Science, technology and traditional knowledge to protect Northern Plains water resources and communities from hazardous metal exposures

Design: Tammy Granados

NIH National Institute of Environmental Health Sciences
Superfund Research Program
P42ES033719

Indigenous communities in the Northern Plains suffer from an epidemic of cardiovascular disease and diabetes

- In North Dakota and South Dakota, American Indians have the highest coronary heart disease rates of the US
  - Over 1/3 of deaths occur before the age of 65 years
  - Diabetes burden is 3x higher than White communities
- European colonization and US policies have contributed to these inequalities
- Sovereignty, cultural resilience, and traditional knowledge remain strong and positive influences

Breathett et al. Circulation 2020

Arsenic exposure an established risk factor for disease

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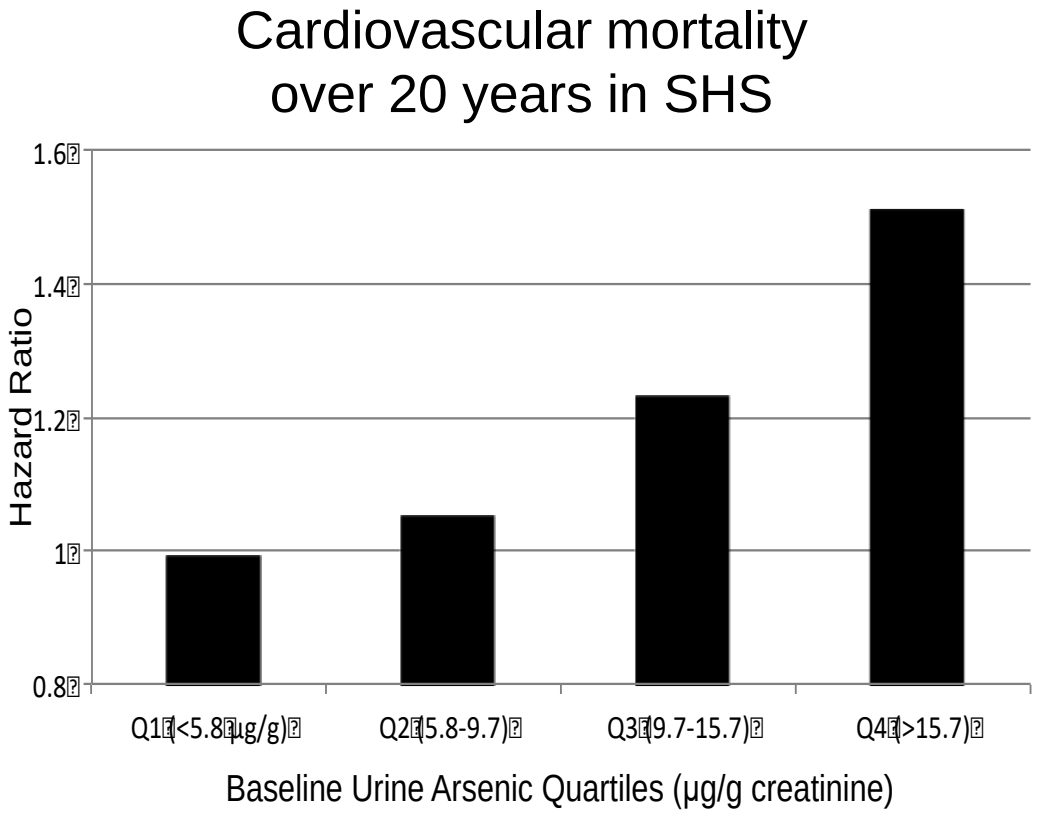
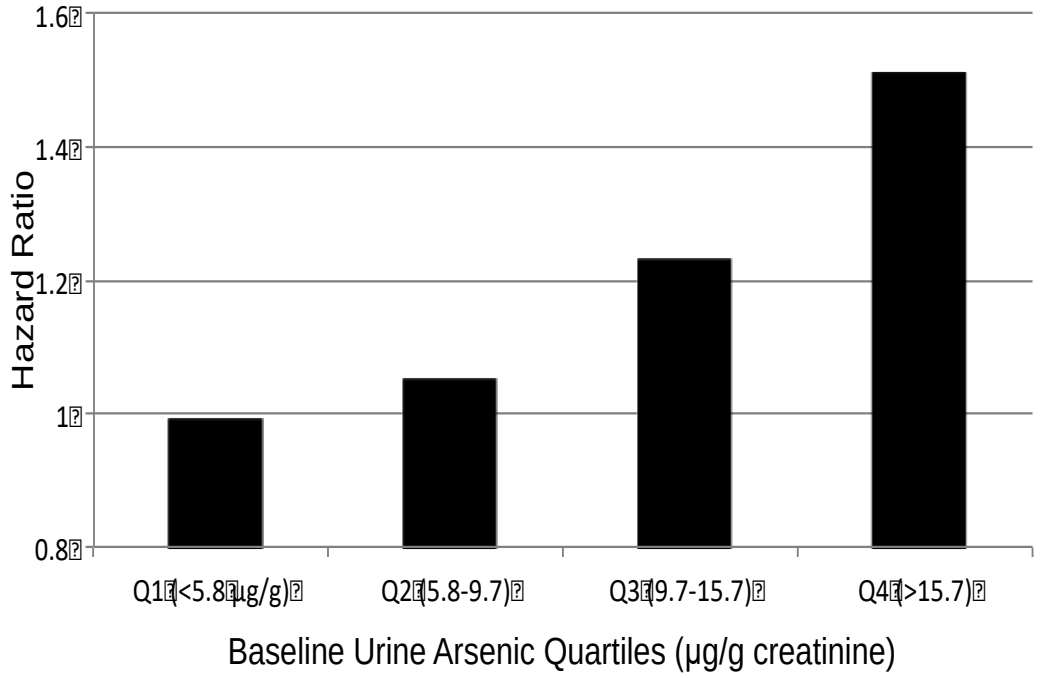


Moon et al. Ann Intern Med 2013

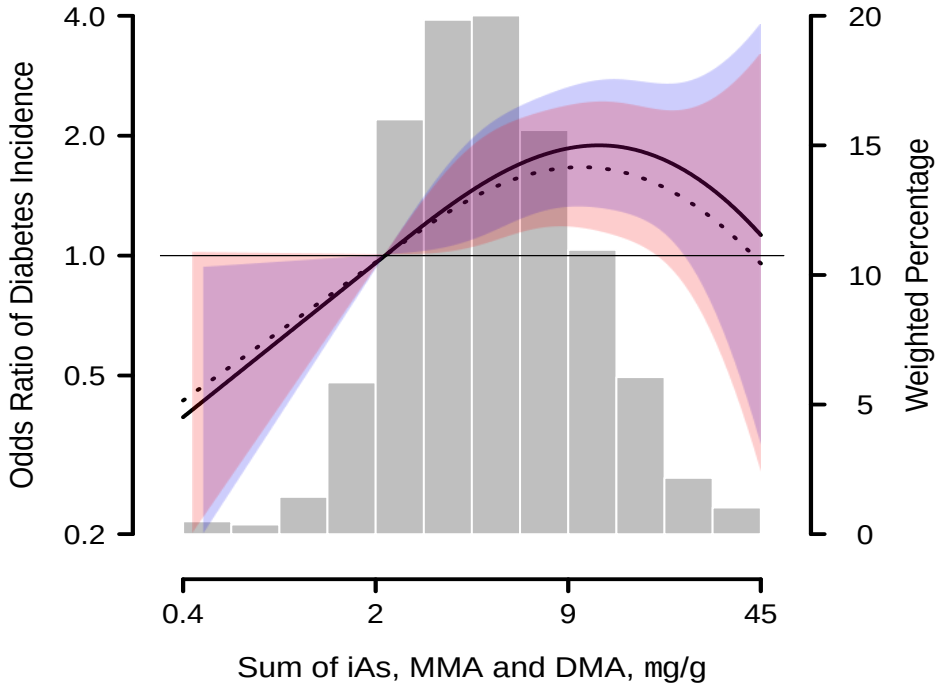
Arsenic exposure an established risk factor for disease

Cardiovascular mortality over 20 years in SHS



Moon et al. Ann Intern Med 2013

Diabetes incidence over 6 years in SHFS



Grau-Perez et al. EHP 2017

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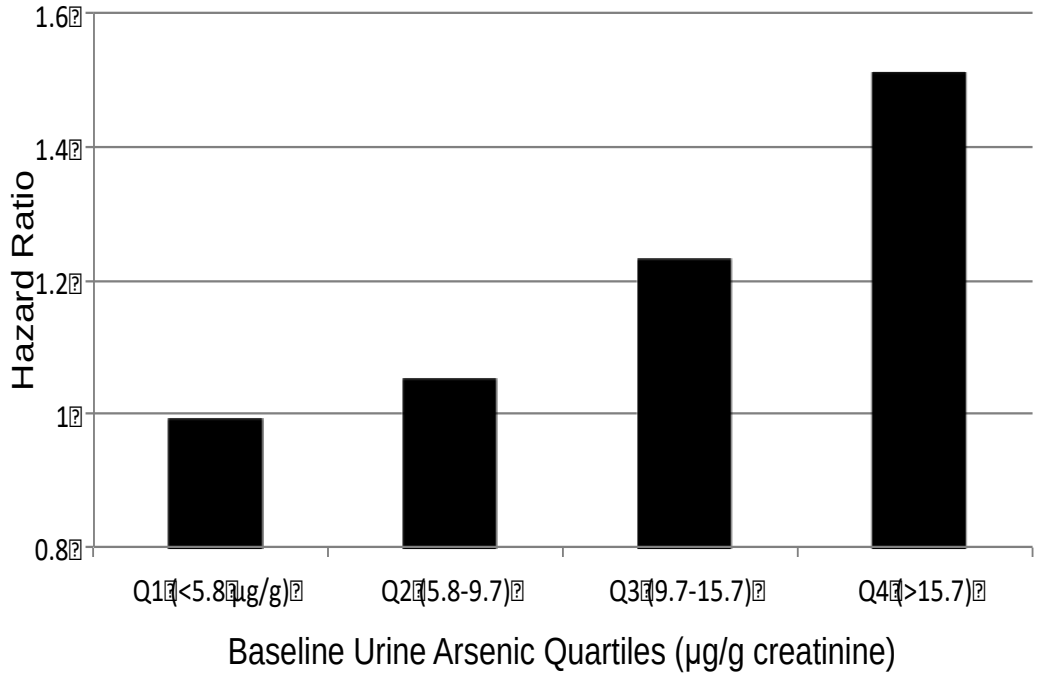

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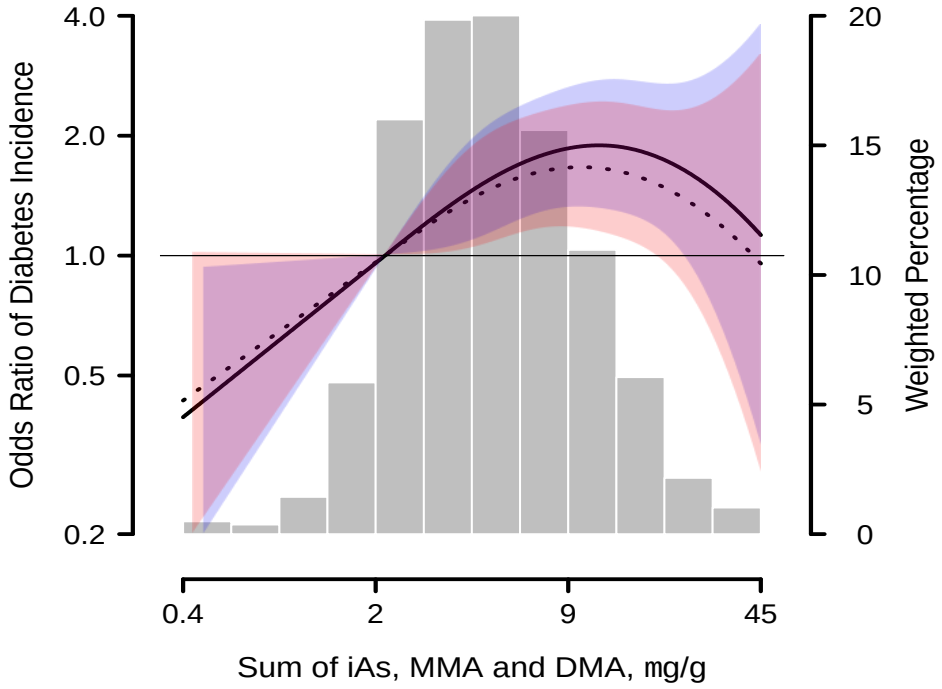
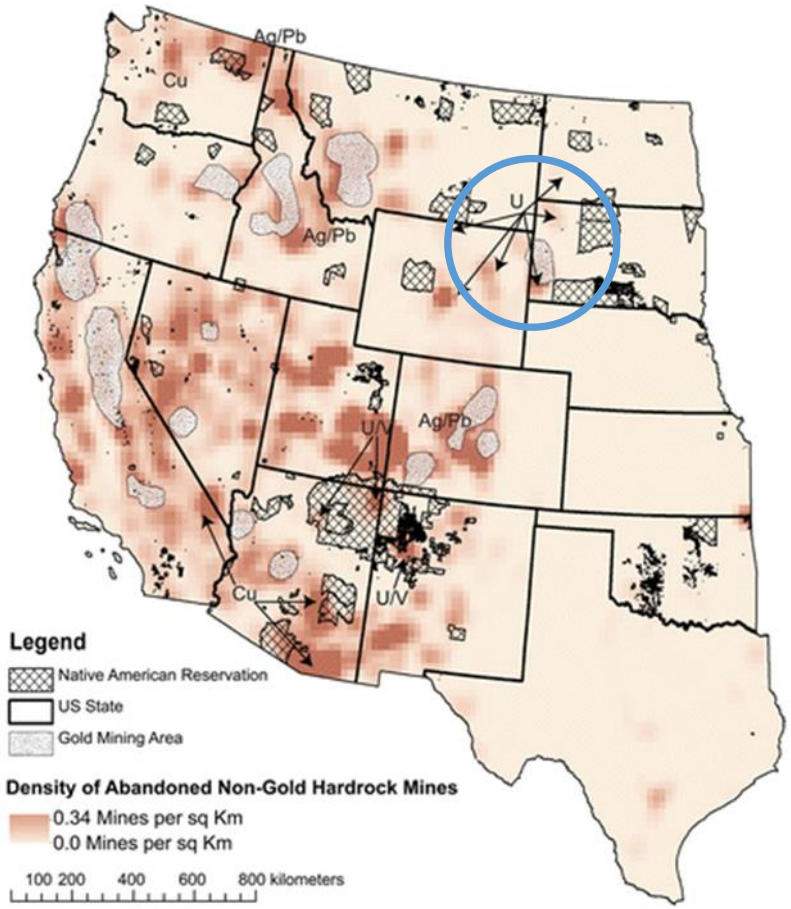


Grau-Perez et al. EHP 2017

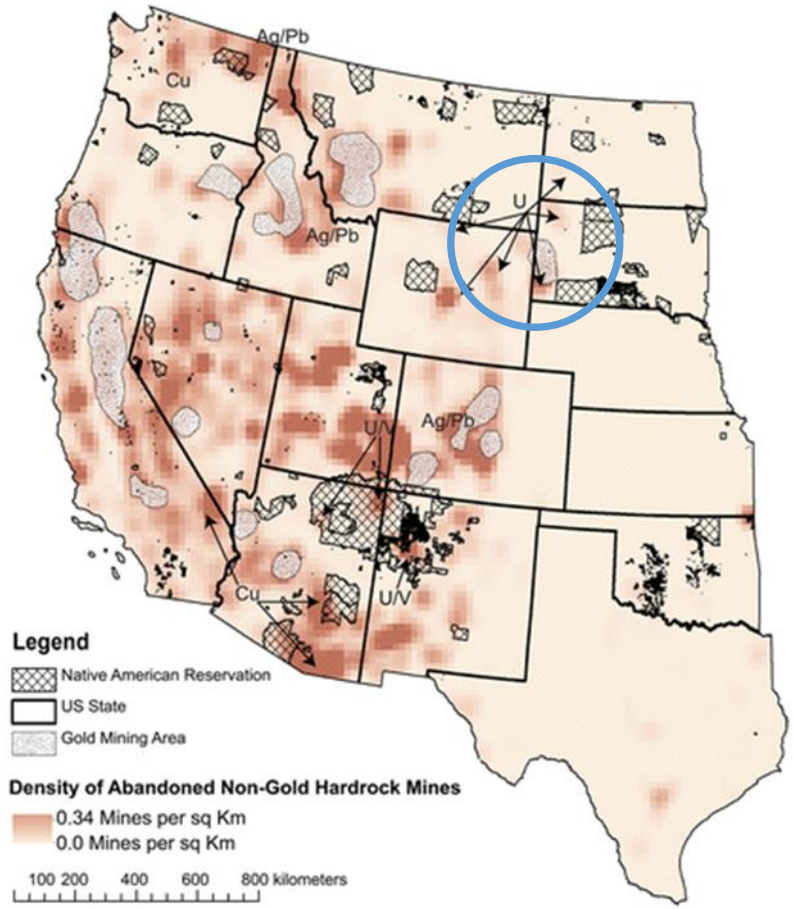
Other health endpoints associated with arsenic in the Strong Heart Study:
cancers of the lung, prostate and pancreas, chronic kidney disease, impaired lung function

Mining and metal exposures in Indigenous Communities



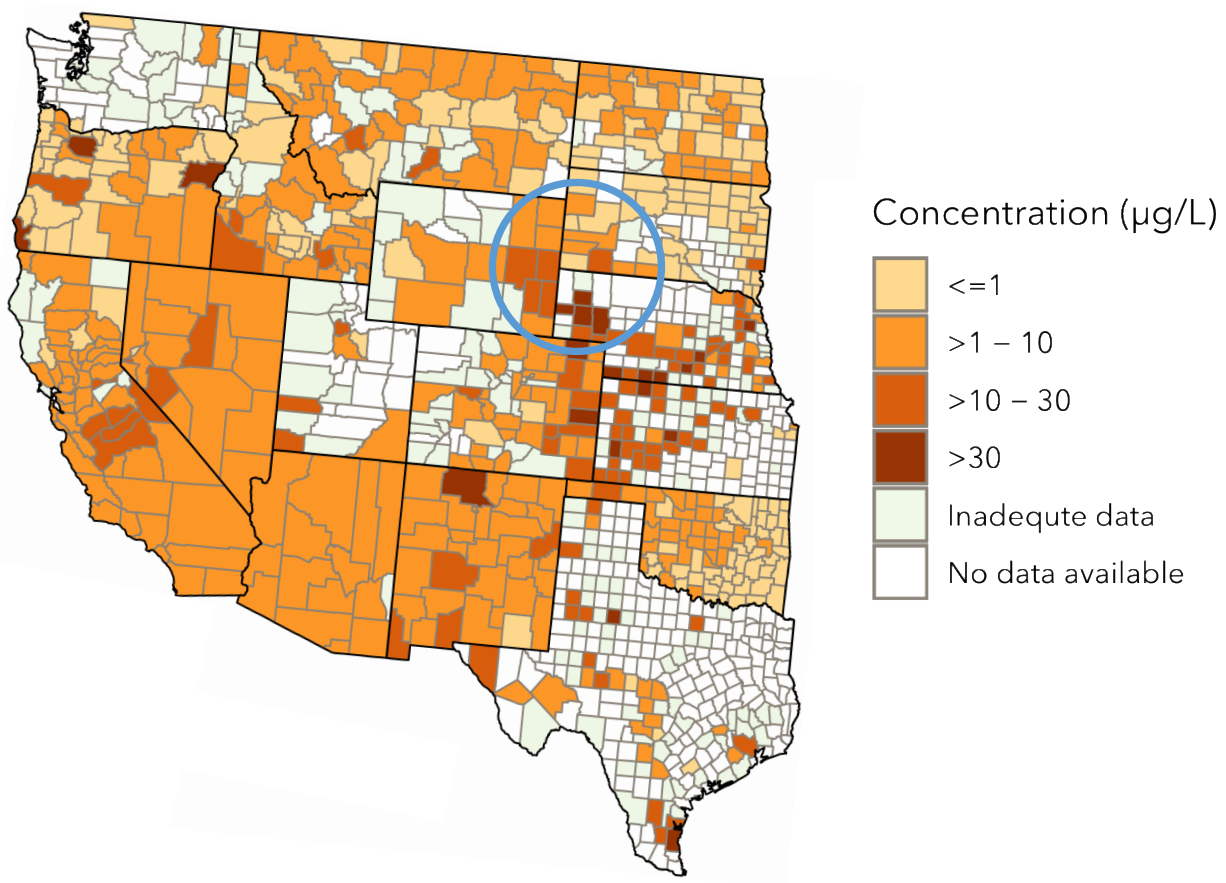
Lewis et al. Current Environmental Health Reports 2017

Mining and metal exposures in Indigenous Communities



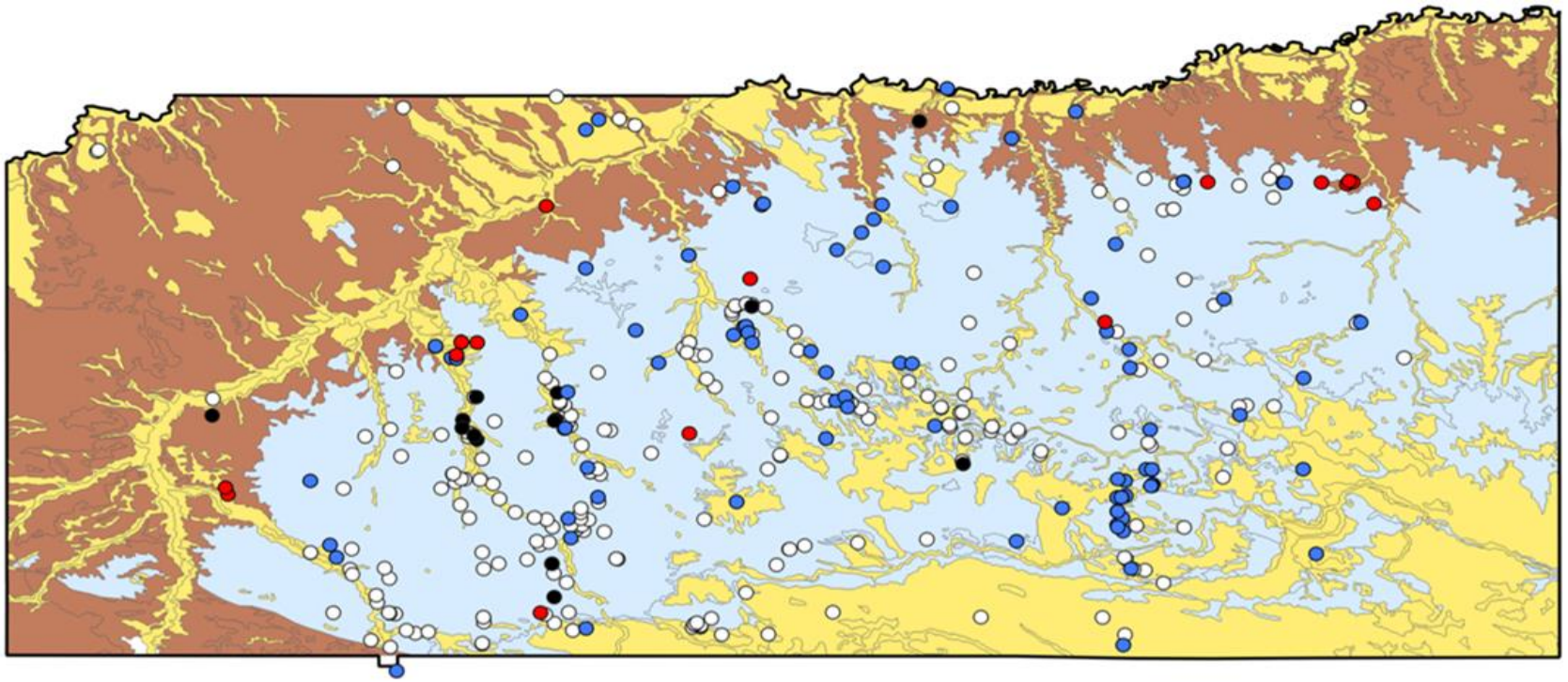
Lewis et al. Current Environmental Health Reports 2017

County average uranium levels (µg/L) in public water systems, 2000-2011



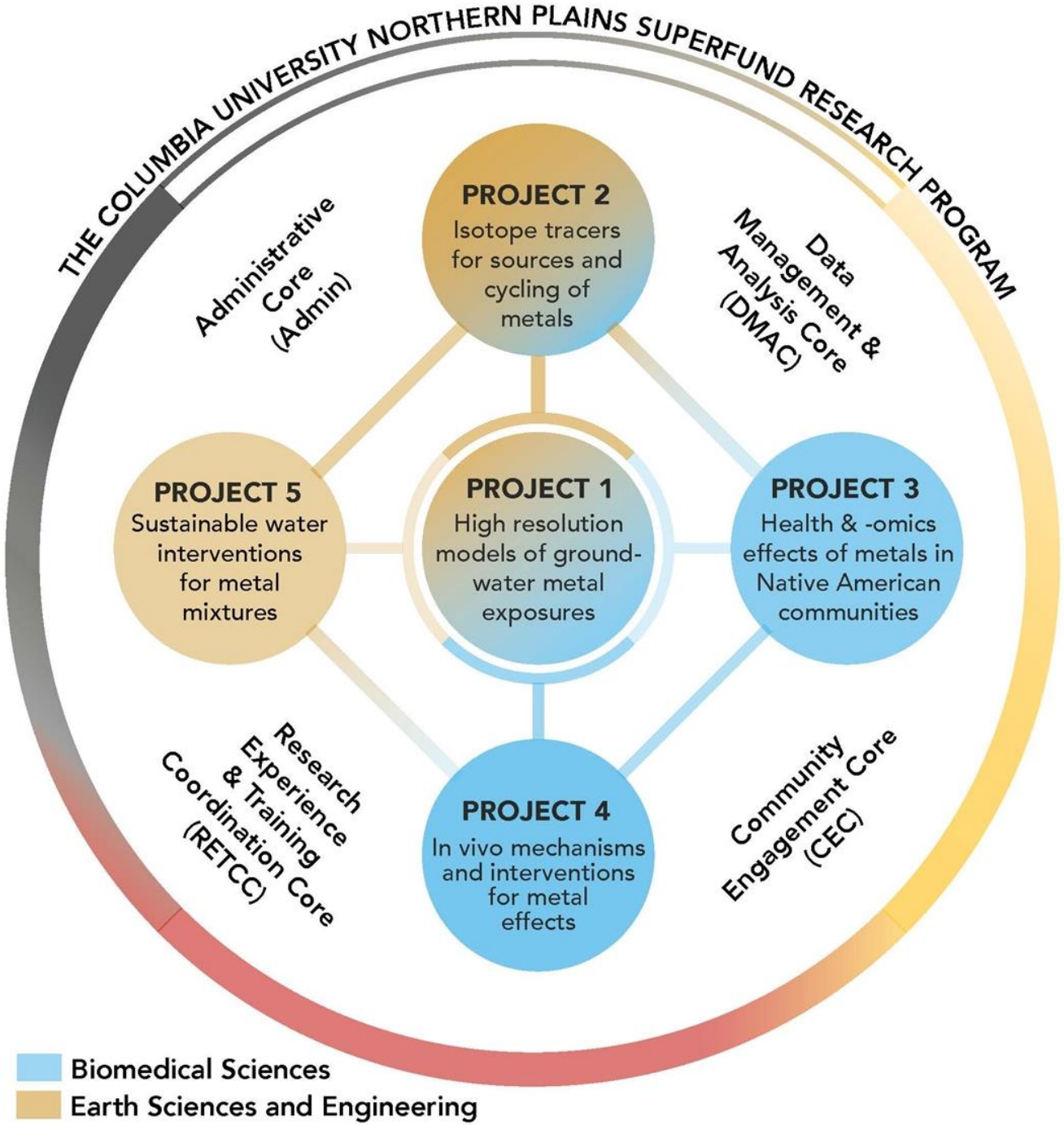
Ravalli et al. Lancet Public Health 2022

Arsenic and uranium spatially correlate in water samples



Marisa Sobel

Sobel et al. Environ Pollution 2021



MISSOURI BREAKS
Creating Opportunities for Health

STRONG HEART STUDY
ND
SD
AZ
OK

COLUMBIA
MAILMAN SCHOOL OF PUBLIC HEALTH

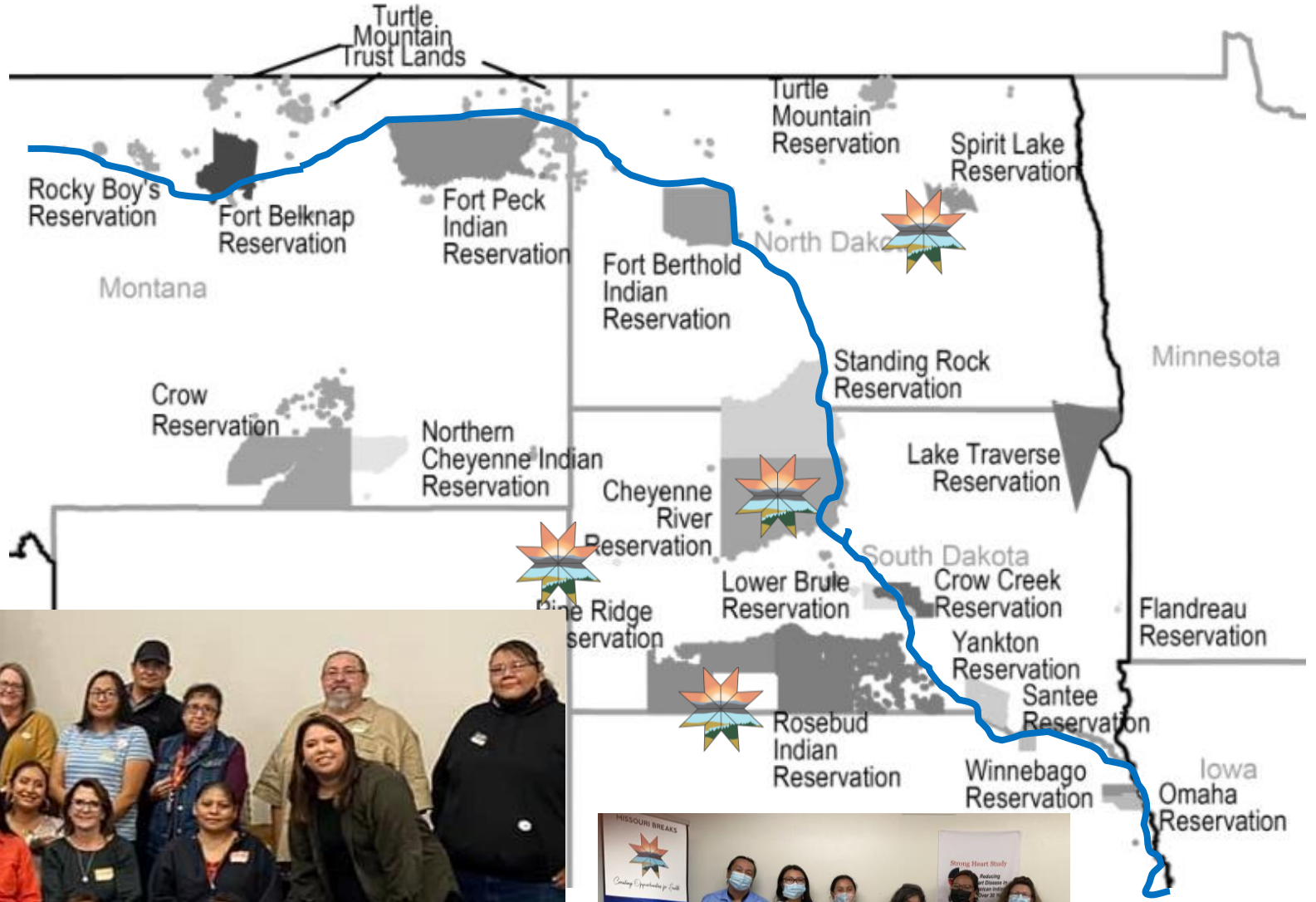
LAMONT-DOHERTY EARTH OBSERVATORY

COLUMBIA CLIMATE SCHOOL
Climate, Earth, and Society

MISSOURI BREAKS

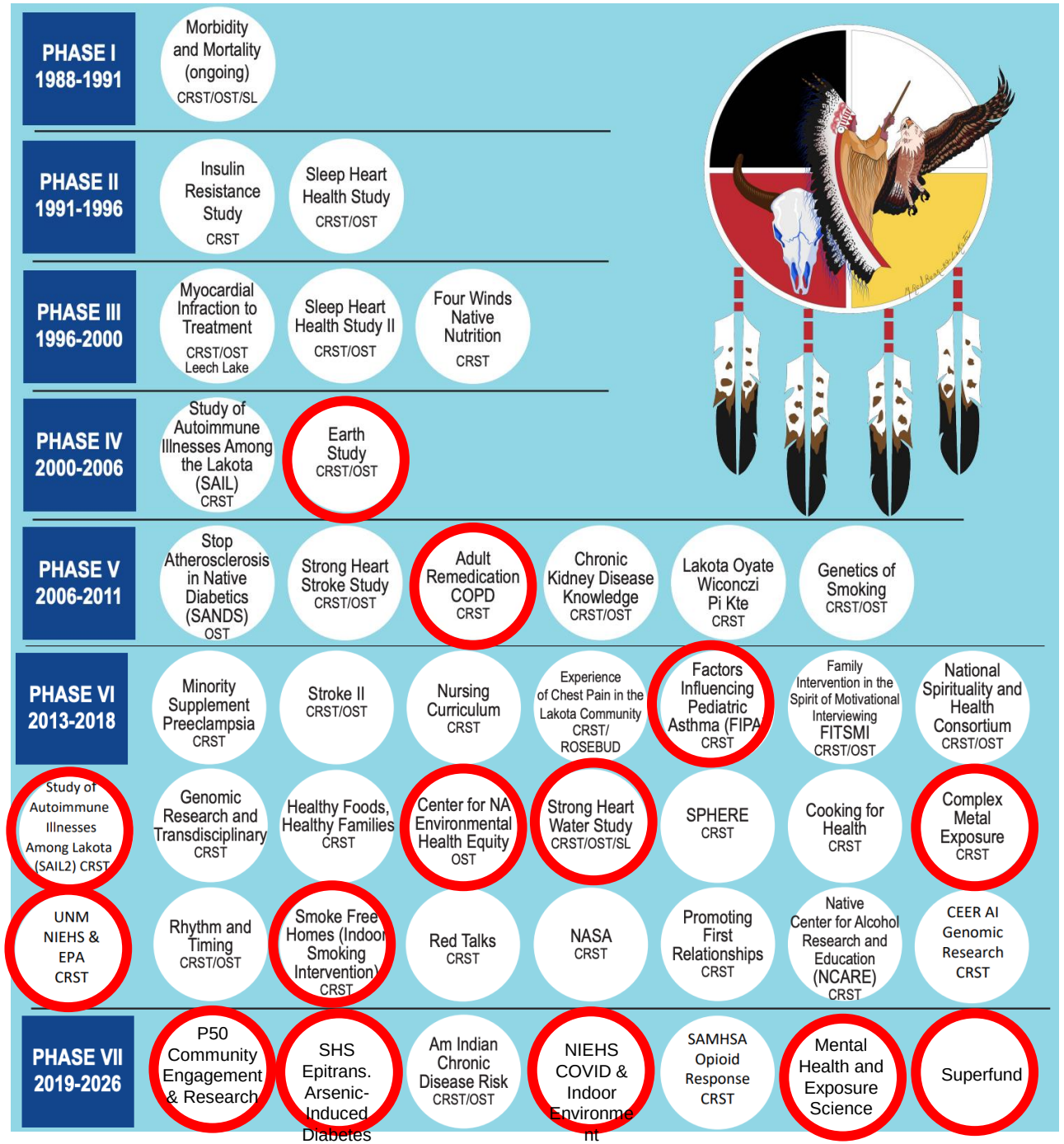
Creating Opportunities for Health

ADVANCING INNOVATIVE SOLUTIONS THROUGH
PARTNERSHIPS, DATA & UNDERSTANDING

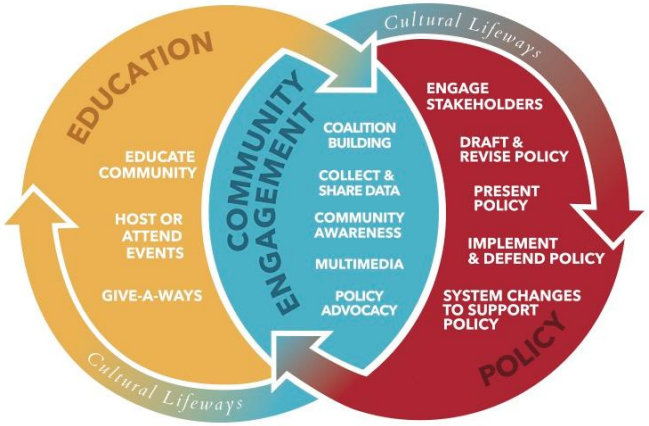


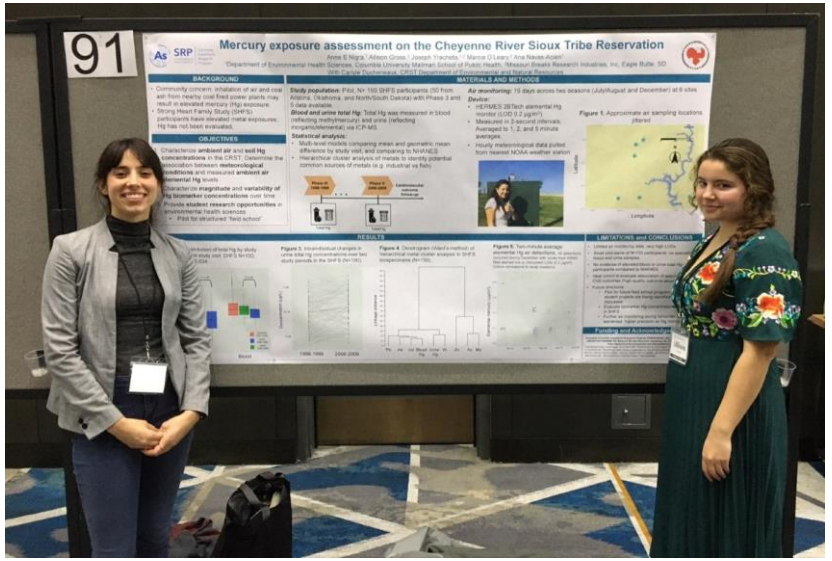
Community Projects & Studies

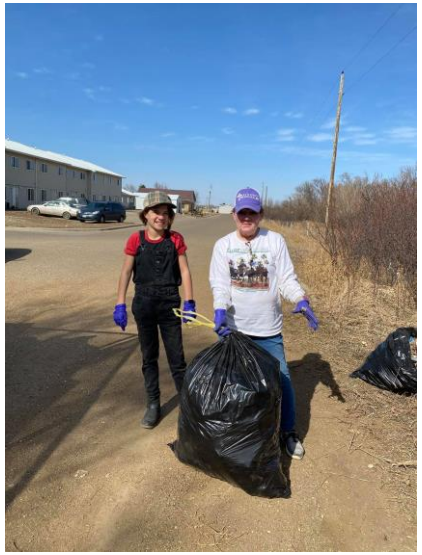
- The Strong Heart Study is the largest longitudinal study of the American Indian population.
- >90% retention rate
- All of these Lakota community-based studies and projects are built on the Strong Heart Study foundation



Community Engagement Examples







- Sharing findings at community research symposium
- Supporting water collection

Project 1: Models of groundwater metal exposure

- Characterize factors that control the distribution of As and U in the Northern Plains
  - **Aim 1: Increase data density on or near tribal lands**
  - Differentiate factors that mobilize As and U
  - Aim 2: Develop groundwater models at the household scale for As and U
  - Aim 3: Estimate long term As and U exposure from drinking water for Project 3

- Plays an integrating role


PI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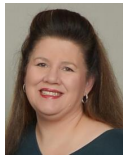
Columbia University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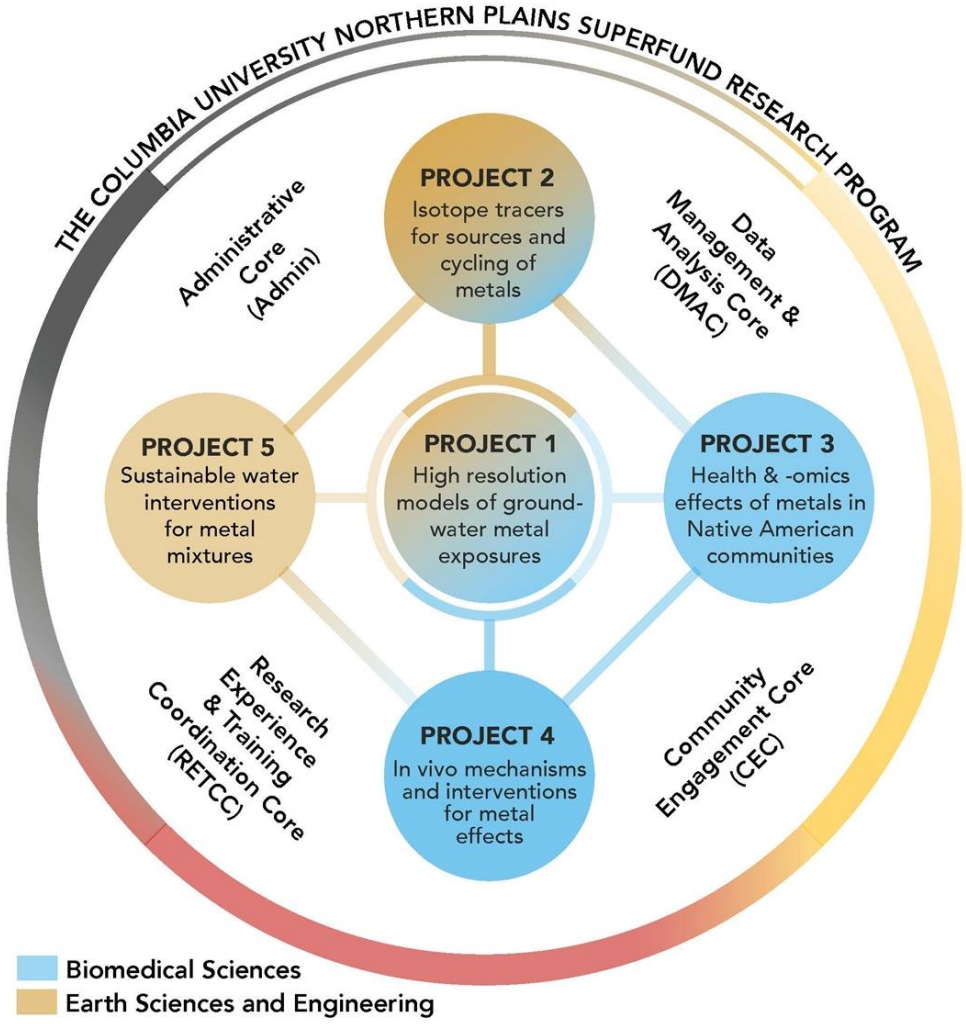
Co-I

MBIRI

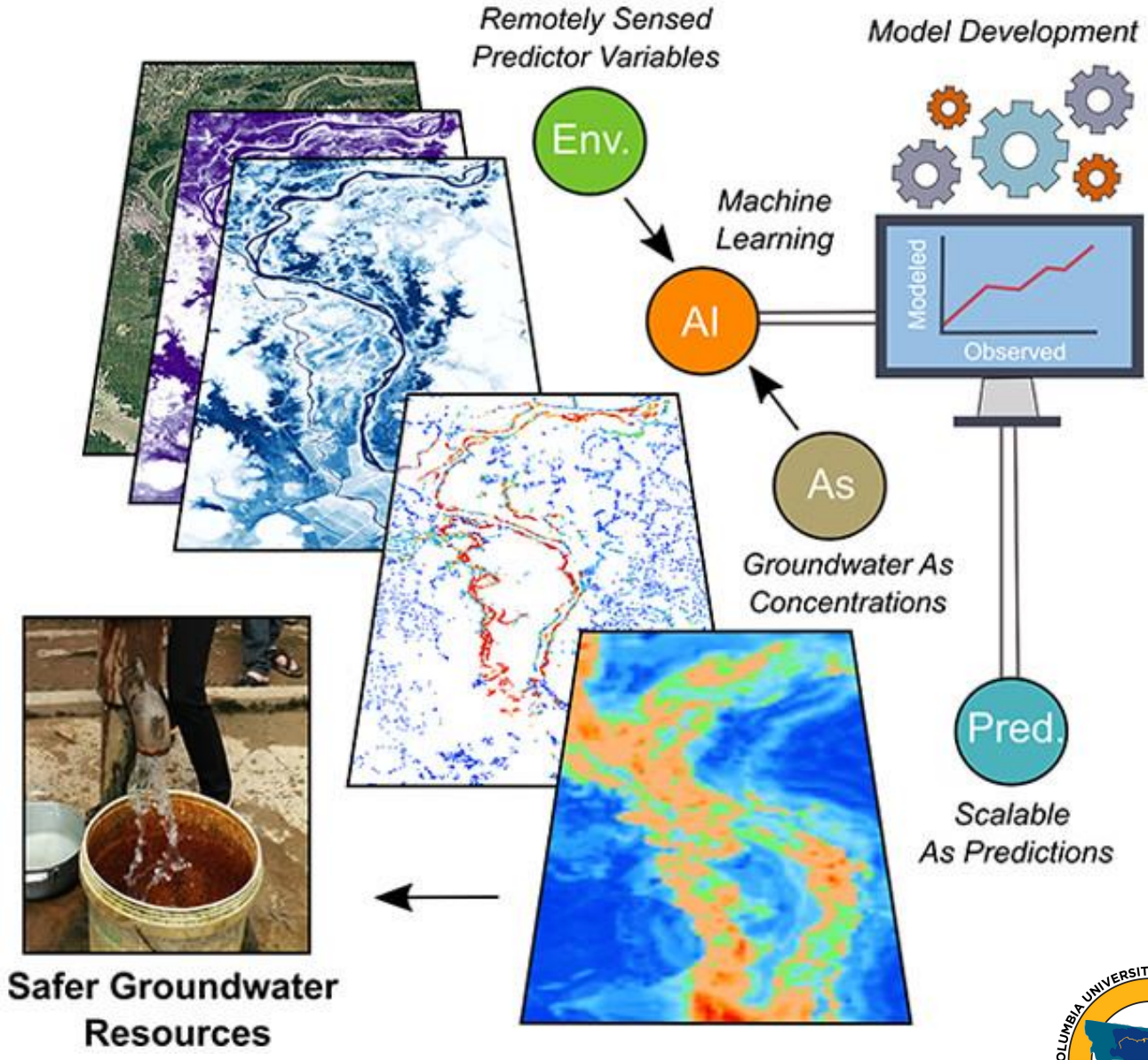

Sub co-I

Union College



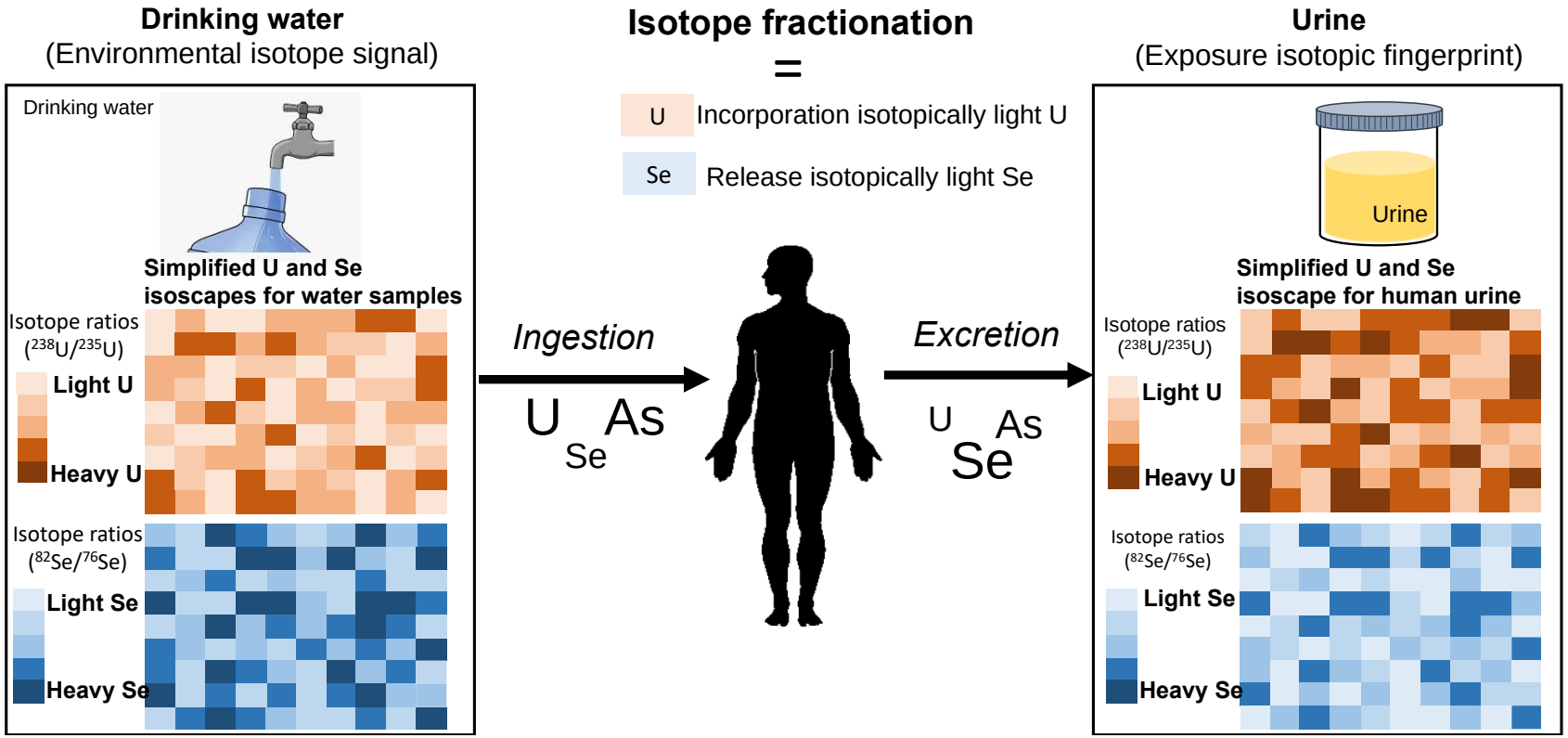
Aim 2. Prediction models

- Overarching approach
  - Best models should be grounded in a mechanistic understanding of geochemical processes that control water quality.
  - Models need predictor variables at a fine spatial scale to make discrete predictions at fine spatial scale
- Remote sensing: one of the few data sets that provides fine spatial scale data
  - Flooding frequency and flooding duration as master variable



Connolly et al. ES&T (2022)
https://doi.org/10.1021/acs.est.1c05955

Project 2: Isotope tracers for sources and cycling of metals



PI

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- Spatial distribution of isotope ratios (“isoscapes”) for U and Se isotopes
- Temporal evolution of metal isotope ratios

→ Inform whether contamination is from a local or distant source- even estimate how far it has travelled

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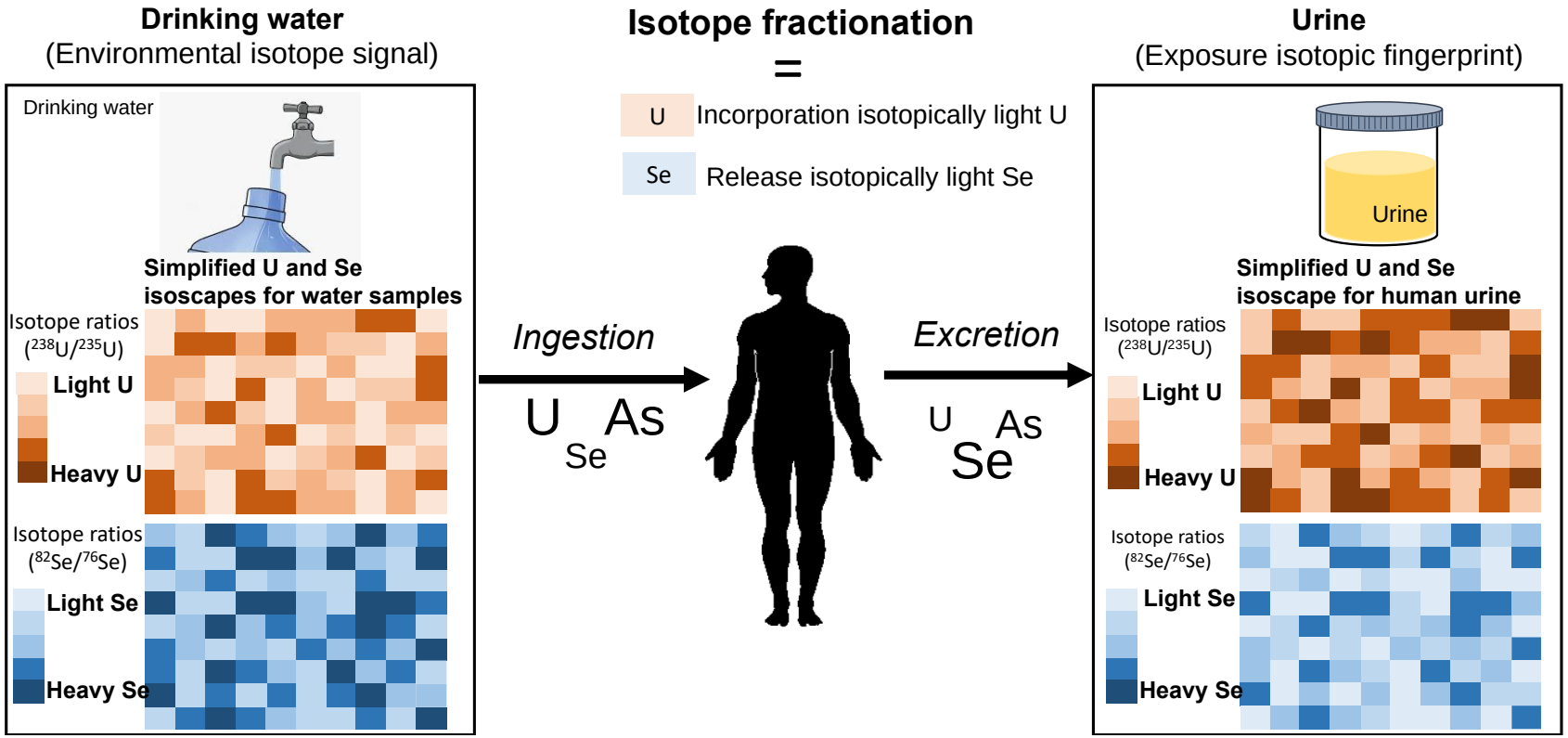

PI

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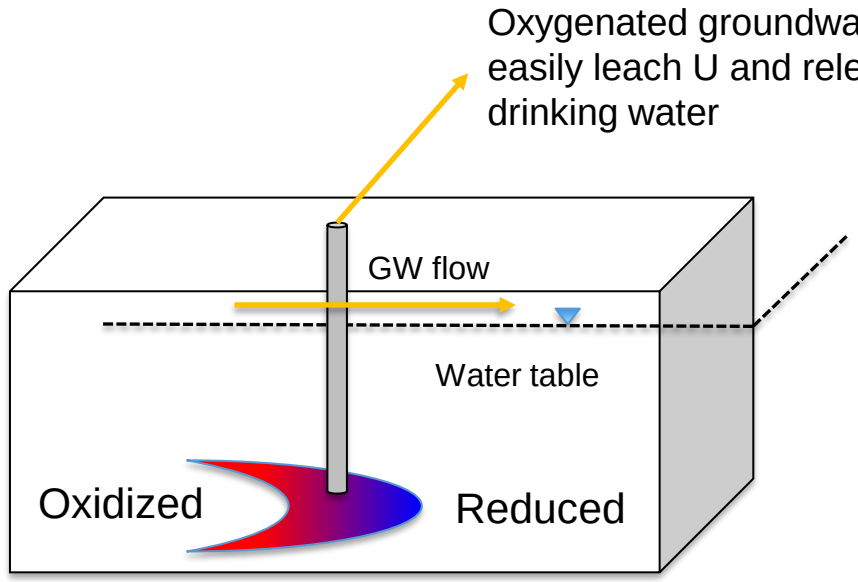
→ Inform whether gw contamination is from a local or distant source- even estimate how far it has travelled

- Novel biomarkers in humans
- Novel application to animal model research

Roll fronts develop in sandstone aquifers

"In configuration, they were something like comets, or crescent moons with trailing horns – convex in the direction in which groundwater had flowed. As Love and his colleagues worked out the chemistry, they began with the fact that six-valent uranium is very soluble, and in oxidized water easily turns into uranyl ions. As the solution moves down the aquifer, a roll front will develop where the water finds an unusual concentration of organic matter. The organic matter goes after the oxygen. The uranium, dropping to a four-valent state, precipitates out as UO_2 – the ore that is called uraninite."

- John McPhee, Rising from the Plains



- U isotopes provide mechanistic tracers of redox cycling and U transport
  - $^{238}U/^{235}U$ – redox cycling tracer
  - $^{234}U/^{238}U$ – source tracer of transport
  - ^{235}U enrichment in water indicates U removal by reduction
  - In U deposits- $(^{234}U/^{238}U) < 1$
  - Far from U deposits $(^{234}U/^{238}U) > 1$

Project 5: Light-Based Approaches to Effective and Sustainable Small-Scale Water Treatment

- **Develop treatment systems that are effective and sustainable** by leveraging natural constituents in groundwater including microbes

  → Produce and recycle iron (Fe) oxide media for coagulation.

- **Enhance treatment through light** to change water contaminants to less soluble forms.

- **Develop a drinking water quality monitor** into the treatment system

  → Test water treatment systems to ensure it is working well.

- **Translation goal: begin to adapt and commercialize research designs** in collaboration with MBIRI and community members for product development related to improved water treatment.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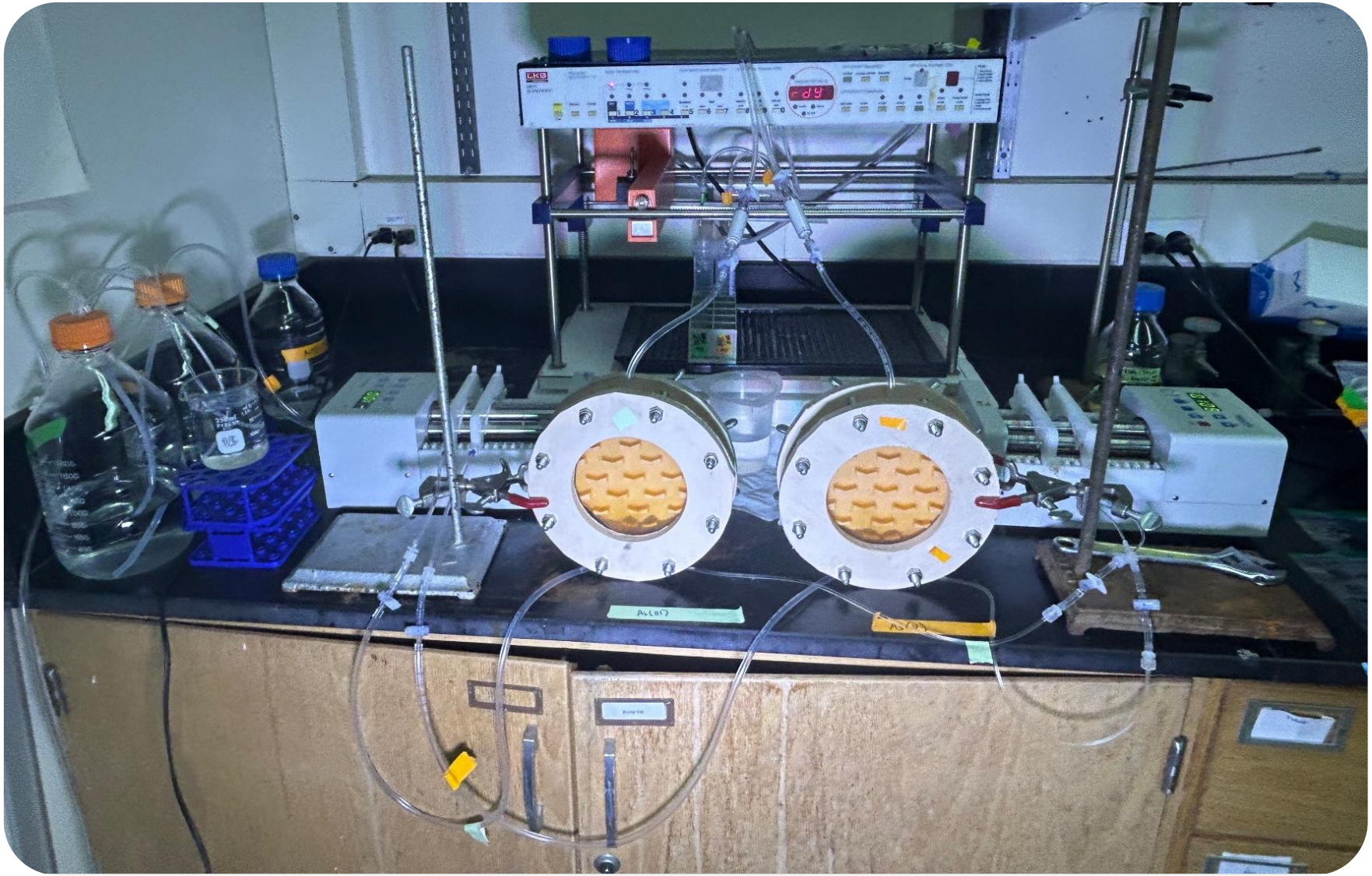
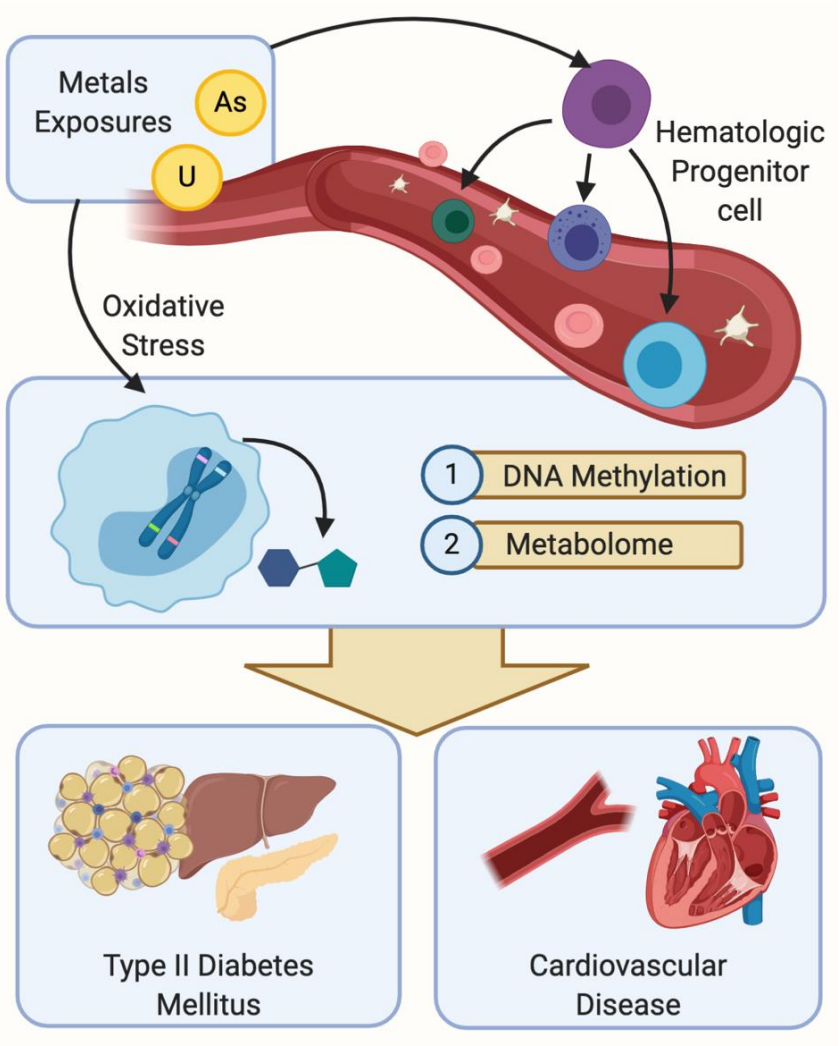


- Current Reactor Design (Adelina Rolea)

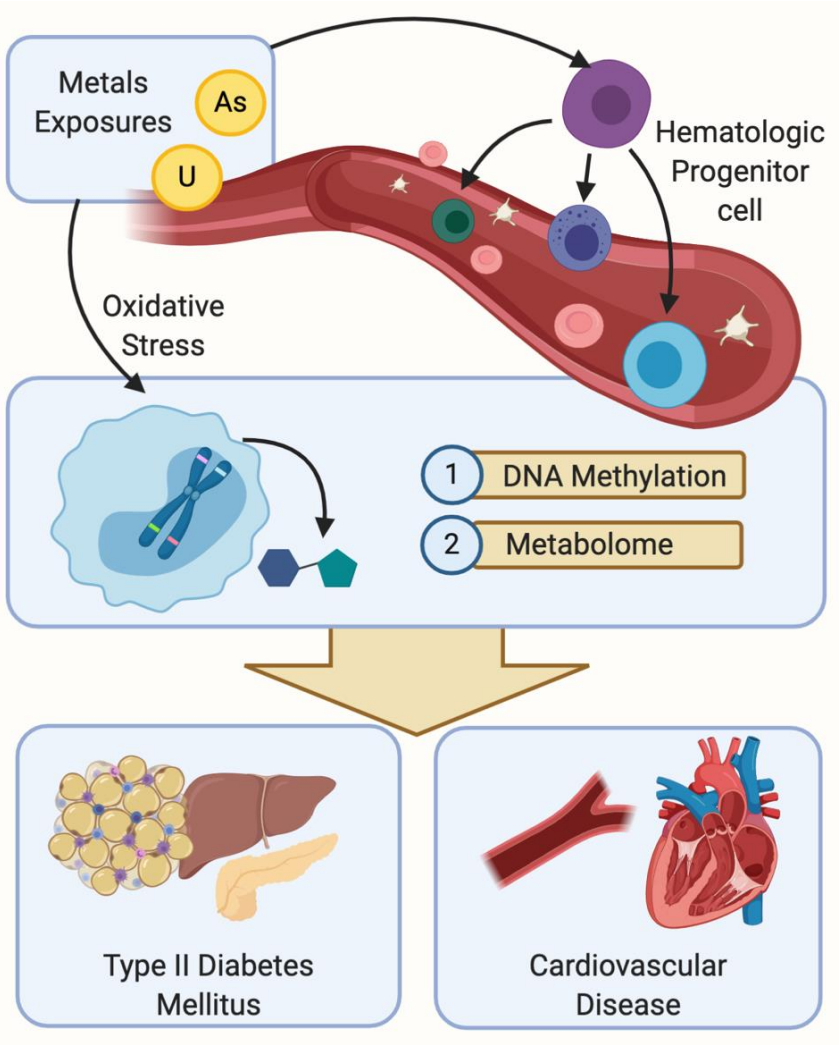
Project 3: Health effects of metals in Native American communities: a multi-omics longitudinal study



Hypotheses:

- As and U exposures have latent and concurrent cardiometabolic effects
- As and U exposures induce epigenomic and metabolomic changes leading to increased cardiometabolic risk

Project 3: Health effects of metals in Native American communities: a multi-omics longitudinal study



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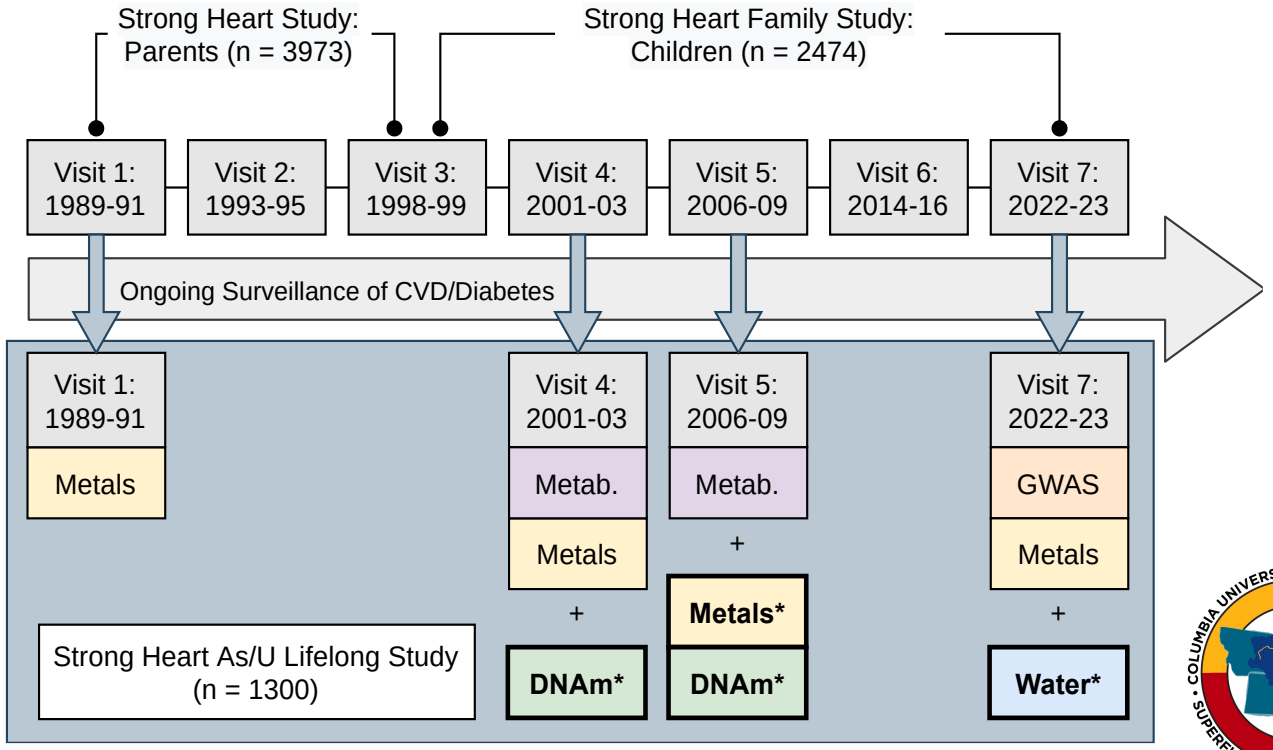
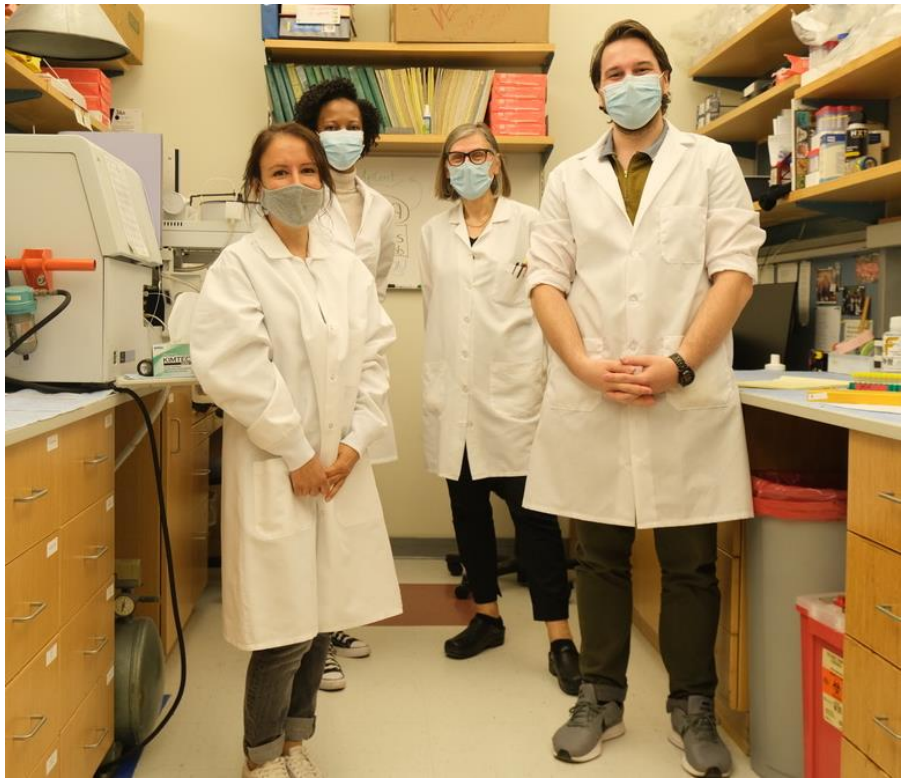


Metallomics Core Facility



Kathrin Schilling

Chiugo Izuchukwu

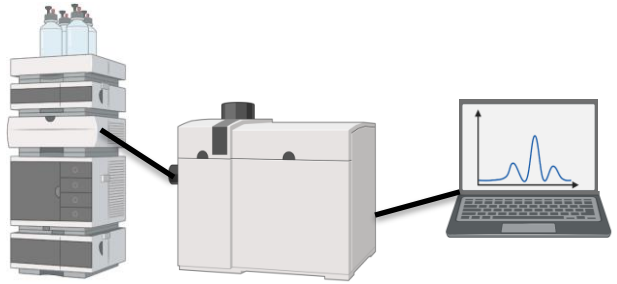
Olgica Balac

Rony Glabonjat

ICPMS

Elements

HPLC-ICPMS



Species

MC-ICPMS

Isotopes

N~8,300 Samples for 22 projects in 2022

ICPMS: Inductively couple plasma mass spectrometry
HPLC: High performance chromatography
MC: multi-collector to measure ions

Maternal DNA methylation signatures of arsenic exposure is associated with adult offspring insulin resistance in the Strong Heart Study

Christian Dye
Post-doc CU

Christian K. Dye [a,*], Arce Domingo-Relloso [a,b], Allison Kupsco [a], Naomi E. Tinkelman [a], Miranda J. Spratlen [a], Anne K. Bozack [c], Maria Tellez-Plaza [b], Walter Goessler [d], Karin Haack [e], Jason G. Umans [f,g], Andrea A. Baccarelli [a], Shelley A. Cole [e], Ana Navas-Acien [a]

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[c] *Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, Berkeley, CA, USA*
[d] *Institute of Chemistry, University of Graz, Graz, Austria*
[e] *Population Health Program, Texas Biomedical Research Institute, San Antonio, TX, USA*
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Environment International

Volume 173, March 2023, 107774

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[b] *Department of Chronic Diseases Epidemiology, National Center for Epidemiology, Carlos III Health Institutes, Madrid, Spain*
[c] *Division of Environmental Health Sciences, School of Public Health, University of California, Berkeley, Berkeley, CA, USA*
[d] *Institute of Chemistry, University of Graz, Graz, Austria*
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[f] *MedStar Health Research Institute, Washington, DC, USA*
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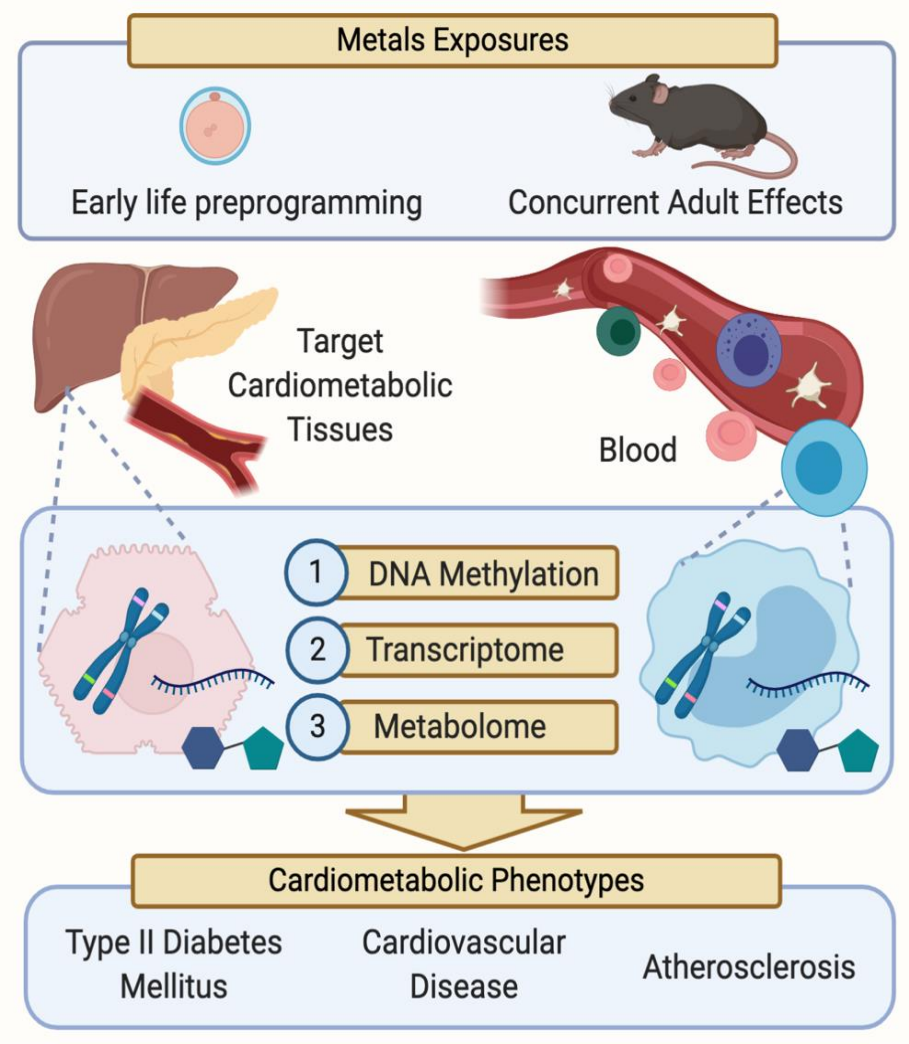
The association between maternal As-related DNA methylation with offspring insulin resistance was attenuated after adjustment for offspring adiposity but not for maternal adiposity

Project 4: Causal molecular mechanisms linking drinking water metal exposures to cardiometabolic disease

PI

co-PI



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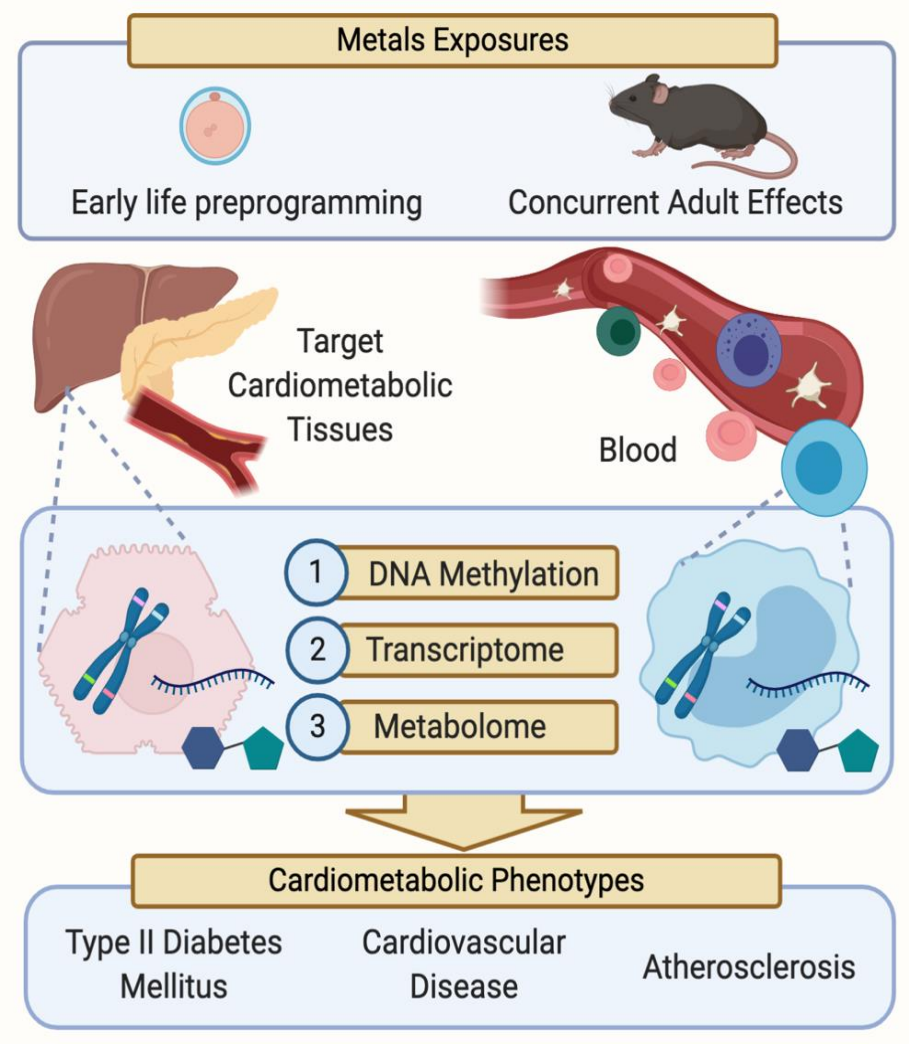
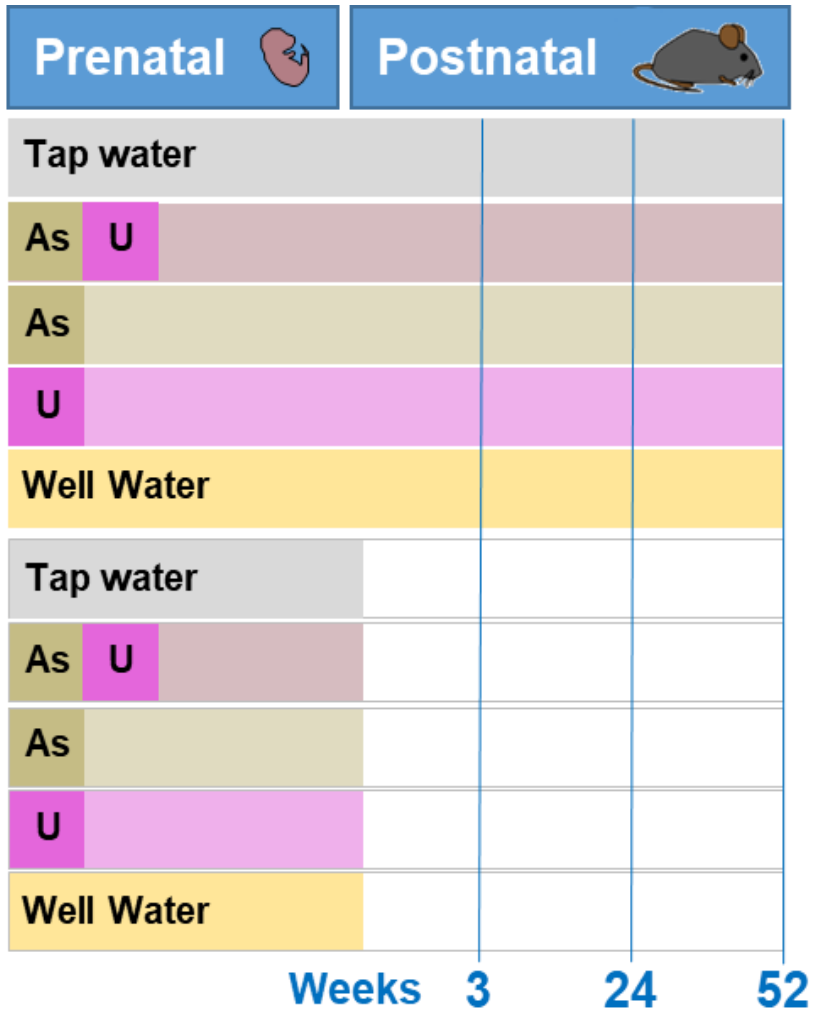
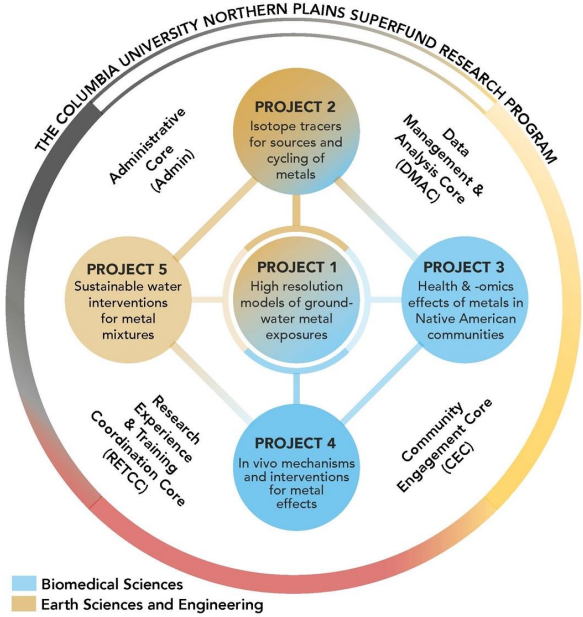


Aims 1 and 2 experiments



Expected impacts in 5 years

- Predictions on where to drill for low As and U groundwater and which groundwater to use for community water systems
- Data on the distance the groundwater U is coming from, key information for our tribal partners
- Advanced understanding of the latent and concurrent effects of As and U, and relevant pathways
- Validated new isotope biomarkers of As and U uptake and cycling for toxicological and epidemiological research
- Positioned to help launch a tribally owned company to scale production and distribution of the remediation technologies including prediction models and long-lasting treatment filters with automated detection of contaminants



Indigenous principles that motivate our work and partnership

Image: Dakota access pipeline protest

- Value traditional knowledge
  - Water is life (Mní wičhóni)
  - 7th generation principle: how our decisions affect our descendants
- Collective leadership
- Sovereignty and data ownership

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Study Team

Director
PI of Project 3

Co-Director
PI of Project 1

CEC Leader
Admin Core

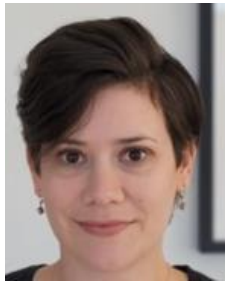
OST Leader
Project 3, CEC Co-I

MBIRI Director Senior advisor
Project 3, 5 Co-I

Co-PIs of Project 2

Co-PIs of Project 4

DMAC Leaders



Co-PIs of Project 3

PI of Project 5
CEC Co-leader

RETCC Leader
Co-I Project 1

RETCC co-I

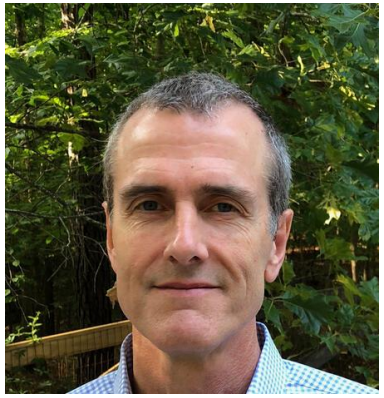
Scientific
coordinator

Business
Manager

Columbia University Northern Plains Superfund Research Program (CUNP-SRP)

External Advisory Committee Members (EAC)

Bhramar Mukherjee (Chair), PhD, Chair of Biostatistics, School of Public Health, University of Michigan



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Otakuye Conroy-Ben, PhD, Associate Professor, School of Sustainable Engineering and the Build Environment, Arizona State University

CAPT David Harvey, **MS, MPH,** Deputy Director of the Division of Sanitation Facilities Construction, Indian Health Service.

Dean Jones, PhD, Professor of Medicine, Division of Pulmonary, Allergy, and Critical Care Medicine, Emory University

Donald Smith, PhD, Distinguished Professor of Microbiology and Environmental Toxicology, University of California

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