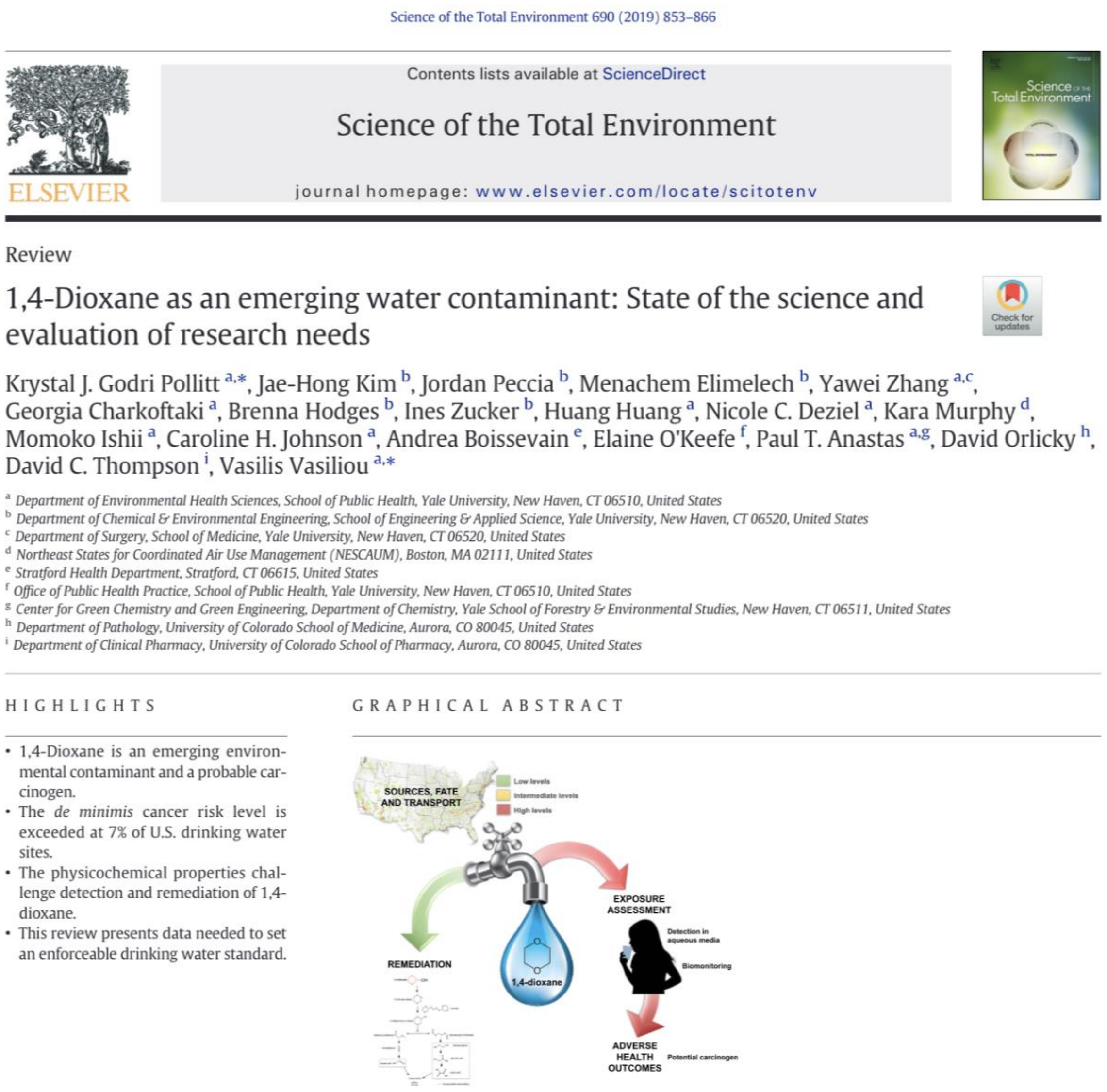
Lawrence Hajna, (DEP)
Larry.Hajna@dep.nj.gov

View Complaint

TRENTON – Attorney General Matthew J. Platkin, the New Jersey Department of Environmental Protection (DEP), and the Division of Consumer Affairs (DCA) today announced the filing of a lawsuit against the Dow Chemical Company (Dow), Ferro Corporation (Ferro), and Vulcan Materials Company (Vulcan), as well as other unnamed companies, for widespread 1,4-dioxane contamination across New Jersey. The suit alleges both environmental and consumer fraud claims, seeking natural resource damages, punitive damages, and other damages and penalties.

1,4-Dioxane: Emerging Water Contaminant



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Review

1,4-Dioxane as an emerging water contaminant: State of the science and evaluation of research needs

Krystal J. Godri Pollitt [a,*], Jae-Hong Kim [b], Jordan Peccia [b], Menachem Elimelech [b], Yawei Zhang [a,c], Georgia Charkoftaki [a], Brenna Hodges [b], Ines Zucker [b], Huang Huang [a], Nicole C. Deziel [a], Kara Murphy [d], Momoko Ishii [a], Caroline H. Johnson [a], Andrea Boissevain [e], Elaine O'Keefe [f], Paul T. Anastas [a,g], David Orlicky [h], David C. Thompson [i], Vasilis Vasiliou [a,*]

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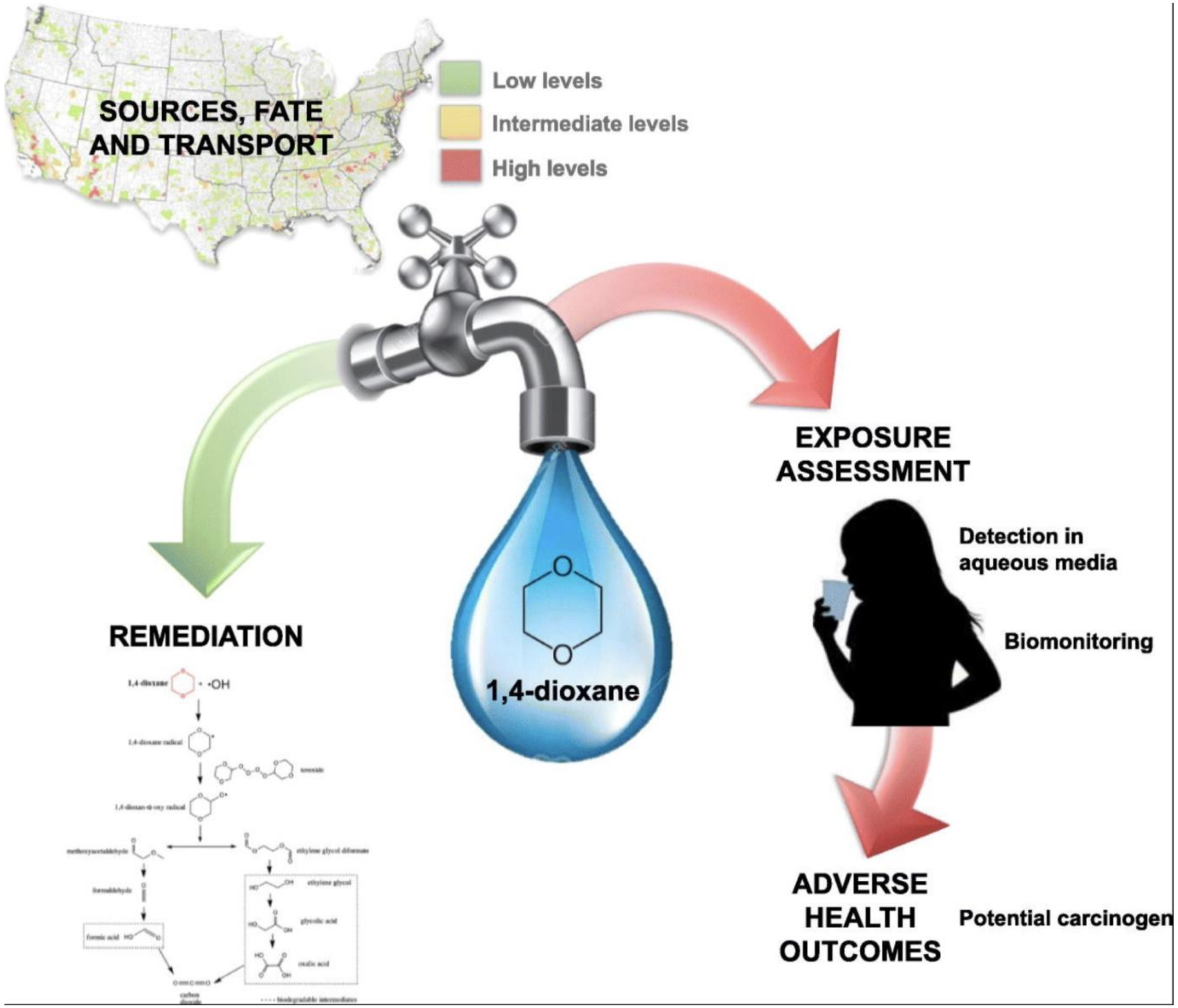
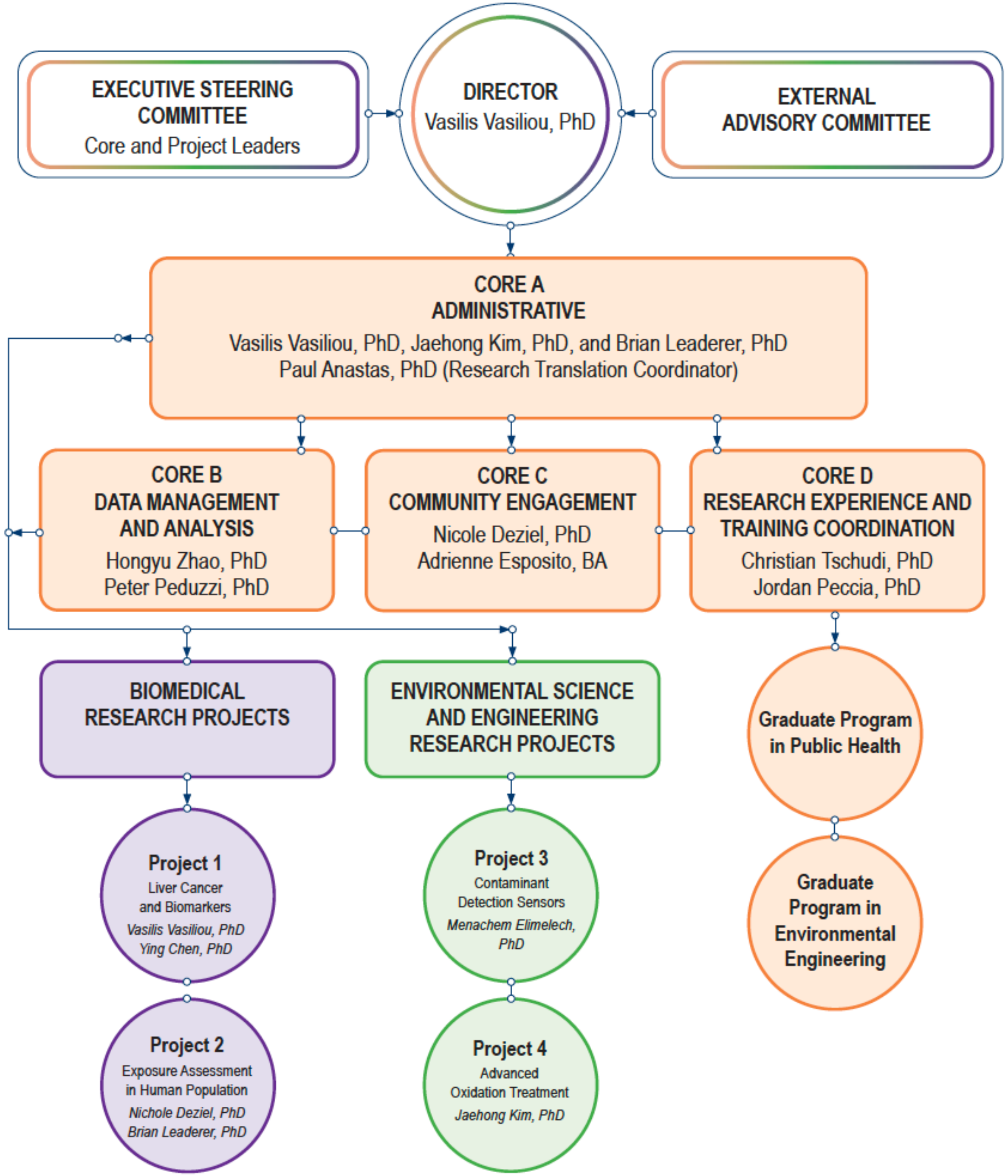
[f] Office of Public Health Practice, School of Public Health, Yale University, New Haven, CT 06510, United States
[g] Center for Green Chemistry and Green Engineering, Department of Chemistry, Yale School of Forestry & Environmental Studies, New Haven, CT 06511, United States
[h] Department of Pathology, University of Colorado School of Medicine, Aurora, CO 80045, United States
[i] Department of Clinical Pharmacy, University of Colorado School of Pharmacy, Aurora, CO 80045, United States

HIGHLIGHTS

- 1,4-Dioxane is an emerging environmental contaminant and a probable carcinogen.
- The *de minimis* cancer risk level is exceeded at 7% of U.S. drinking water sites.
- The physicochemical properties challenge detection and remediation of 1,4-dioxane.
- This review presents data needed to set an enforceable drinking water standard.

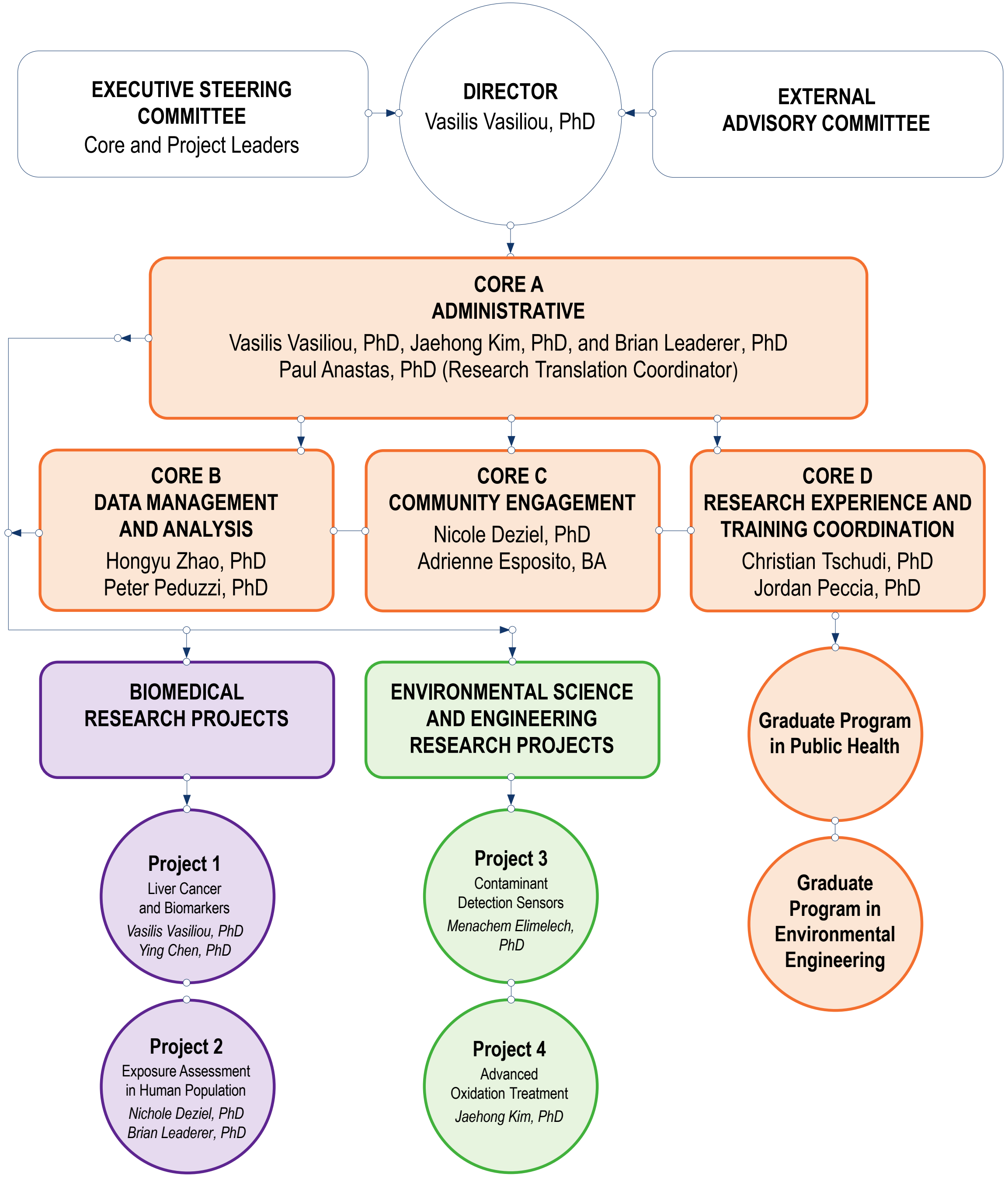
GRAPHICAL ABSTRACT





YSPH, YSEAS, YSE, and YSM

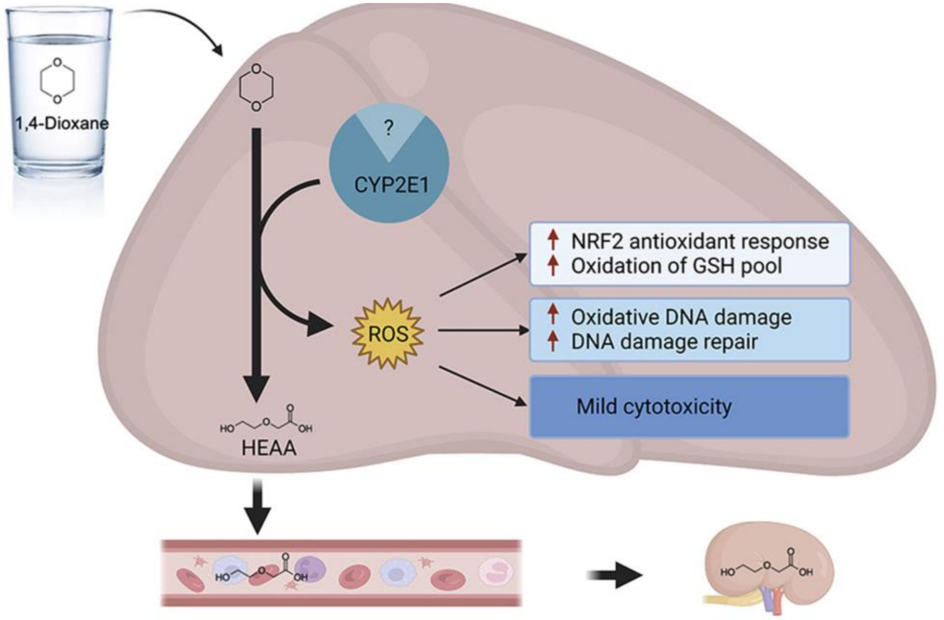
Led by Dr. Vasiliou, the Yale Superfund Research Center is to develop a problem-based, solution-oriented research and training program on emerging contaminants in drinking water, with the primary focus being 1,4-dioxane, and a secondary focus on its co-occurring contaminants, i.e., 1,1,1-trichloroethane, 1,1-dichloroethane, and 1,1,1-trichloroethylene.

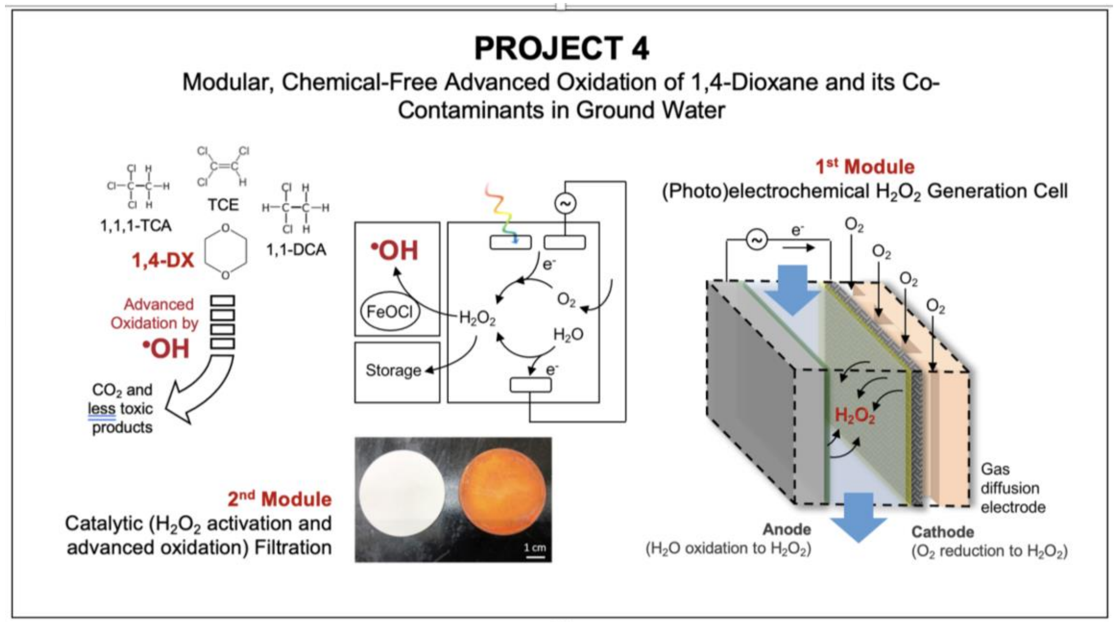


RESEARCH PROJECTS

Biomedical Research (BMR)	Environmental Science & Engineering (ESE)
PROJECT 1 Liver cancer & biomarkers *Vasilis Vasiliou, PhD* *Ying Chen, PhD*	**PROJECT 3** Contaminant detection sensors *Menachem Elimelech, PhD*
PROJECT 2 Exposure assessment *Nicol Deziel, PhD* *Brian Leaderer, PhD*	**PROJECT 4** Advanced oxidation treatment *Jaehong Kim, PhD*

Yale Superfund Research Center





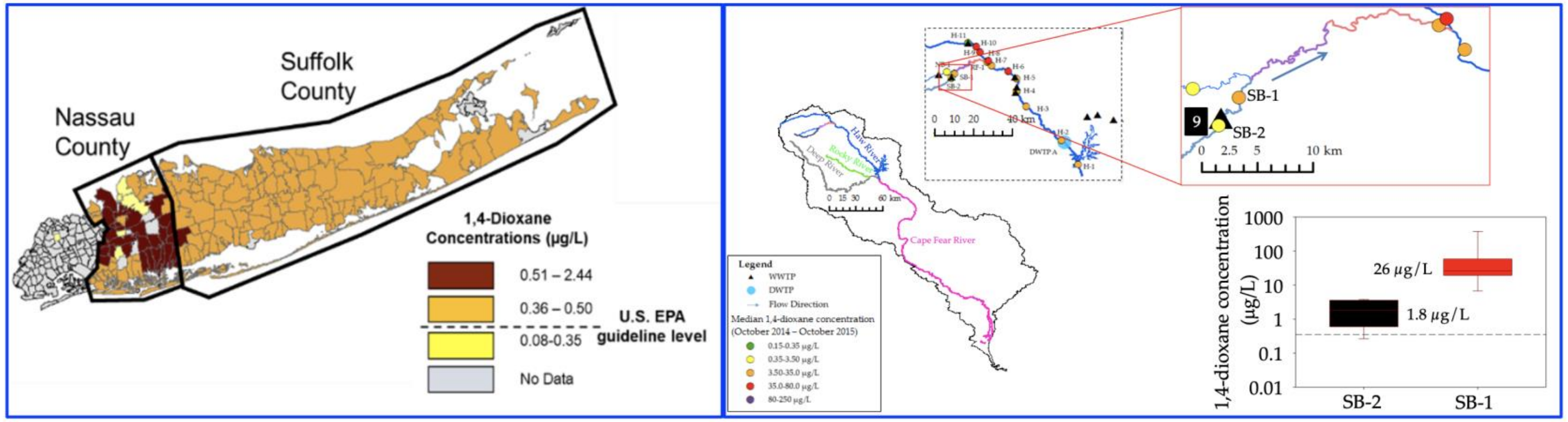


Figure 2. *The two geographical areas to be studied.* Long Island, New York (our primary study area) (left panel) (and Cape Fear River Watershed, North Carolina (secondary study site) (right panel).

CITIZENS CAMPAIGN FOR THE ENVIRONMENT

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Empowering Communities, Advocating Solutions.

The Yale University Superfund Center and Citizens Campaign for the Environment are partnering to

Understand the Impacts of 1,4-Dioxane Contamination on Long Island

Want to learn more about how this emerging contaminant impacts you, your family, and your community? Want to get involved?

Funded by the National Institute for Environmental Health Sciences, Citizens Campaign for the Environment has partnered with the Yale Superfund Research Center to engage with Long Island communities to better understand the impact of 1,4-dioxane exposure on Long Island communities.

What is 1,4 Dioxane?

1, 4-Dioxane, known as one of the "forever chemicals", is an emerging contaminant of concern found in drinking water throughout the nation, including water supplies in Long Island. Past industrial practices including discharging 1,4-dioxane into the ground which eventually seeped into Long Island aquifers that serve as our source of public water supplies and private wells. The EPA has established that 1,4-dioxane is likely carcinogenic to humans. **Exposure to this chemical is linked to tumors of the liver, gallbladder, nasal cavity, lung, skin, and breast.**

Is there 1,4 Dioxane in my community?

The Environmental Protection Agency (EPA) tested 4,400 water supply systems nationwide and Long Island was found to have some of the highest levels of 1,4-dioxane detection in the US, with some water systems in both Nassau and Suffolk containing levels over 100 times the EPA's cancer risk guideline of 0.35 ppb. Exposure to 1,4-dioxane most likely occurs through drinking contaminated water, however, it may also be inhaled or absorbed through skin.

STUDY SEEKS DIOXANE LINK TO LIers' HEALTH

'First of its kind' look into effects of exposure

BY LISA L. COLANGELO
lisa.colangelo@newsday.com

Yale researchers are looking for 500 Long Islanders to participate in a study that will help them better understand exposure to the chemical 1,4-dioxane, a likely carcinogen found in both drinking water and common household products.

Participants will have their blood as well as their home's tap water tested to help determine if there is any correlation between levels of 1,4-dioxane found in water and a person's body, researchers said. The study is part of an effort to understand links between exposure to 1,4-dioxane and potential health risks.

The study, being conducted by the university's Yale Superfund Research Center with a grant from the National Institutes of Health, will start with a small pilot project this summer.

The chemical — found in drinking water on Long Island — has been used as a stabilizer in solvents such as paint strippers and waxes. It is also a byproduct in the manufacture of shampoos, shower gels and other consumer goods and in laboratory animal tests has been linked to cancers as well as liver and kidney damage.

"Who has one of the highest exposures in the nation? Long Island. And that's where this is focused on," Vasilis Vasiliou, director of the Yale Superfund Research Center, said Monday during a virtual conference to discuss the study and seek participants.

"We really just don't have a lot of information or data on this chemical," said Nicole Deziel, associate professor at the Yale School of Public Health and a graduate of Longwood High School in Middle Island who is leading the study. "Exposures and health impacts are really poorly understood and we really hope to provide more information to better understand this chemical so we can reduce people's exposures and risk."

The study is part of a larger initiative at the Yale Superfund Research Center that includes examining how 1,4-dioxane can cause cancer, monitoring water for the chemical in real time and developing affordable methods for purifying water, said Vasiliou. The center this fall received a $7.3 million grant over five years from the National Institute of Environmental Health Sciences for the research.

Deziel said it has not been determined yet when the study finding would be released.

In recent years, New York State has enacted strict limits on 1,4-dioxane in drinking water and household products. Drinking water must not contain more than 1 part per billion of the chemical while personal care and household cleaning products were required not to exceed 2 parts per million by the end of 2022. That limit drops to 1 ppm by the end of 2023.

Newsday reported Monday that the state has granted temporary waivers to manufacturers allowing more than 1,400 products over the state limit to remain on store shelves. Waivers are permitted under the state's law, which gives manufacturers time to comply with the limits.

The Long Island-based Citizens Campaign for the Environment, which advocated for limits of the chemical, is working with researchers to help them find volunteer participants.

"This is the first of its kind study we believe anywhere in the nation and specific to Long Island," said Adrienne Esposito, executive director and cofounder of the CCE.

People interested in more information about the study can go to the CCE website to sign up.

Deziel said growing up on Long Island sparked her interest in environmental health.

"When I was growing up in the '80s and '90s there were a lot of concerns about cancer clusters," she said, noting people wondered if pesticides from farms or power lines could be the cause. "I was really frustrated by the lack of information and uncertainty about these exposures and that really motivated me to get my degree in this area and become an environmental epidemiologist."

Researchers are hoping to get a cross section of Long Islanders including residents connected with municipal water systems and those who rely on well water.

Participants take a 90-minute survey at home with researchers, who will take a sample of their blood and tap water. In return they will receive a $20 gift card and all test results.

Yale Superfund Research Center

Project 1

Toxicity and Liver Carcinogenicity of 1,4-Dioxane: Single Chemical and Mixtures Studies

NIEHS Superfund Research Program (SRP)
Progress in Research Webinar Series

April 28, 202

Project 1 Team

Yale School of Public Health

Ying Chen, PhD (PI)

Vasilis Vasiliou, PhD (PI)

Yewei Wang
PhD

Georgia Charkoftaki
PhD

Caroline Erickson
MPH

Collaborators

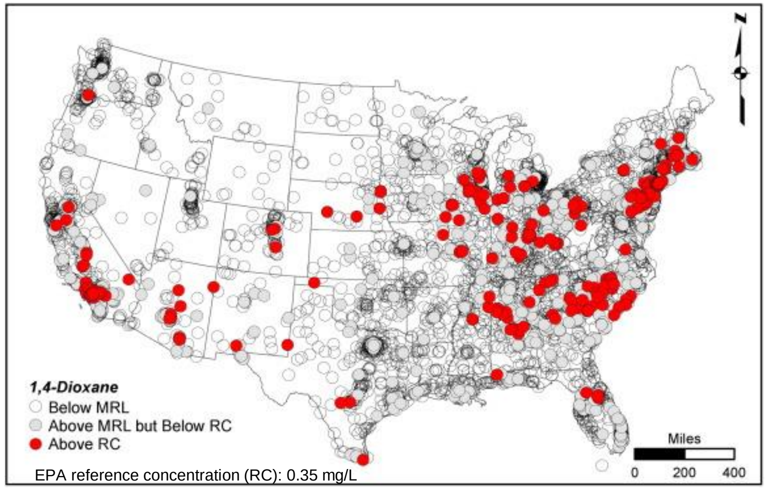
Steven Ferguson, PhD
NIEHS

Robyn Tanguay, PhD
Oregon State University

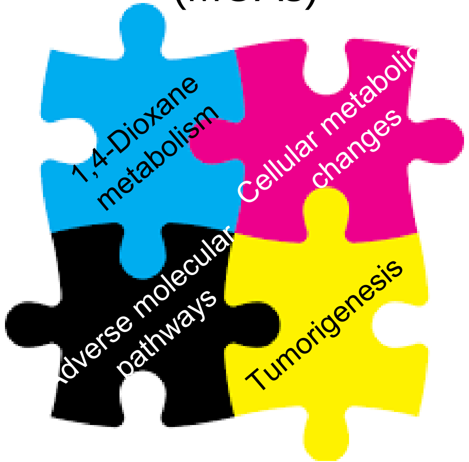
Goals

What we know…

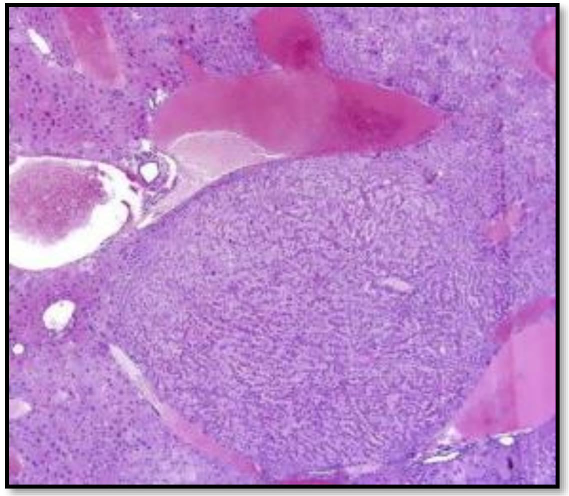
Widespread water contamination in USA



Mechanisms of Action (MOAs)



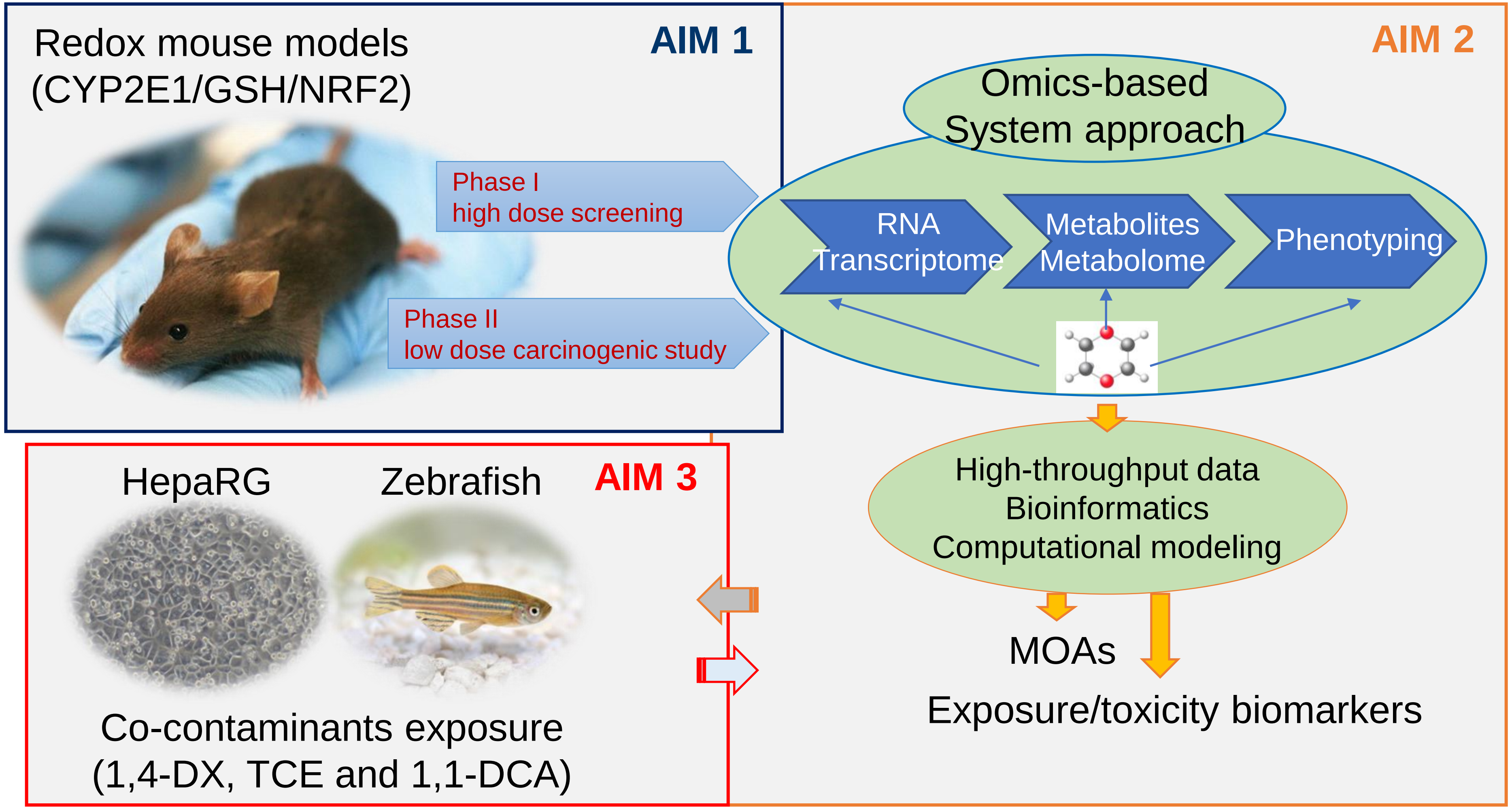
IARC group 2B liver carcinogen



What we do not know…

The goals of this project are to identify molecular mechanisms involved in 1,4-dioxane (1,4-DX) liver carcinogenicity and to assess the capacity of co-occurring contaminants (TCE and 1,1-DCA) in modifying 1,4-DX carcinogenicity.

Approach (Specific Aims)



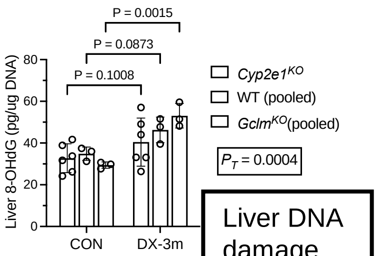
Year 1 Progress – AIM 1

Phase I
high dose screening (5000 ppm x 3 months)

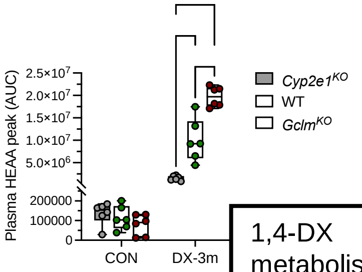
Oxidative stress, glutathione, and CYP2E1 in 1,4-DX liver cytotoxicity and genotoxicity: insights from animal models. (*Wang et al.* Curr Opin Environ Sci Health. 2022)

HIGHLIGHTS

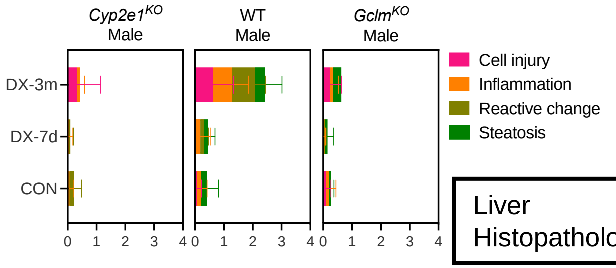
- A direct genotoxic effect by 1,4-DX involving oxidative stress
  (*Chen et al*. Sci Total Environ. 2022)
- A dominant role of CYP2E1 in 1,4-DX metabolism to HEAA and 1,4-DX liver cytotoxicity
- 1,4-DX liver genotoxicity likely involves CYP2E1-independent pathway(s)
  (Wang et al. To be submitted*)*



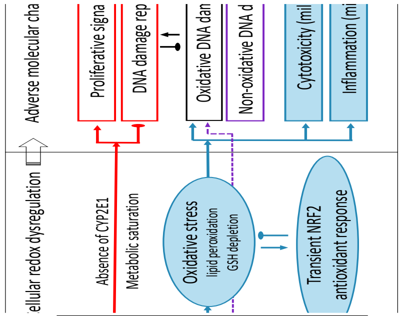
Liver DNA damage



1,4-DX metabolism



Liver Histopathology Score



Proposed MOA

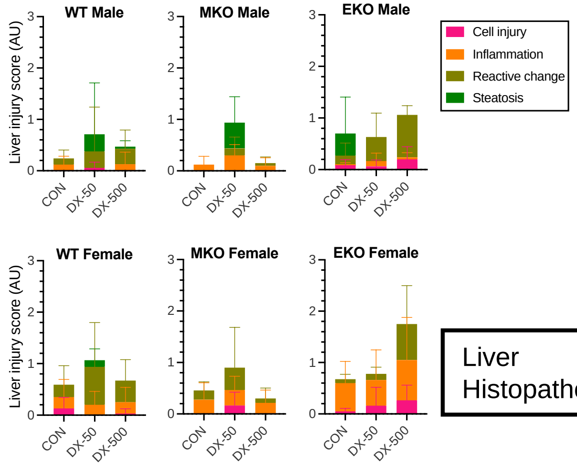
Year 1 Progress – AIM 1

Phase II
low dose carcinogenic study (50, 500 ppm x 6 months)

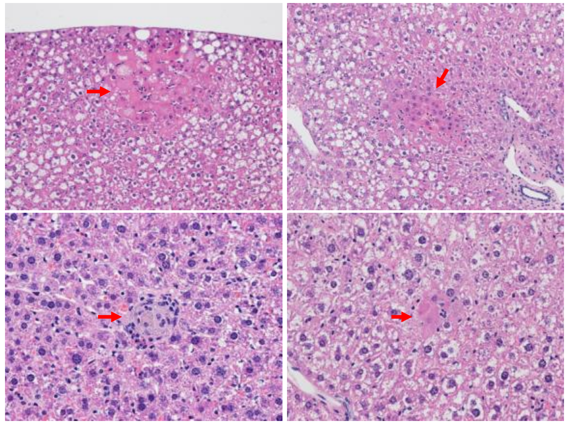
Initial phenotypic characterization of chronic exposure to environmentally-relevant low doses of 1,4-DX.

PRELIMINARY FINDING

- Minimal systemic and hepatic toxicity
- A higher incidence of developing hepatocellular hyperplasia in the *Gclm*[KO] male mice



Liver
Histopathology Score



Hepatocellular hyperplasia (case/total animals)			
MALE	**WT**	**MKO**	**EKO**
CON	0/5	0/5	0/6
DX-50	0/9	**2/5**	0/6
DX-500	0/7	**1/7**	0/6
FEMALE	**WT**	**MKO**	**EKO**
CON	0/10	0/5	0/4
DX-50	0/10	0/6	0/5
DX-500	**1/10**	0/6	0/6

Year 1 Progress – AIM 2
Data collection

- ✓ Plasma metabolomics
- ✓ Liver metabolomics and transcriptomics (high dose)

Yale Superfund Research Center

Project 1

Toxicity and Liver Carcinogenicity of 1,4-Dioxane: Single Chemical and Mixtures Studies

NIEHS Superfund Research Program (SRP)
Progress in Research Webinar Series

April 28, 2023

Yale Superfund Research Center

Project 4

Modular, Chemical-Free Advanced Oxidation of 1,4-Dioxane and its Co-Contaminants in Ground Water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Professor

John Fortner (Co-I)
Associate Professor




Dr. Wensi Chen
Postdoctoral Researcher

David Kim
5th year Ph.D. Student

Seung Hee Chae
2nd year Ph.D. Student

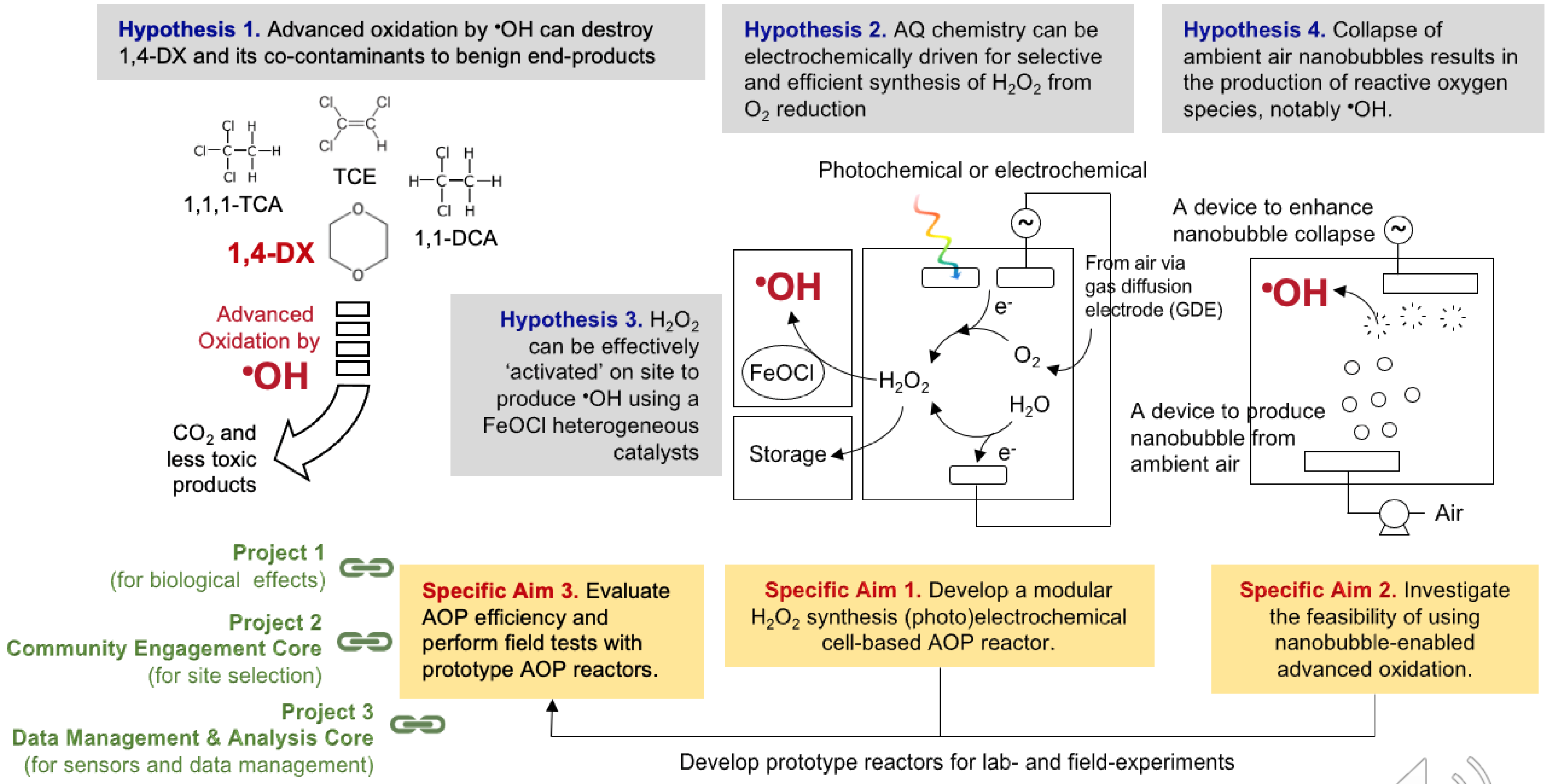
Leslie Arrazolo
1st year Ph.D. Student

Project Objectives

Develop **point-of-use, small-scale, and chemical-supply-free water** treatment units that can destroy 1,4-dioxane and its frequently co-occurring pollutants from contaminated ground water through **advanced oxidation.**

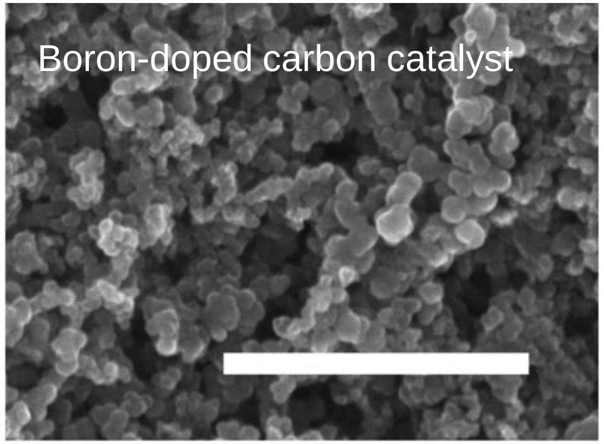
Test the prototype reactors both in the lab and in Region 1 field sites to verify the feasibility of real-world use, to confirm the elimination of human toxicity, and to establish faster technology transfer in collaboration with other project teams.

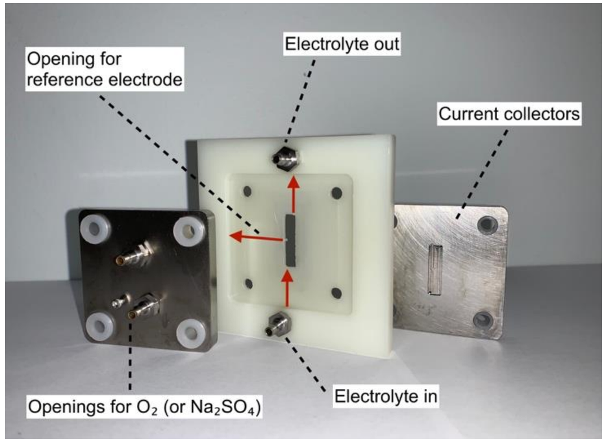
Specific Aims

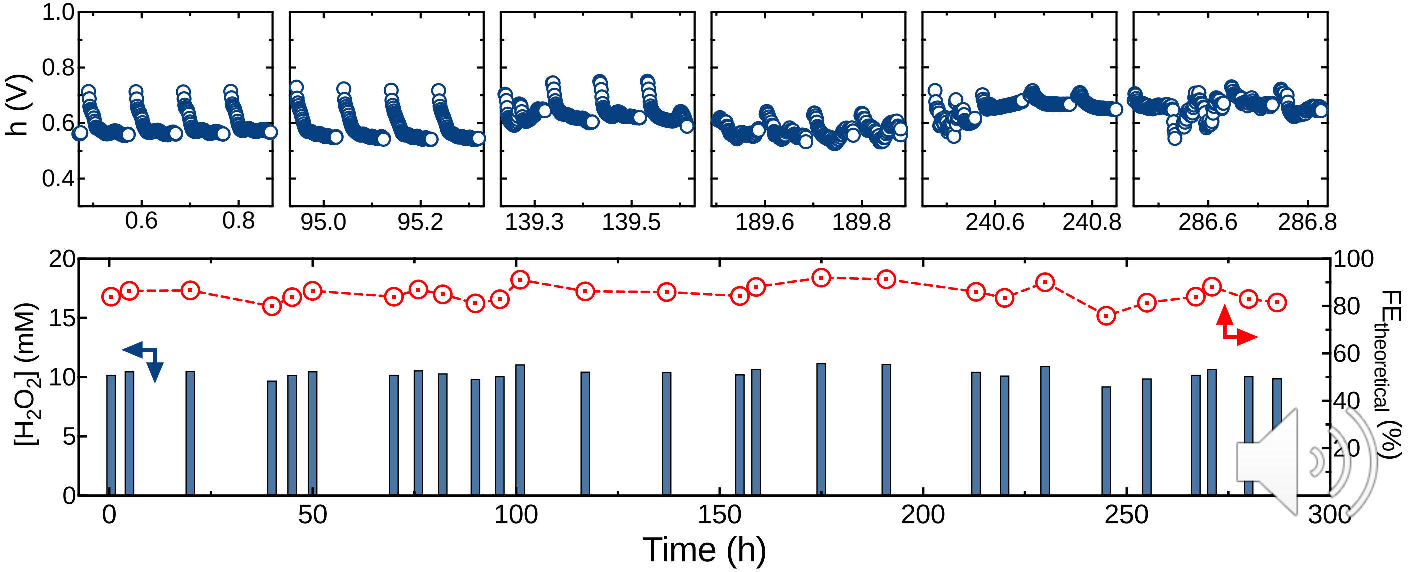


Year 1 Progress Specific Aim 1

Kim et al., *Environmental Science & Technology,* submitted



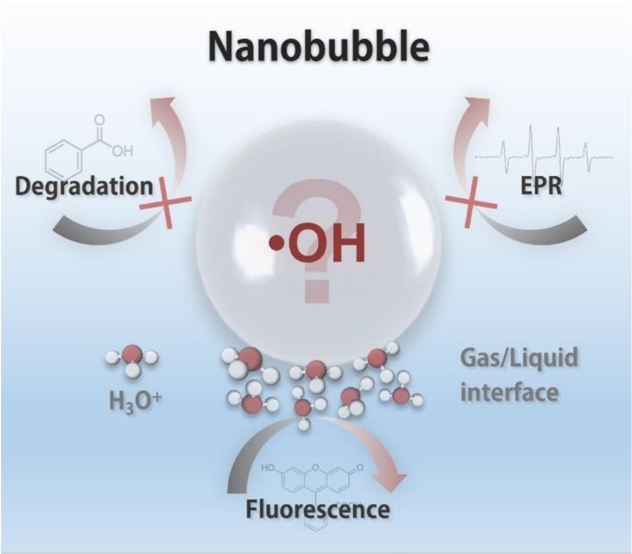


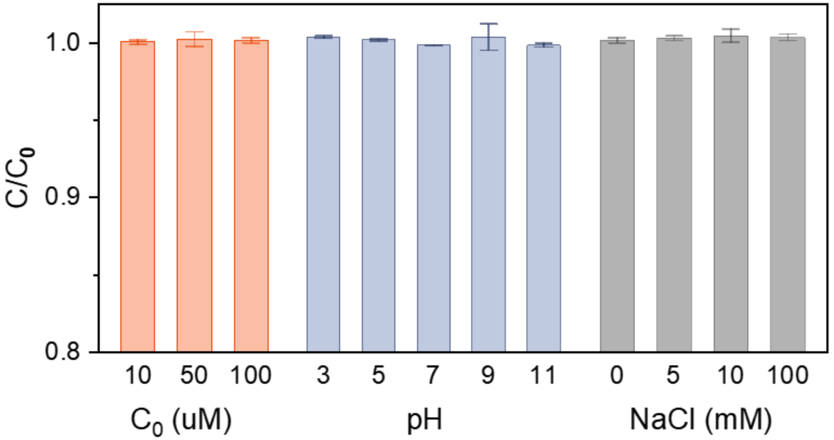


Pulsed Electrolysis for long-term H_2O_2 production (~300 hours)

Year 1 Progress Specific Aim 2

Chae et al., *ACS ES&T Engg.*, submitted





False fluorescence signaling for •OH resulting from local pH change