Superfund Research Center

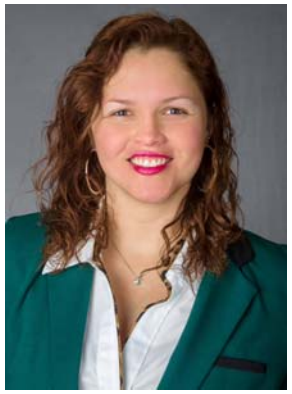
Superfund Research Program Progress in Research Webinar
Part 2: Legacy and Emerging Contaminants (PAHs, PCBs, PFAS)

October 28, 2020

Presenters:

Dr. Kelly Pennell

Dr. Pan Deng



Dr. Angela Gutierrez

Director: Kelly Pennell, Ph.D., P.E. (kellypennell@uky.edu)
Deputy Director: Bernhard Hennig, Ph.D., R.D. (bhennig@uky.edu)
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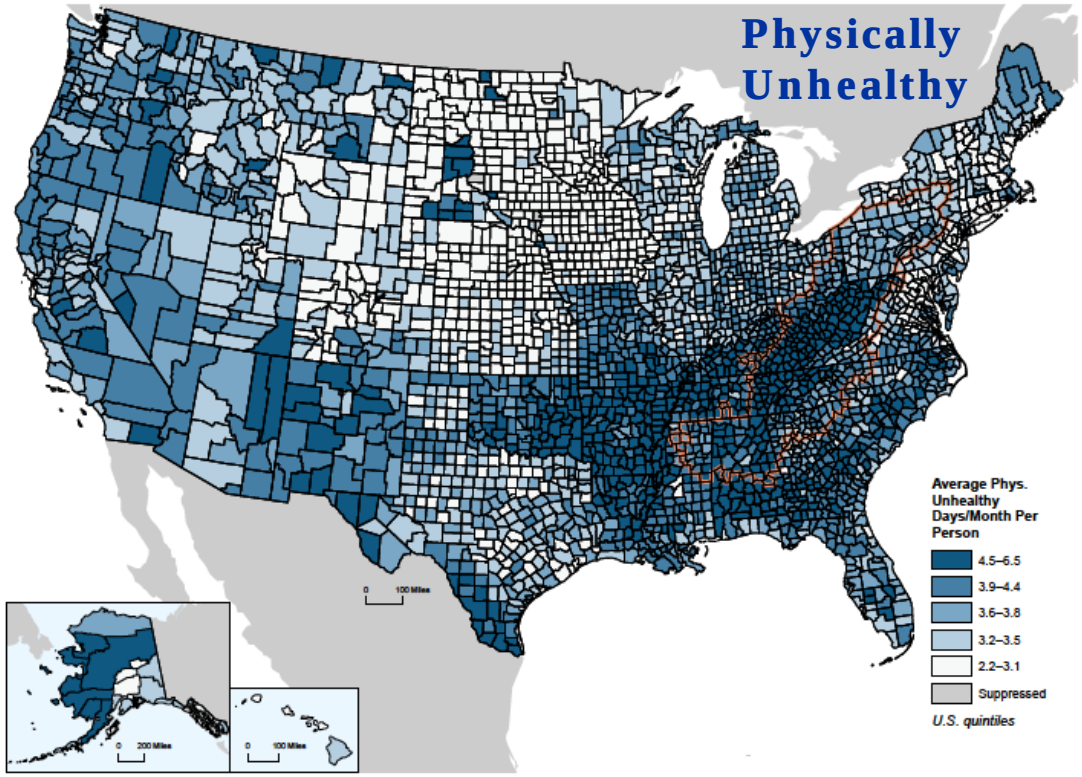
NIEHS Grant: P42ES007380

http://superfund.engr.uky.edu/

@UK_SRC

Health Disparities

- Within Central Appalachia, there is a higher risk of premature death due to diabetes (27% higher), cardiovascular disease (82% higher), and adult obesity (34.7% higher), as compared to national averages as a whole.



Data source: County Health Rankings & Roadmaps, 2016 edition. University of Wisconsin Population Health Institute supported by Robert Wood Johnson Foundation http://www.countyhealthrankings.org/rankings/data.

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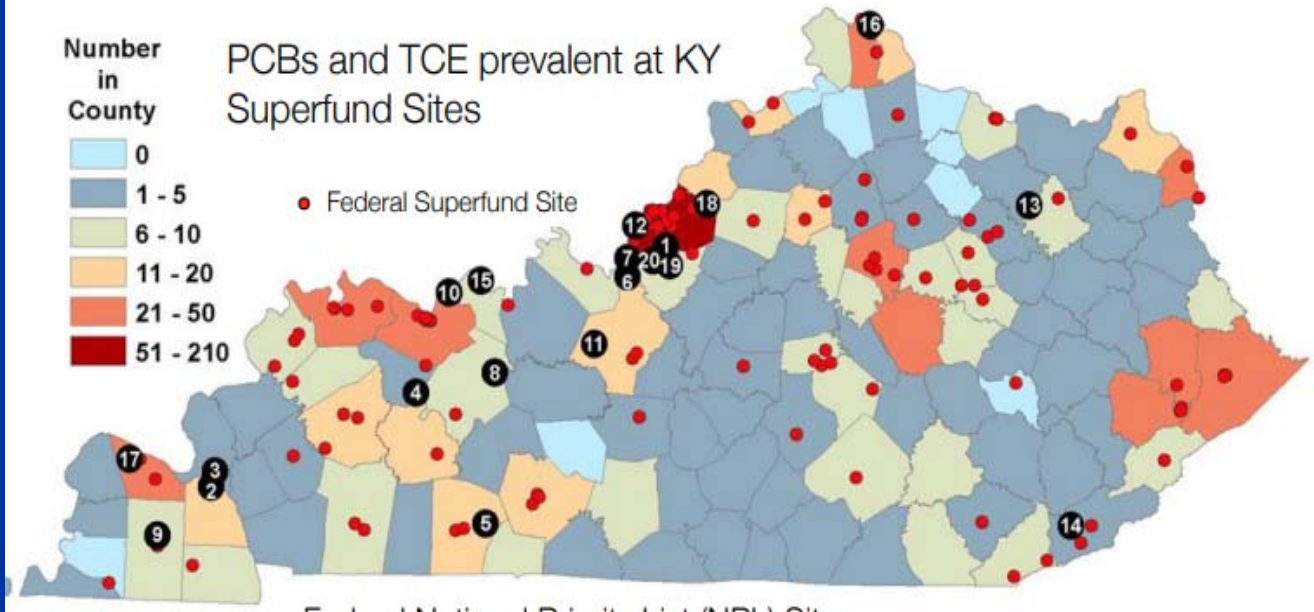
Kentucky's Superfund Sites

- Kentucky contains hundreds of contaminated sites, of which thirteen (13) are listed on the National Priority List (NPL).
- There are approximately 250 sites in Kentucky, which are referred to as "state-led" Superfund sites, with over 400 more sites pending review.
- Pollutants of interest include: PFAS, PCBs and chlorinated ethenes (TCE, PCE, etc.)



Federal National Priority List (NPL) Sites

1. A.L. Taylor (Valley of the Drums) *
2. Airco
3. B.F. Goodrich
4. Brantley Landfill
5. Caldwell Lace Leather Co.
6. Distler Brickyard
7. Distler Farm
8. Fort Hartford Coal Co. Stone Quarry
9. General Tire and Rubber (Mayfield Landfill) *
10. Green River Disposal
11. Howe Valley Landfill *
12. Lee's Lane Landfill *
13. Maxey Flats Nuclear Disposal
14. National Electric Coil/Cooper Industries
15. National Southwire Aluminum Co. *
16. Newport Dump *
17. U.S. DOE Gaseous Diffusion Plant
18. Red Penn Sanitation Co. Landfill *
19. Smith's Farm
20. Tri-City Disposal Co.

* Sites that are no longer active on the National Priority List.

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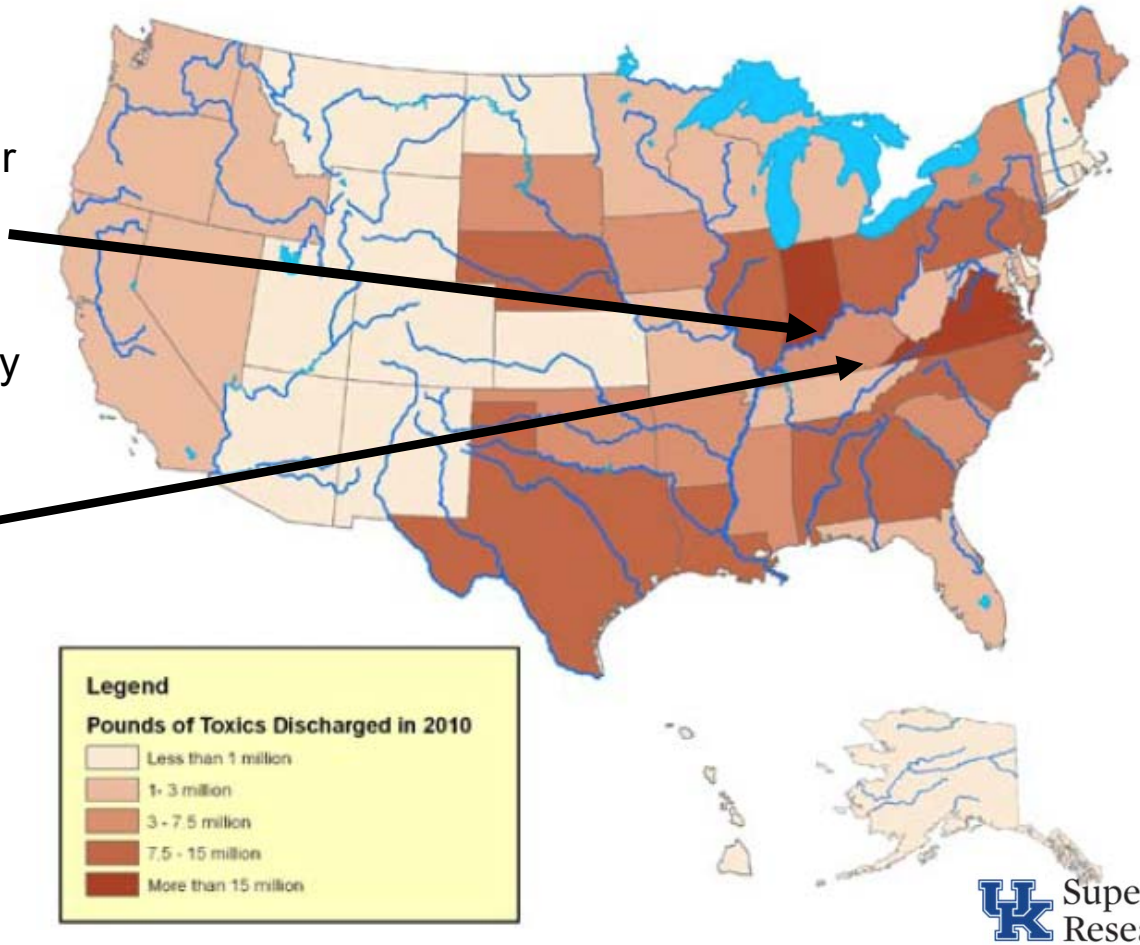
Toxics - PCBs…and PFAS

Kentucky ranks moderate for toxic discharges, but is bordered by two states ranked highest.

- To the north, the Ohio River serves as an important waterway for KY and has the highest toxics discharges of any waterway in the US.
- Kentucky's southeast border has high health disparities.



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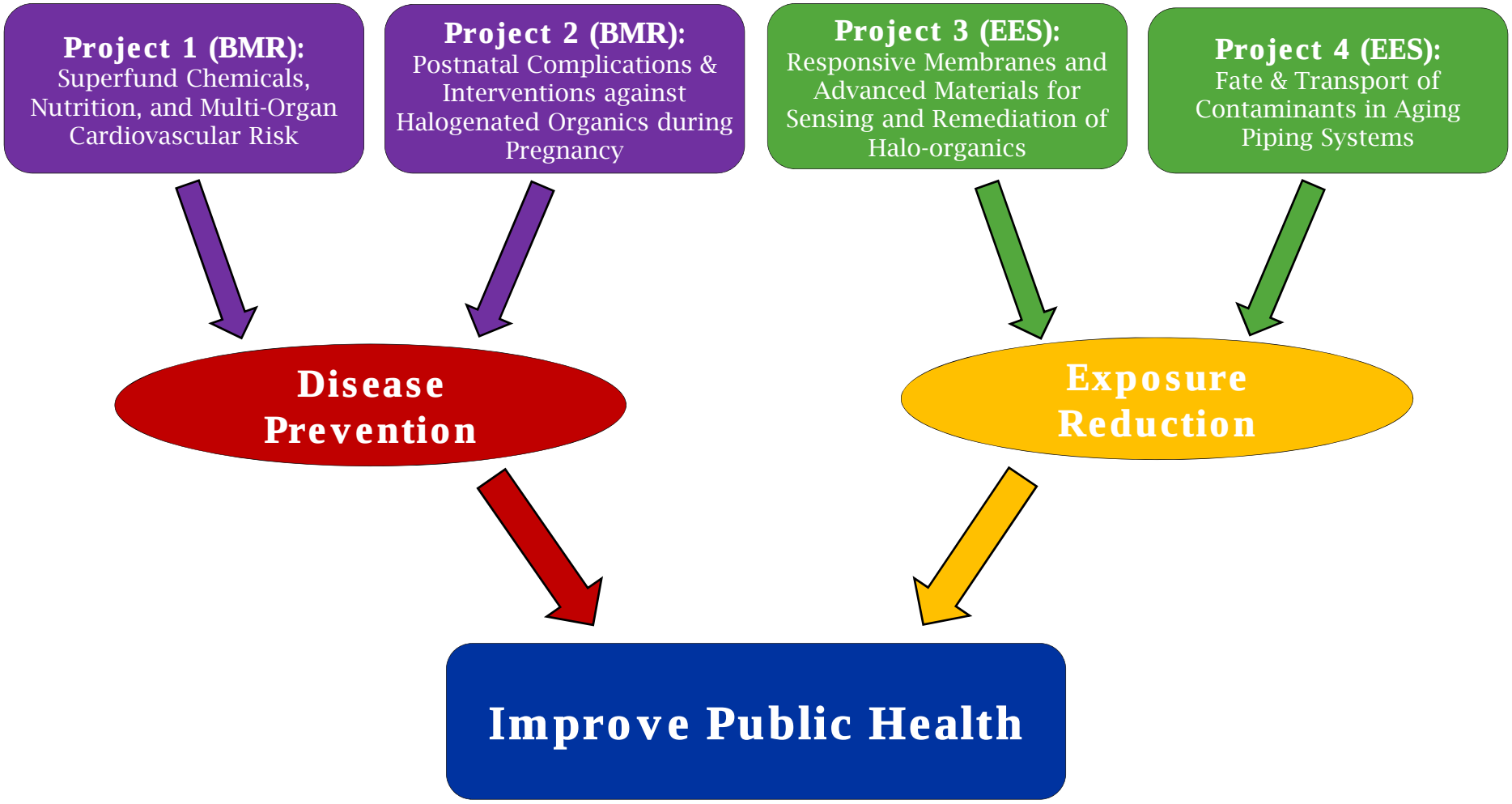

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NIH National Institute of Environmental Health Sciences
Superfund Research Program

ATSDR AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Administrative Core

Data Management and Analysis Core

Biomonitoring and Environmental Analytical Chemistry Core

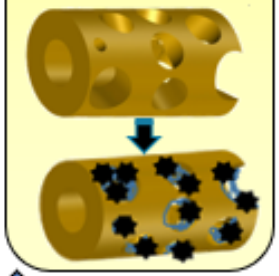
Biomedical Research Projects

Environmental Science Engineering Projects

Project 1 Chemicals, Nutrition

Project 2 Perinatal Impacts

Project 3 Sensing, Remediation



Project 4 Transport, Fate

Research Experience and Training Coordination Core

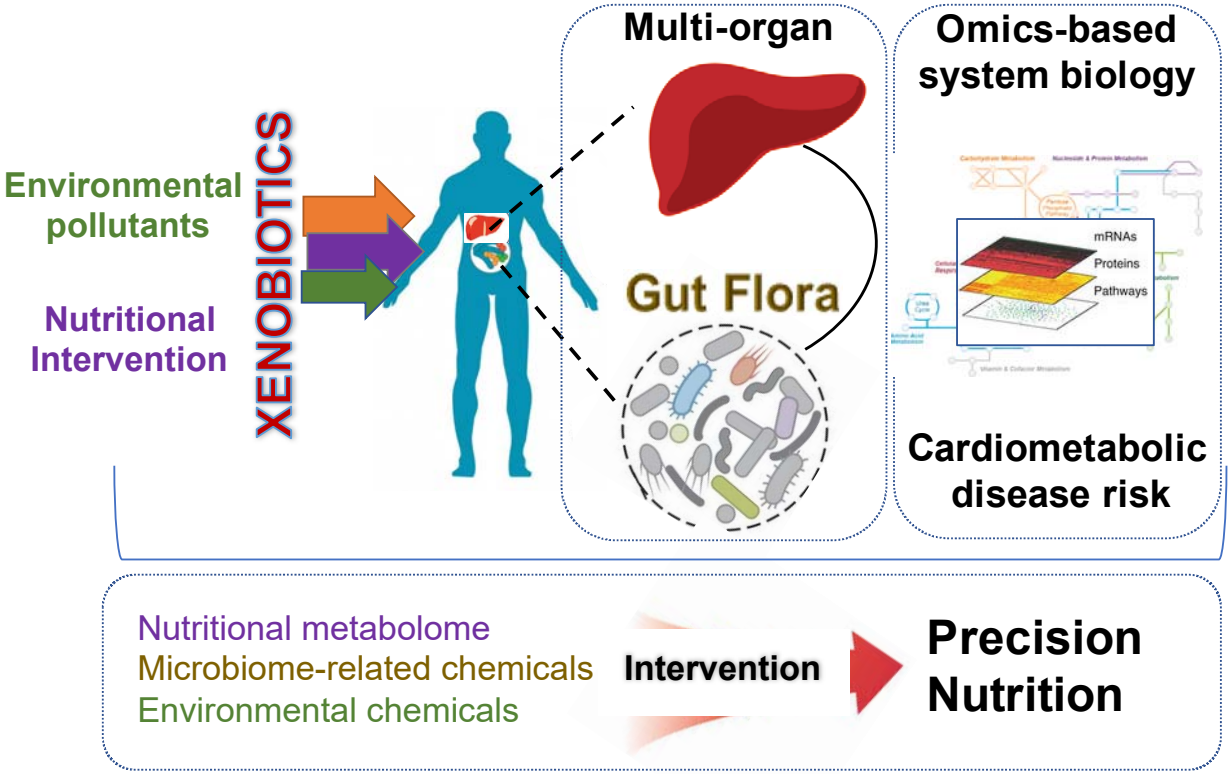
Community Engagement Core

UK SRC Projects

Project 1: Superfund Chemicals, Nutrition, and Multi-Organ Cardiovascular Risk

Goal: Understand the signaling pathways and metabolic or biological changes by which bioactive nutrients modulate impacts of acute or chronic exposure to persistent organic pollutants such as PCBs and PFAS.

Expected Outcomes: Scientific evidence towards the paradigm that healthful nutrition interventions offer a powerful strategy to reduce disease risks associated with environmental toxic insults to prevent inflammatory diseases, such as atherosclerosis, that have been linked to exposure to Superfund pollutants.




Dr. Bernhard Hennig


Dr. Pan Deng


Dr. Hunter Moseley

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Omics-based System Biology Approaches

Toxicity and environmental disease

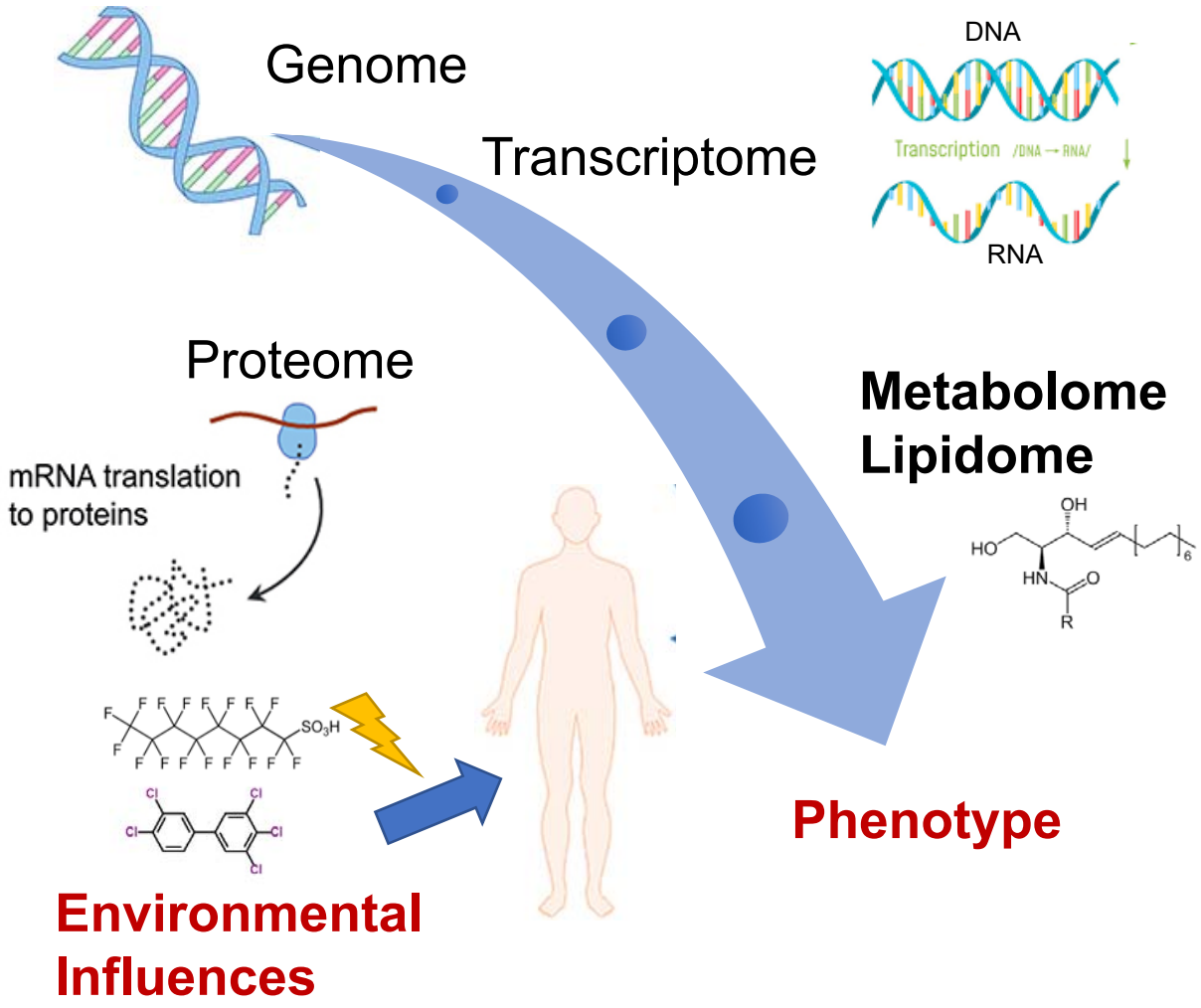
- Deng P et. al., Chemosphere, 2019
- Deng P et. al., Rev Environ Health, 2019
- Deng P et. al., Toxicol. Appl. Pharmacol, 2020

Nutritional intervention

- Deng P et. al., J Lipid Res, 2020
- Deng P et. al., J Proteome Res, under review

Metabolic disease mechanism

- AlSiraj Y et. al., Nat Commun, 2019
- Guo YB et. al., Nat Commun, 2020



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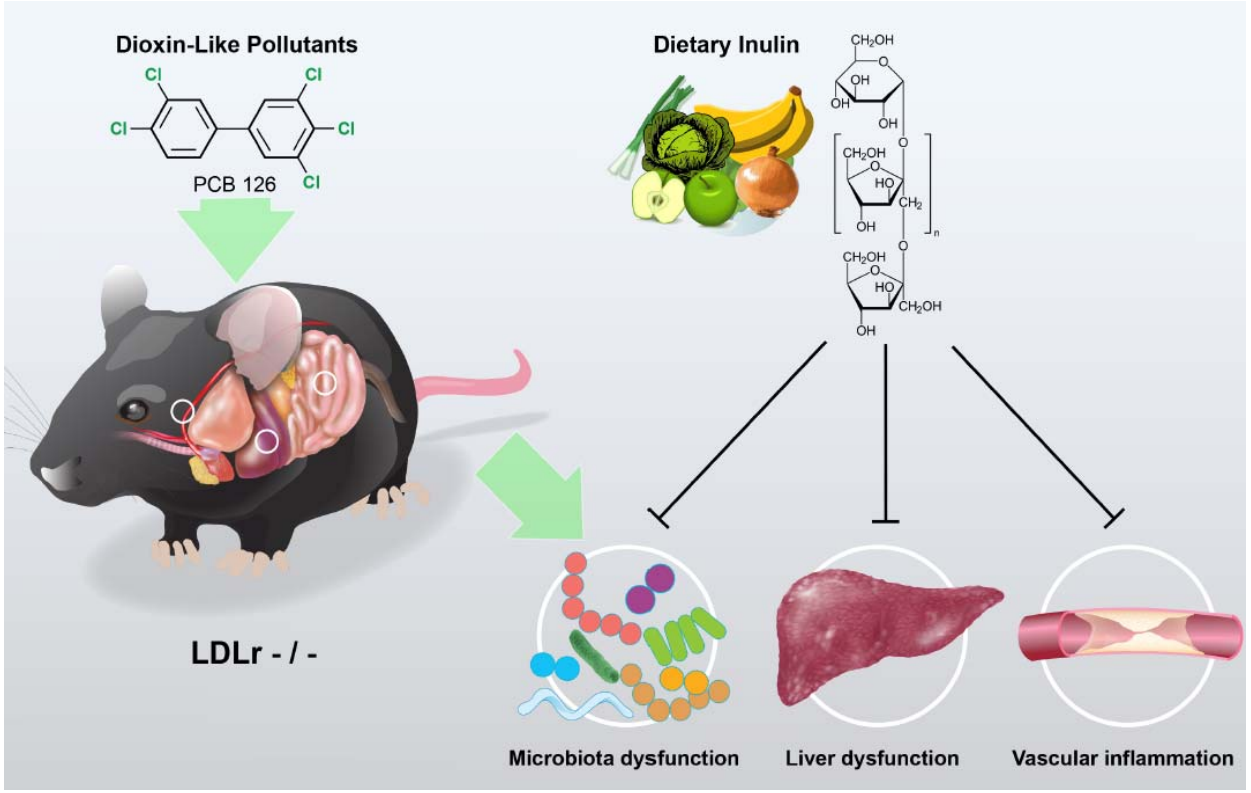
Inulin fiber consumption reduces dioxin-like PCB 126-mediated hepatotoxicity and gut dysbiosis in hyperlipidemic mice

- Liver histology
- Hepatic gene expression
- Cytokine and CVD markers
- Gut microbiome sequencing
- Lipidomics
- Transcriptomics



Deng P et. al., J Lipid Res, 2020.
Hoffman J. et.al., Environ Pollut. 2020.

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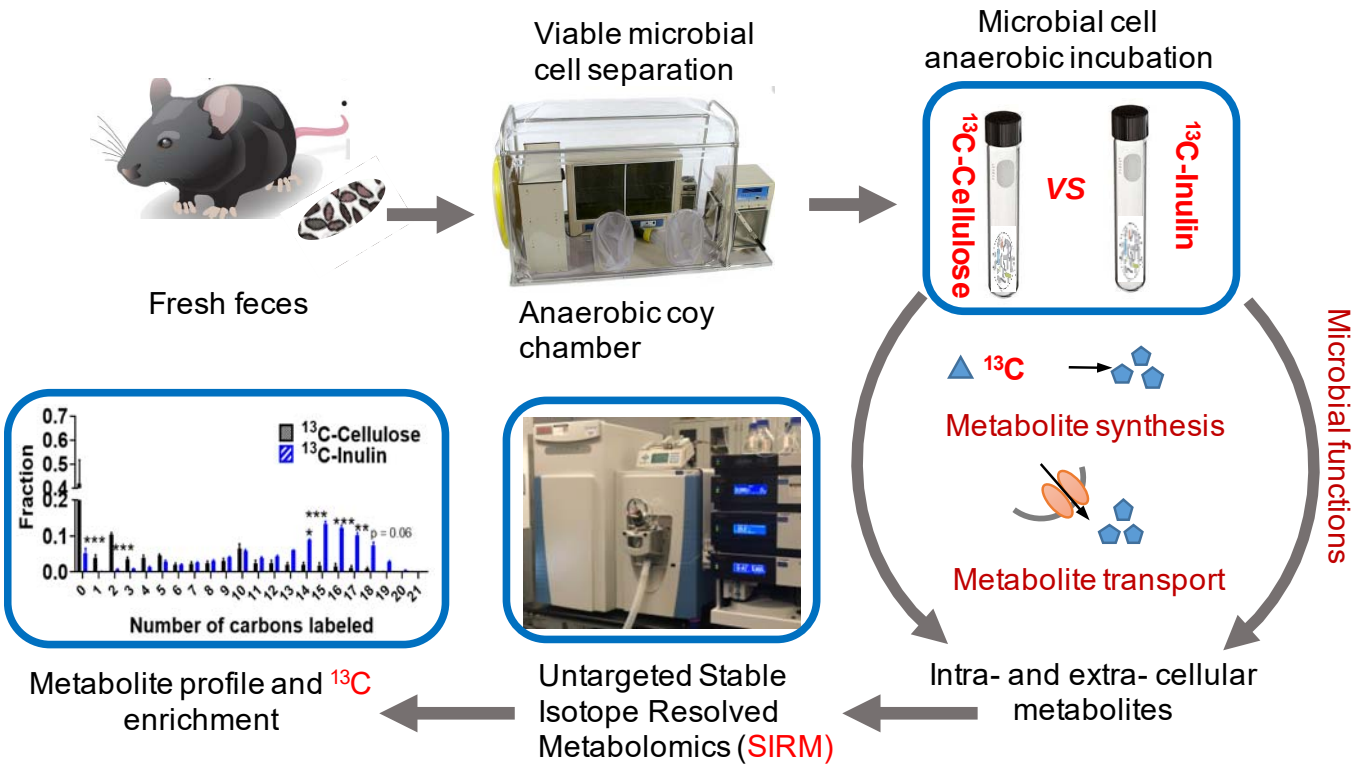
Platform to investigate gut microbiota metabolism

- Generated a metabolome list specific to the microbial cells.
- Revealed new insights into how dietary fibers can modulate microbial metabolism.
- Paved the road to the precision intervention



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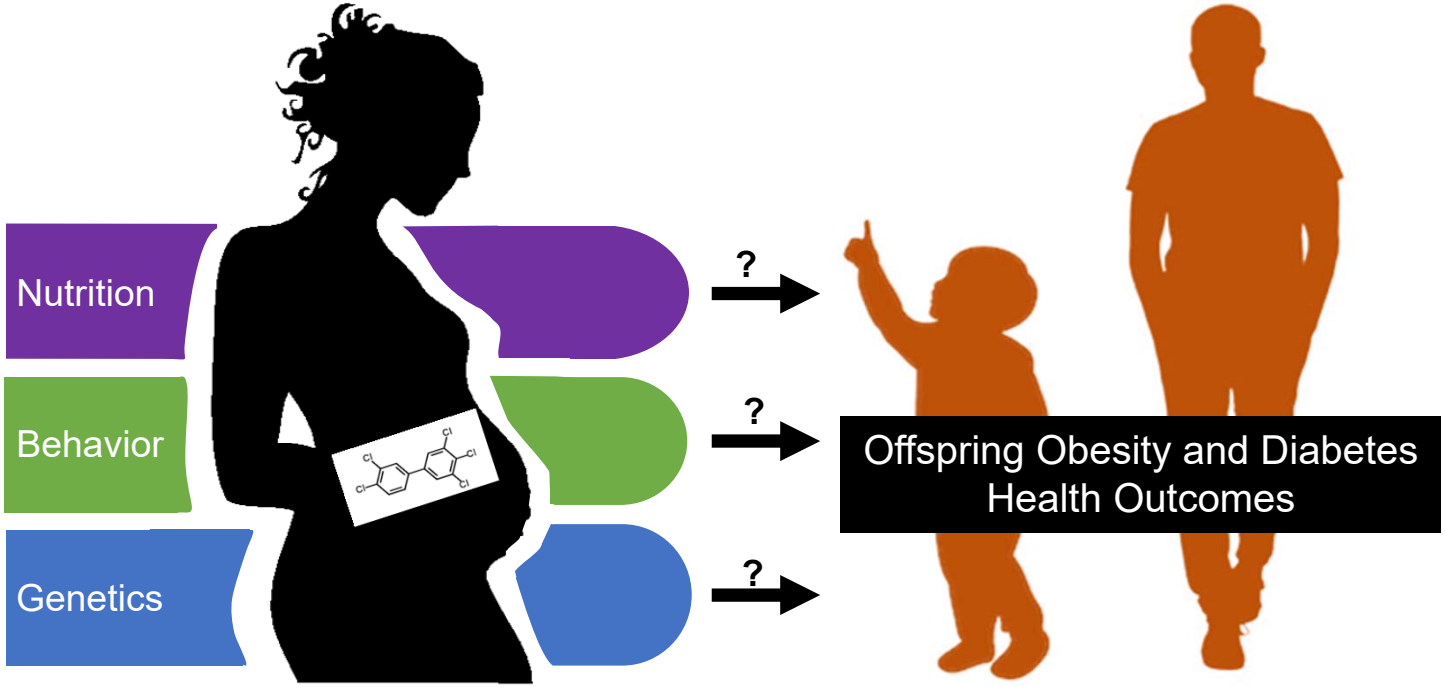
Project 2: Postnatal Complications & Interventions against Halogenated Organics during Pregnancy

Goal: Investigate lifestyle strategies (nutrition-based approaches or exercise) in order to reduce the impact of exposure to PCBs and related insults during pregnancy. Research will also include cells from babies to investigate the effects of various in utero environmental exposures on metabolic outcomes in children.

Expected Outcomes: New insights about the role of exercise in mitigating the health impacts of in utero PCB exposure to better understand the molecular and cellular mechanisms underlying the toxicity of persistent halogenated organic pollutants. Model-derived new preventative and intervention approaches targeting the identified pathways.

Dr. Kevin Pearson

Dr. Hollie Swanson



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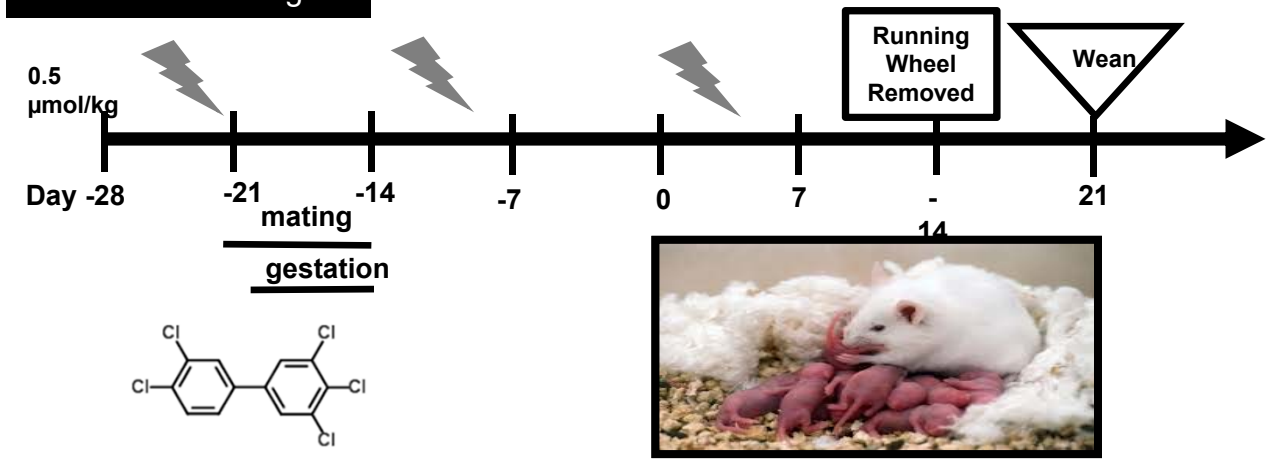
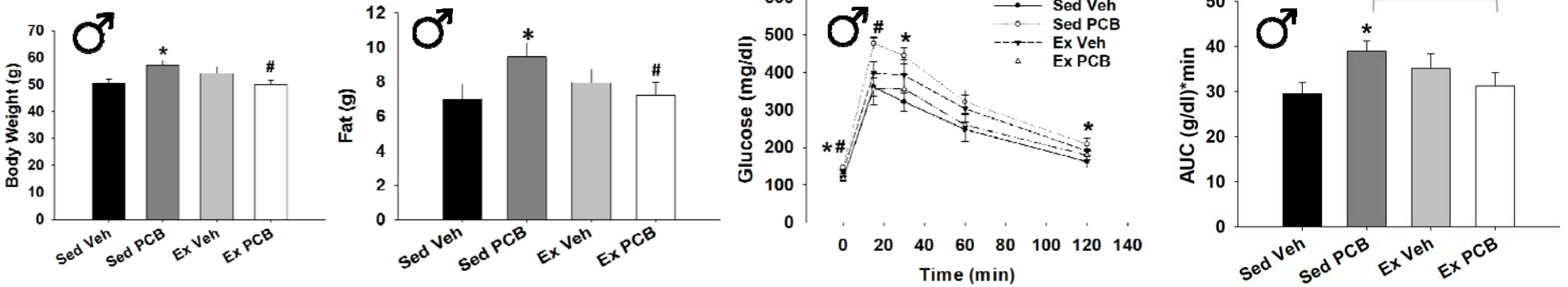
Maternal exercise protects against negative effects associated with perinatal PCB126 exposure

Research Paradigm



Offspring body composition and glucose tolerance at 6 months of age

Offspring Data – 6 months



Values are representative of mean ± SEM, *p < 0.05 compared to Sed Veh, #p < 0.05 compared to Sed PCB; running data, n = 12 per group; body weight and composition data, n = 21 -22 per group; glucose tolerance data, n = 10 – 11 per group.

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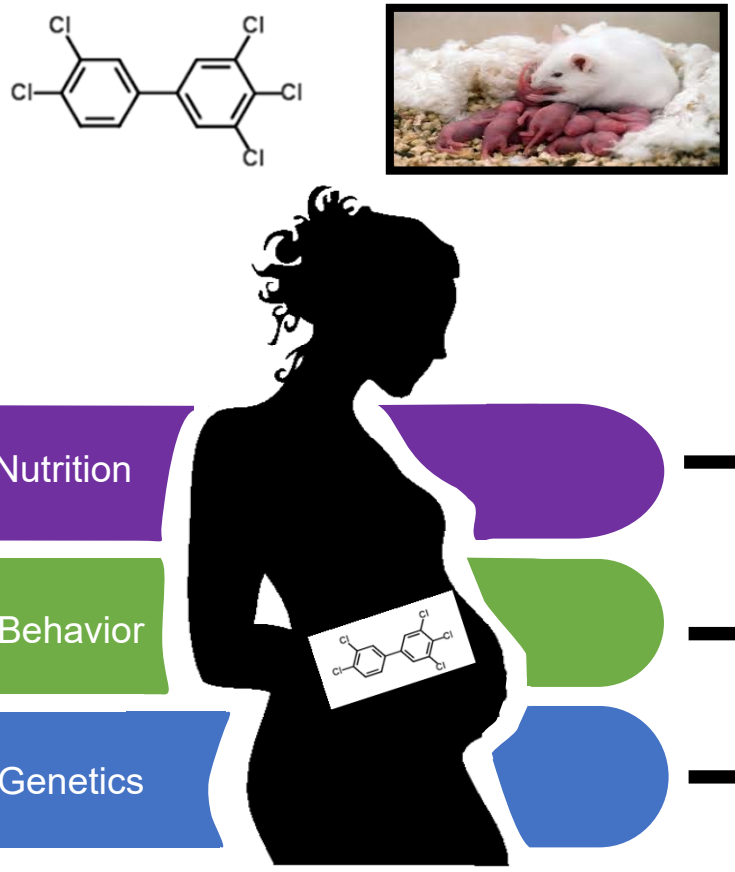
Project 2: Summary of Findings from Mice



- **Both sexes are affected, but male offspring are more sensitive perinatal PCB126 exposure.**
- **The *in utero* period is the critical exposure window for long-term programming of diabetes.**

- **Maternal resveratrol consumption in the diet (nutritional) offered no protection against perinatal PCBs.**
- **Maternal exercise (behavioral) offers protection against perinatal PCBs.**
- **The lack of Nrf2 did not exacerbate the effects of developmental PCB exposure.**

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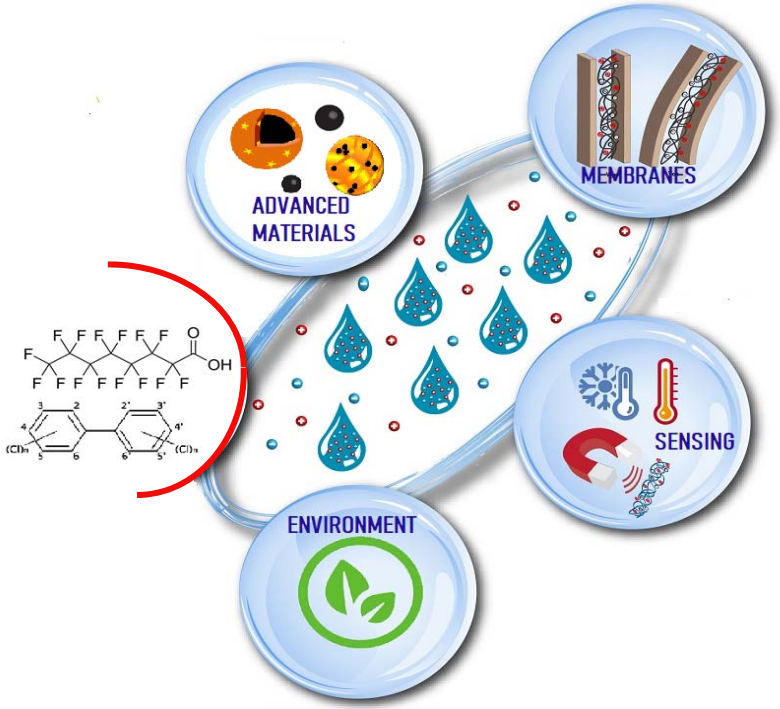
Project 3: Responsive Membranes and Advanced Materials for Sensing and Remediation of Halo-organics

Goal: Investigate the use of advanced membrane, responsive hydrogel-based, and magnetic nanocomposite-based sustainable technologies to prevent and reduce environmental exposure risks associated with halogenated organic compounds.

Expected Outcomes: Cost-effective technologies for remediation of chemicals, such as TCE, PCE and PCBs. And, superfast sorption of PFAS compounds with responsive polymer materials.




Dr. Dibakar Bhattacharyya


Dr. Zach Hilt


Dr. Tom Dziubla


Dr. Isabel Escobar


Dr. Lindell Ormsbee

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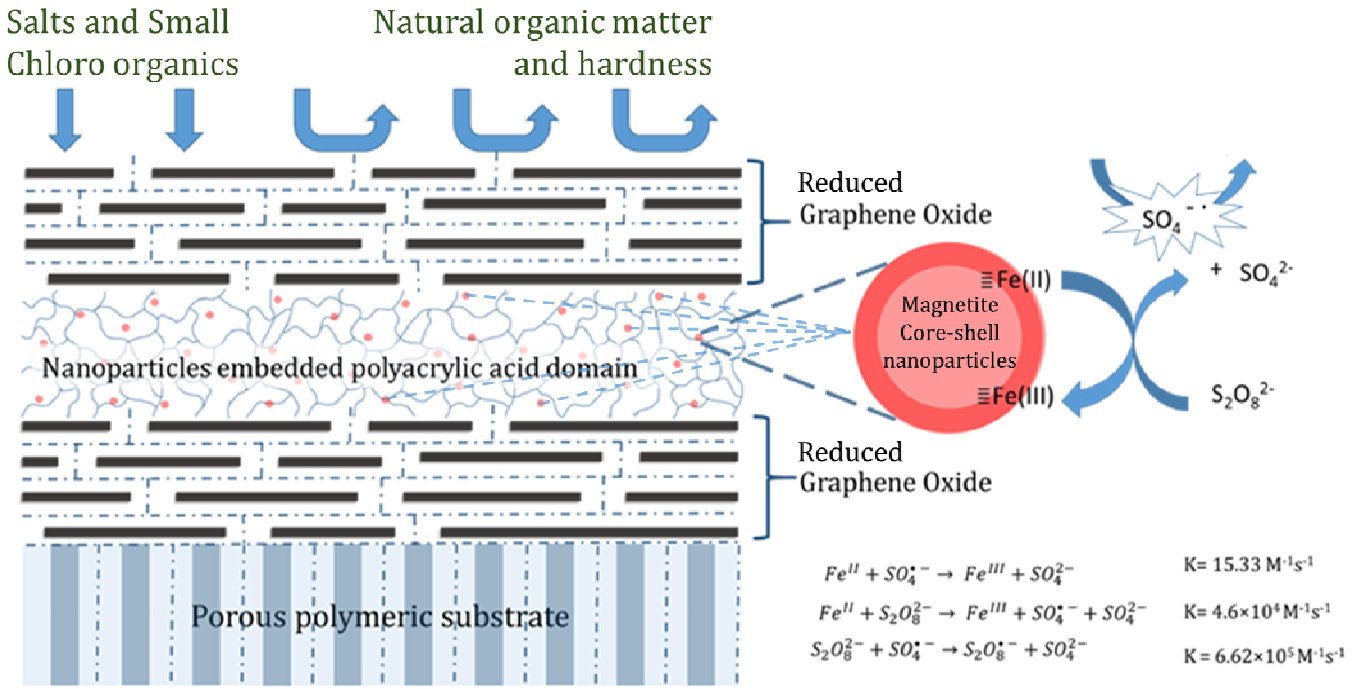
Nanocomposite Reduced Graphene Oxide Membranes for Oxidative Degradation of Toxic Organics (TCE) by Sulfate Radicals

- Integration of advance oxidation with membranes
- Catalyst immobilization
- Removal of larger organic contaminants by molecular sieving
- Easy control over residence time and extent of reaction



Aher, Nickerson, Ormsbee, Bhattacharyya, RSC Advances (2019) on Oxidative degradation aspects.

Aher, Ormsbee, Bhattacharyya, et al, "Ion and Organic Transport in Graphene Oxide Membranes: Model Development to Difficult Water Remediation Applications", J. Membrane Science (2020).

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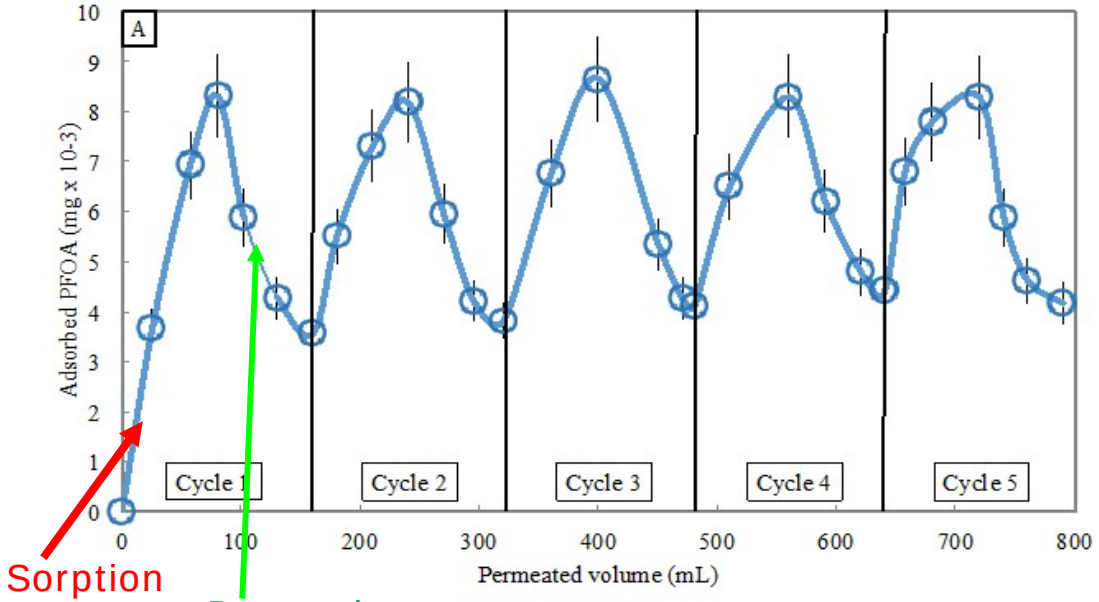
PNIPAAm Functionalized Responsive Membranes and Hydrogels for Temperature Swing PFAS Sorption/desorption

- Converting MF membrane pores to a temperature responsive platform
- PFOA – Emerging contaminant

- Why not carbon adsorption?
  - High T regeneration
  - Corrosive gas potential

PFOA sorption-desorption from water over multiple cycles: T Responsive PVDF membranes (P= 3.5 bar)



Sorption
Above
LCST

Desorption
below LCST

Saad, A., Mills, R., Wan, H., Mottaleb, MA., Ormsbee, L., & Bhattacharyya, D. J. Membrane Science (2020).

US Patent Pending, 2020, Bhattacharyya, Saad, Ormsbee, et al.

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Example of Research Translation

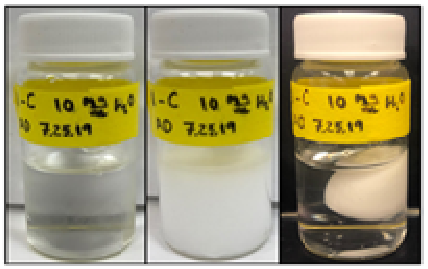
Development of Smart Flocculants for the treatment of PFAS Contaminated Water

Material development within ***Project 3*** led to interesting flocculation properties allowing for submission of provisional patents and an SBIR – Phase I grant that recently was funded

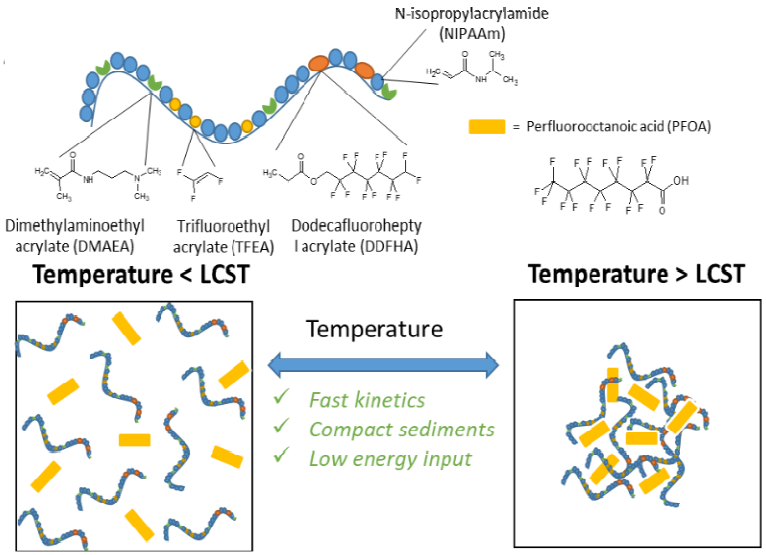
Aim: To develop novel copolymer flocculants and examine their solid-liquid separation efficiency in removing persistent water-soluble contaminates like PFAS from water/wastewaters.

The key advantages of these temperature responsive flocculant system are:

1. Low water retention in the sediment
2. Fast kinetics
3. Lower energy input



bluegrass advanced materials



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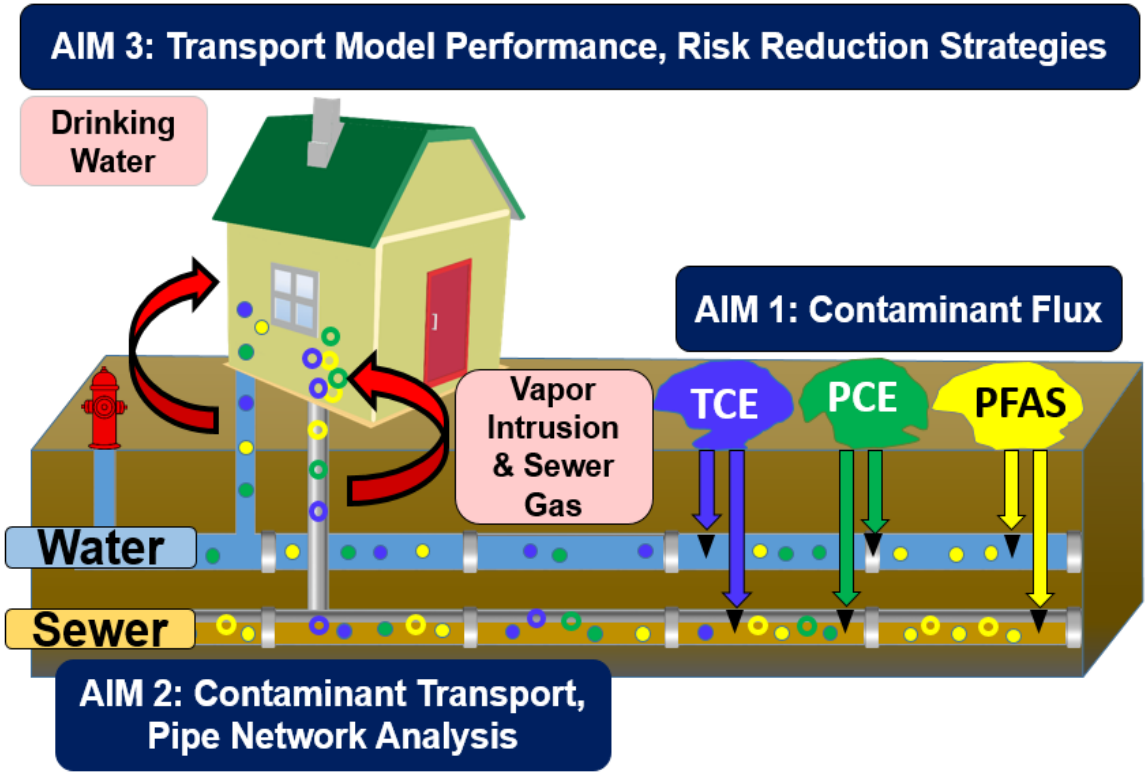
Project 4: Fate & Transport of Contaminants in Aging Piping Systems

Goal: Identify and reduce exposure risks associated with chlorinated ethenes (PCE, TCE, etc.) and per- and polyfluoroalkyl substances (PFAS) by combining piping infrastructure science with environmental fate and transport science.



Dr. Kelly Pennell

Dr. Anna Hoover

Expected Outcomes:
Environmental health literacy (EHL) strategies coupled with fate and transport science that provide solutions to reduce exposure risks to environmental contaminants that are “acceptable” and aligned with stakeholders needs and interests.

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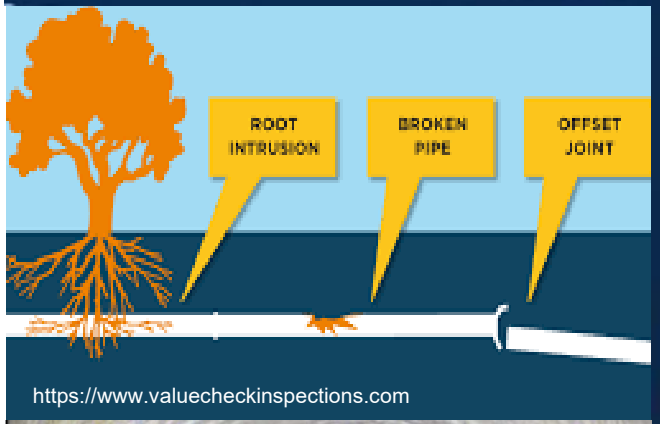
Aging Infrastructure as Sources for Recalcitrant Compounds (CVOCs and PFAS)

https://www.infrastructurereportcard.org



https://www.valuecheckinspections.com

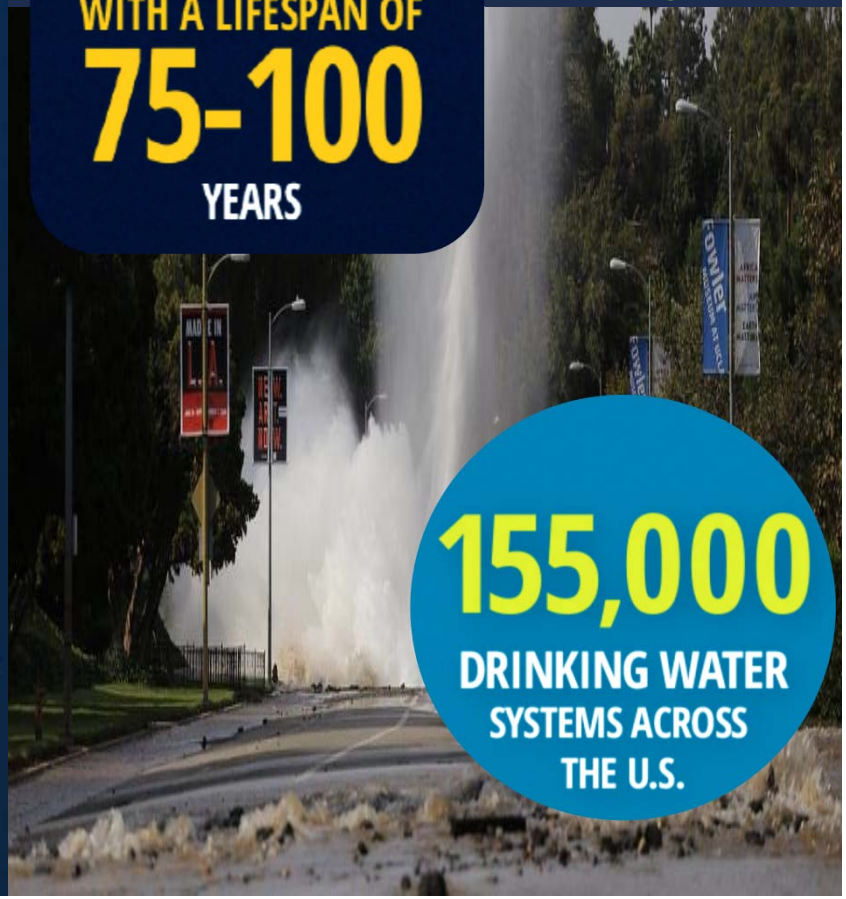
https://data.naperville.il.us

Over 1-million miles of water pipes in the US

MANY WATER MAINS AND PIPES WERE LAID IN THE EARLY TO MID-20TH CENTURY WITH A LIFESPAN OF 75-100 YEARS

D

Drinking Water

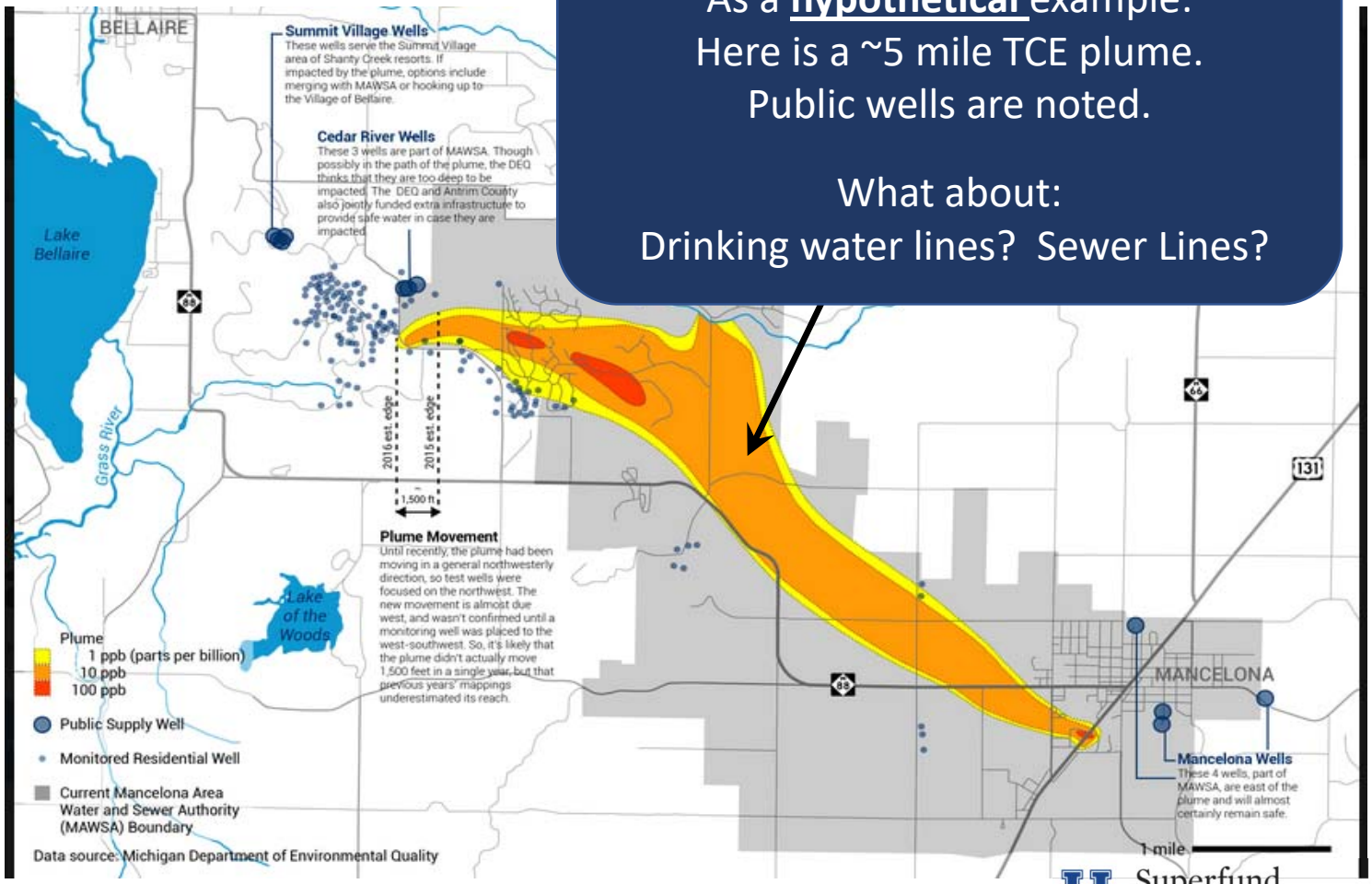


Groundwater plumes can extend for long distances, impacting many individuals. Understanding piping infrastructure is important for mitigating exposure risks.

What other potential exposure risks should we think about when we see long reaching VOC plumes?

As a **hypothetical** example:
Here is a ~5 mile TCE plume.
Public wells are noted.

What about:
Drinking water lines? Sewer Lines?



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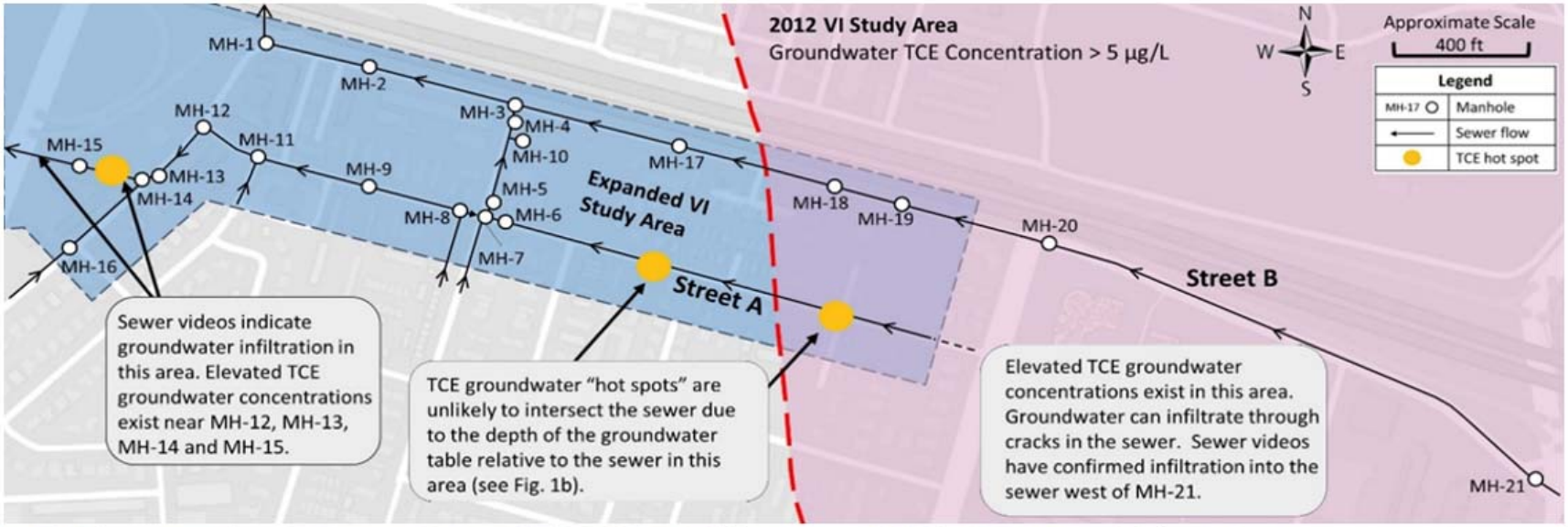
Field Study: UKSRC with NIEHS SBIR Grantee and EPA

(Roghani et al. 2018)

Science of the Total Environment

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

Occurrence of chlorinated volatile organic compounds (VOCs) in a sanitary sewer system: Implications for assessing vapor intrusion alternative pathways



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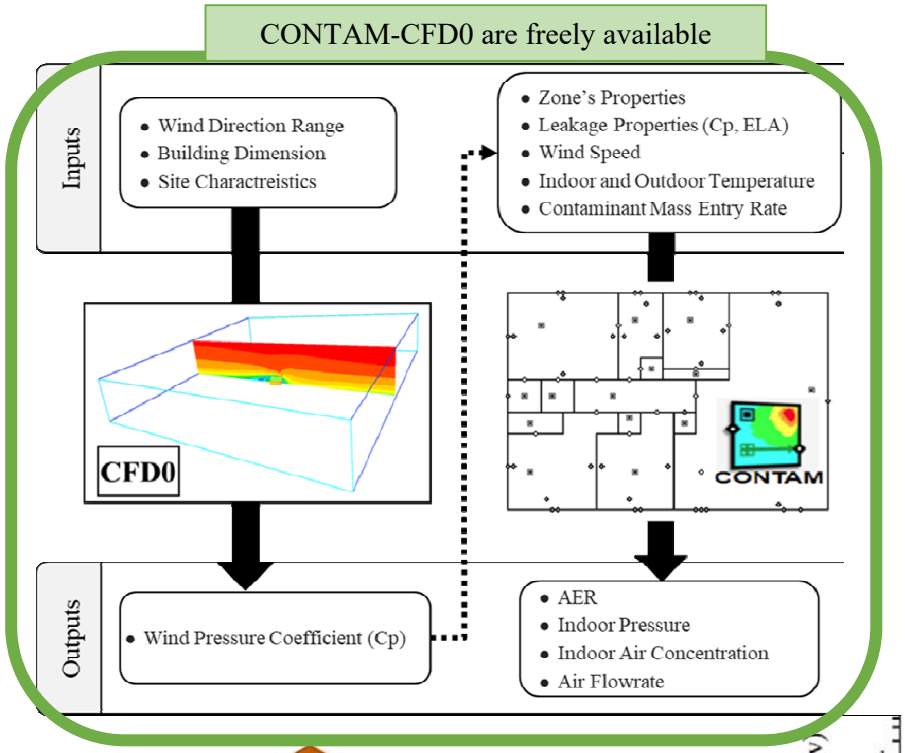
New Modeling Approach Developed by UKSRC

(published Shirazi et al 2017 and Shirazi et al 2020)



Modeling approach verified using field data from house near Hill Air Force Base Superfund Site

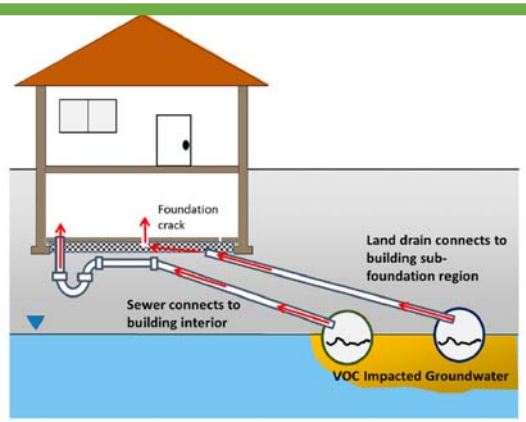


Fig. 1. Conceptual illustration of sewer and land drain vapor intrusion pathways.

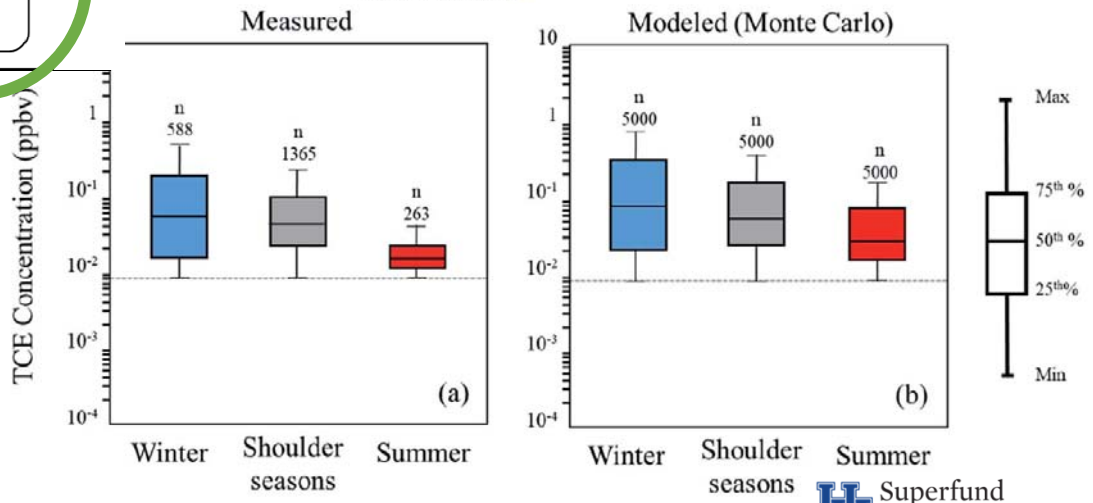
PAPER View Article Online View Journal

Check for updates

Cite this: DOI: 10.1039/c9em00567f

Comparison of modeled and measured indoor air trichloroethene (TCE) concentrations at a vapor intrusion site: influence of wind, temperature, and building characteristics†

Elham Shirazi,[a] Gregory S. Hawk,[b] Chase W. Holton,[c] Arnold J. Stromberg[b] and Kelly G. Pennell[*a]



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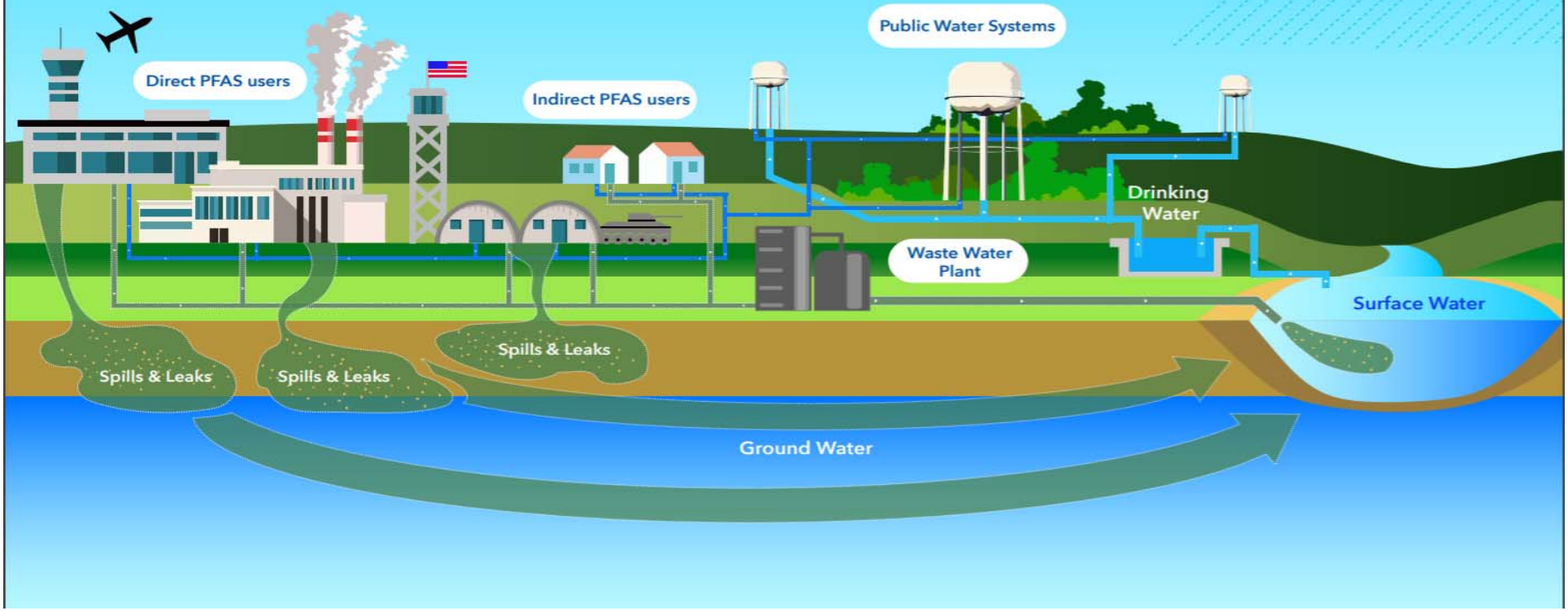
Understanding PFAS Risks in Kentucky's Drinking Water Systems

(Ojha, Li, Hoover, Robinson and Pennell, 2020)

PFAS sources in drinking water sources:

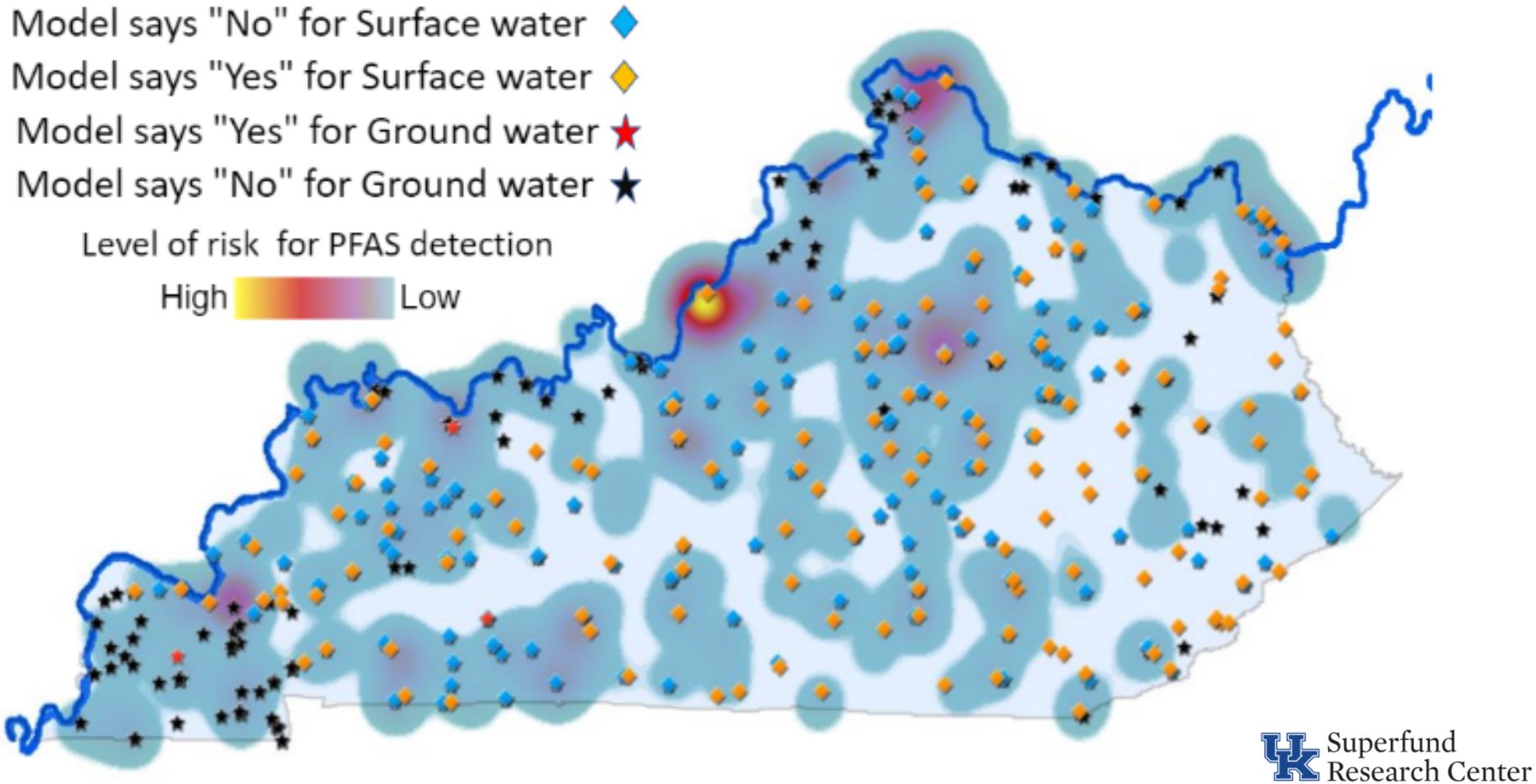
- Wastewater outfalls
- Storm sewers (and runoff from uncontained PFAS sources)
- Contaminated groundwater infiltration to surface water

Drinking water: one source for PFAS exposures



Geospatial Heat Map and Statistical Model Predictions for all PWS in Kentucky

(*Under Review* Ojha, Li, Hoover, Robinson and Pennell, 2020)



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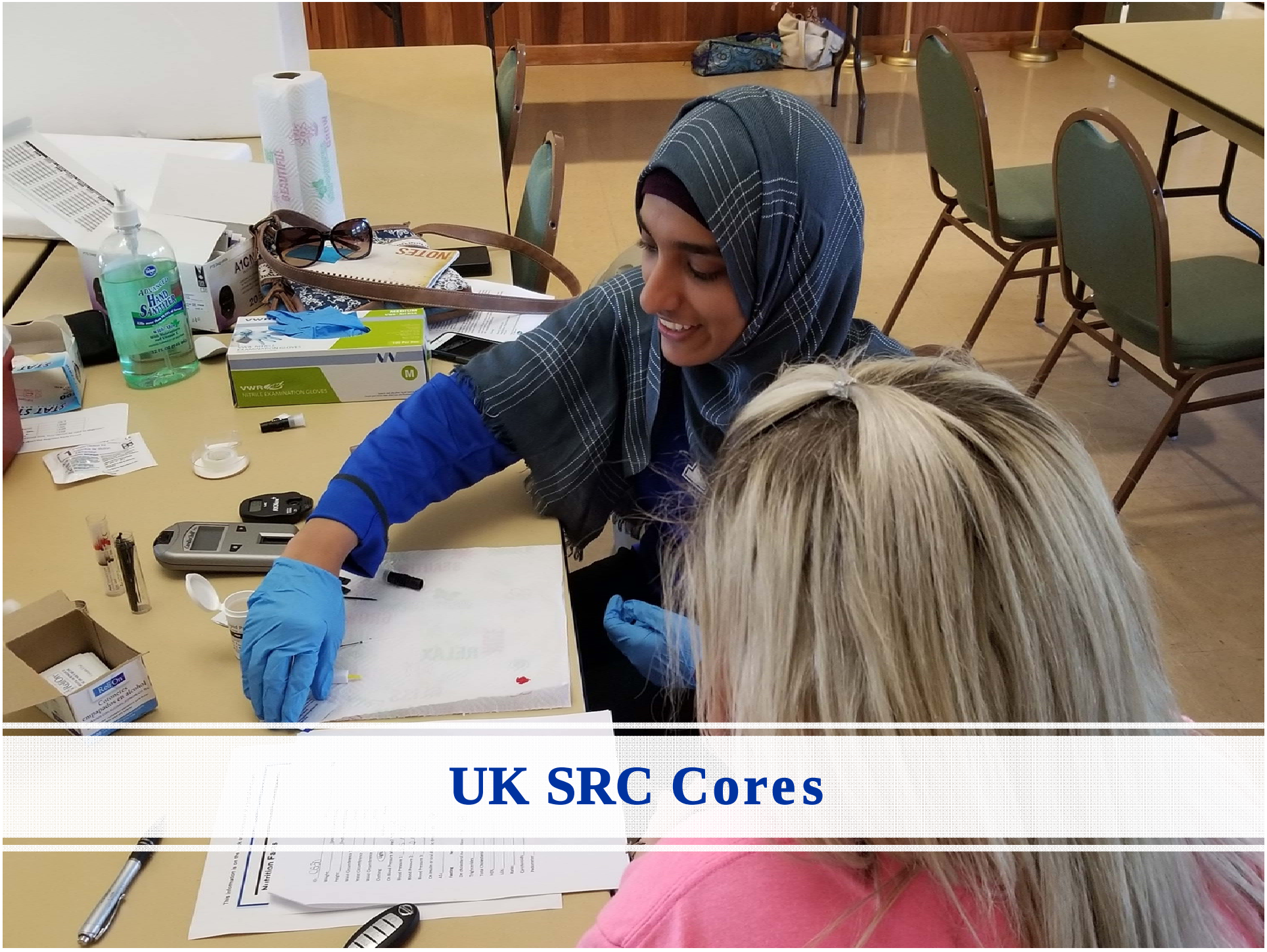

ADVANCED
HAND
SANITIZER
VWR
NITRILE EXAMINATION GLOVES
NOTES

UK SRC Cores

Community Engagement Core

The CEC supports the work of the UKSRC by developing partnerships with targeted communities affected by hazardous waste sites and environmental pollutants. The CEC works with various community partners to develop creative solutions to address the disparities of poor diet, physical inactivity and high rates of obesity and related chronic diseases experienced by Kentuckians, especially those living in Appalachian Kentucky, because of the critical role that healthy lifestyles have in reducing a person's exposure to environmental hazards.

CEC's goal is to improve diet, particularly by increasing fruit and vegetable consumption, increase physical activity among our community participants, and to provide education about environmental pollution in targeted communities.

Dr. Dawn Brewer

Dr. Gia Mudd-Martin

Annie Koempel
Program Manager

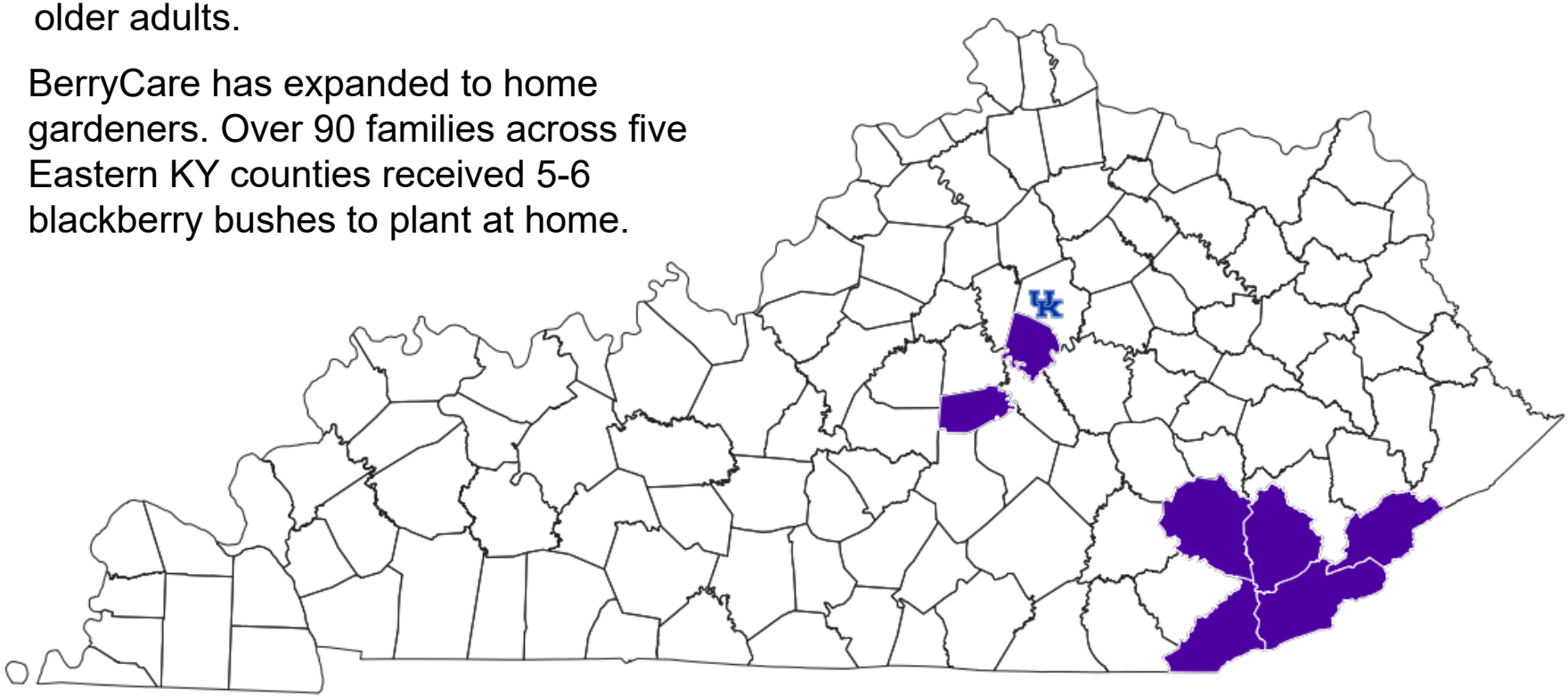
Superfund Research Center

Berry Care Program

- BerryCare is a community program that was originated by the CEC in 2016.
- With the BerryCare program, the CEC connects UKSRC research with the local community by providing access to a sustainable source of phytonutrient-packed blackberries.

Reach of the BerryCare Program

- The BerryCare program is in 7 counties, 5 of which are in the Appalachian Region in Eastern Kentucky.
- In 2020, BerryCare expanded to another senior center located in central KY. A total of 70 bushes have been planted between the two centers that serve approximately 50 older adults.
- BerryCare has expanded to home gardeners. Over 90 families across five Eastern KY counties received 5-6 blackberry bushes to plant at home.



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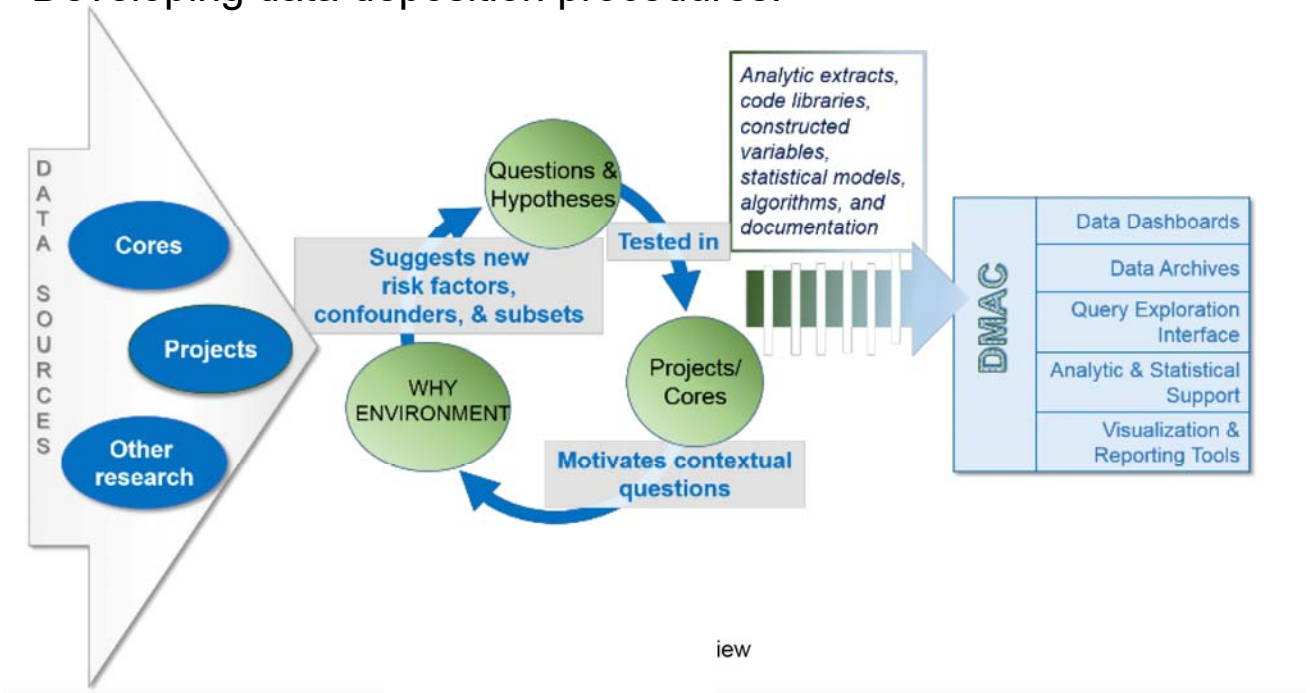
Data Management and Analysis Core

UK SRC's DMAC manages and analyzes:

- Chemistry and biomonitoring data;
- Computational modeling output data (pre- and post-processing);
- Advanced imaging data from scanning and transmission electron microscopes; and
- Stakeholder-specific information.

DMAC facilitates and supports the Center's data management plan by:

- Coordinating with project/cores;
- Fostering data sharing and interoperability;
- Implementing data quality assurance and quality control; and
- Developing data deposition procedures.



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Dr. Kelly Pennell

Dr. Hunter Moseley

Dr. Heather Bush

Dr. Erin Haynes

Dr. Angela Gutierrez

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Biomonitoring and Environmental Analytical Chemistry Core (BEACC)

The Biomonitoring and Environmental Analytical Chemistry Core (BEACC) detects, identifies and measures environmental chemicals in soil, water and samples from humans and animals including blood, urine and hair.

BEACC makes measurements of these chemicals to support center researchers studying how they are distributed in the environment, how they affect the health of exposed individuals and more detailed studies of the underlying mechanisms involved using laboratory mouse models.

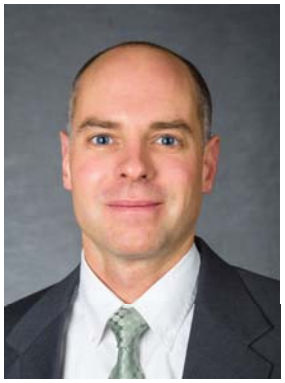
Dr. Andrew Morris

Superfund Research Center

Research Experience and Training Coordination Core (RETCC)

RETCC aims to train students to investigate issues via exposing trainees to interdisciplinary approaches to training, providing opportunities to enhance their professional career development, and through extensive outside laboratory experiences program that coordinates opportunities for participation in the Community Engagement Core (CEC) and the Administrative Core's research translational function, and engaging them with the Data Management and Analysis Core (DMAC).

These diverse activities will give the trainees broad exposure to environmental issues that affect their surroundings and equip them with a unique tool set to make disruptive impacts to the field.



Dr. Zach Hilt

Dr. Bernhard Hennig

Dr. Angela Gutierrez

Superfund Research Center

UKSRC Trainee-Developed Pilot Grant Program

- **Aim:** To foster cross-disciplinary projects (span two or more projects and/or cores) that will help strengthen interactions and collaborations within the UKSRC.
- This program will enable new research directions and encourage exploration of collaborative concepts.
- Through these interactions, trainees stand to gain valuable experience in designing and executing collaborative research projects beyond their primary focus, as well as gain experience in grant writing and budget management.

First pilot grant project funded:
Identification and remediation of KY PFAS hotspots

- Collaboration between Project 3 and 4.
- **Aim:** To analyze and remediate real-world water samples from a few potentially highly contaminated drinking/waste water systems throughout Kentucky by combining Sweta's research (Project 4) that identifies potential PFAS "hotspots" throughout Kentucky via regression statistic analysis, with Molly's research (Project 3) on PFAS sorbent development.

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DMAC Upcoming Workshops: Provide tools for the trainees that will be useful in their graduate program and in their future careers.

- New programming languages (i.e., Python)
- Statistical analysis tools (i.e., R)

MS Teams Trainees Group:

- Monthly trainee-led meetings.
- Means to stay connected.
- Sharing seminars, conferences, workshops details.

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Questions?

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