National Institute of Environmental Health Sciences
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SRP-Funded Research in Metal/Metalloid Remediation Technologies

Heather Henry, PhD

Program Administrator, Superfund Research Program
National Institute of Environmental Health Sciences

SRP is Part of the National Institutes of Health

Fundamental Knowledge

NIH Research Mission

Health Outcomes

…of living systems

…reduced illness & disability

National Institutes of Health

…with environmental exposures

…including health effects, assessing risks, detection and remediation

National Institute of Environmental Health Sciences

Superfund Research Program (SRP)
SARA Legislation

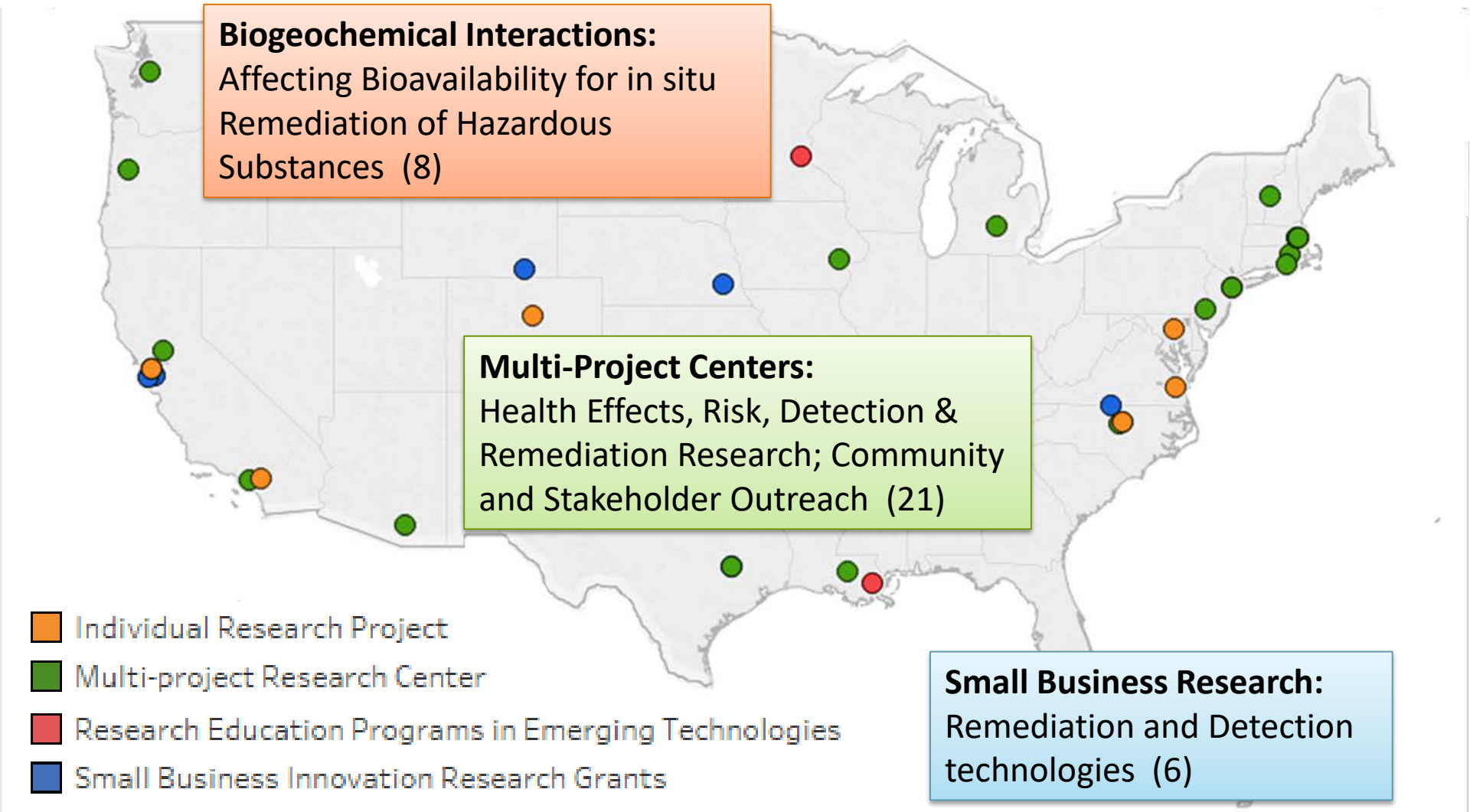
…caused by hazardous substances

…relevant to Superfund stakeholders

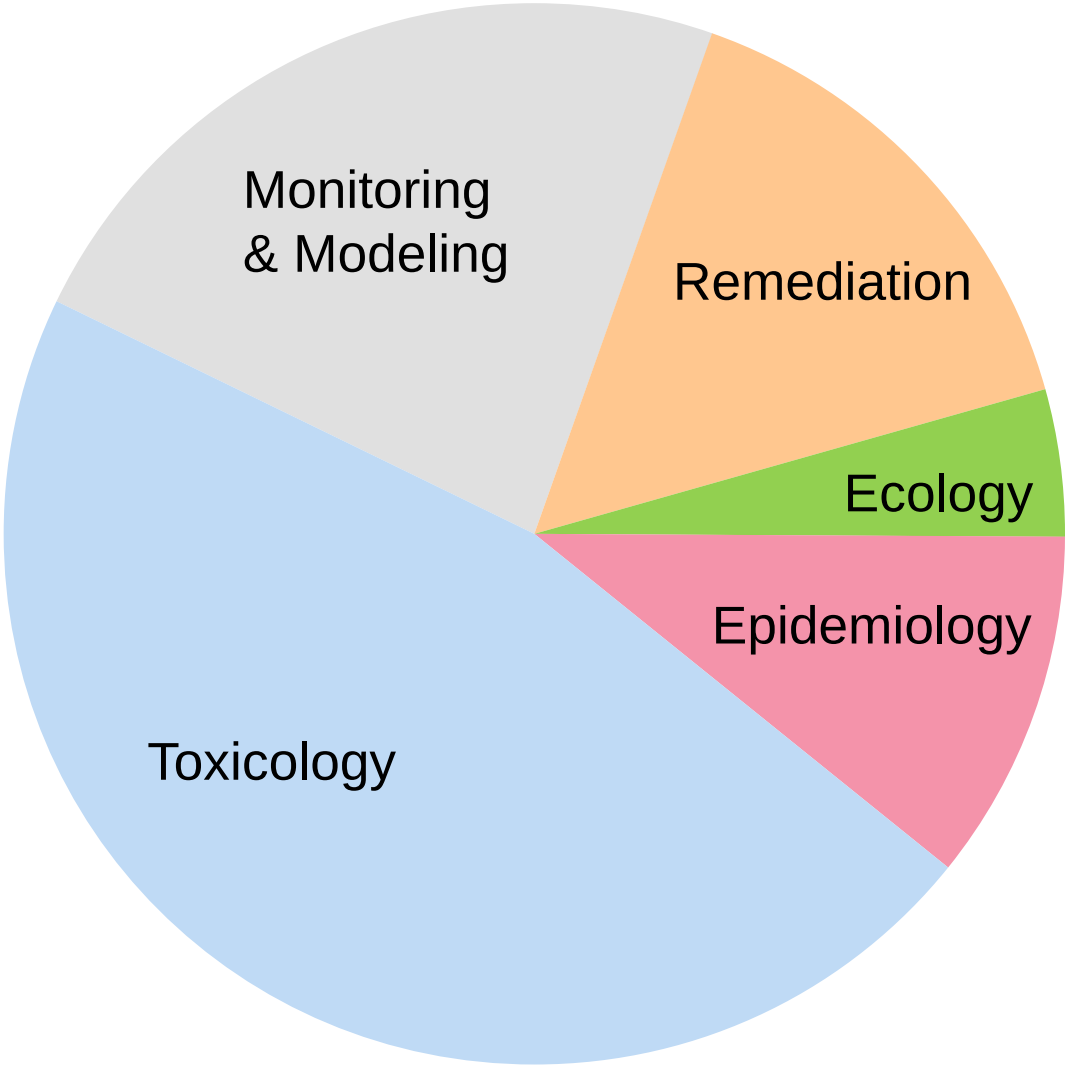
NIEHS Superfund Research Program (SRP)

- **Mission**: Provide practical science to solutions to protect human health
- NIH peer-reviewed, competitively awarded grants to Universities and small businesses
- **Unique team-science approach**
  - Brings together diverse disciplines: health researchers, engineers, biologists, ecologists, earth scientists, and social scientists
  - Aims to understand and reduce exposure to potentially harmful contaminants and improve health
- Works closely with industry, government, tribal, and business partners to deliver practical solutions

SRP – Funded Research Across the U.S.A.



SRP Research Portfolio (2017)



Remediation Portfolio

Physical/Chemical (7)
- **Barrier: 2**
- **Chemical: 3**
- **Electro/Thermal: 2**

Biological (8)
- **Extraction: 3**
- **Degradation: 5**

Highlights:
SRP Metals Remediation and Related Research & Activities

Sustainable Solutions – Phytostabilization of Mine Tailings

PI: Raina Maier
University of Arizona

Phytostabilization Technology for Mining Wastes in Arid and Semiarid Environments: Plant-Microbe-Metal Indicators to Predict Sustainability

Researchers started a field trial at the Iron King Mine and Humboldt Smelter Superfund site in Arizona in 2010.

Sustainable Solutions – Phytostabilization of Mine Tailings

PI: Raina Maier, University of Arizona

Phytostabilization Technology for Mining Wastes in Arid & Semiarid Environments

- Targeted Metals: Arsenic, lead
- Innovation: Revegetation strategy "compost-assisted phytostabilization." Plants accumulate metals in root zone → prevent from entering food chain. Collected data will help assess phytostabilization as a remediation technology in semi-arid environments.
- Status: Field study at Iron King Superfund site in Dewey-Humboldt, AZ. Currently being translated to major mining companies to improve mine-tailing remediation practices.
- Relevant Publications:
  - Santos et al., PeerJ, 2017
  - Gil-Loaiza et al., Sci Total Environ, 2016

Sustainable Solutions – Stabilization of Metals in Soil

PI: Malcolm Burbank
BioCement Technologies, Inc

Microbial Induced Calcite Precipitation by Indigenous Soil Bacteria to Reduce Mobility of Lead and other Metals in Soil*

BioCement

BioCement stabilizes metals in soil

*Previously Funded

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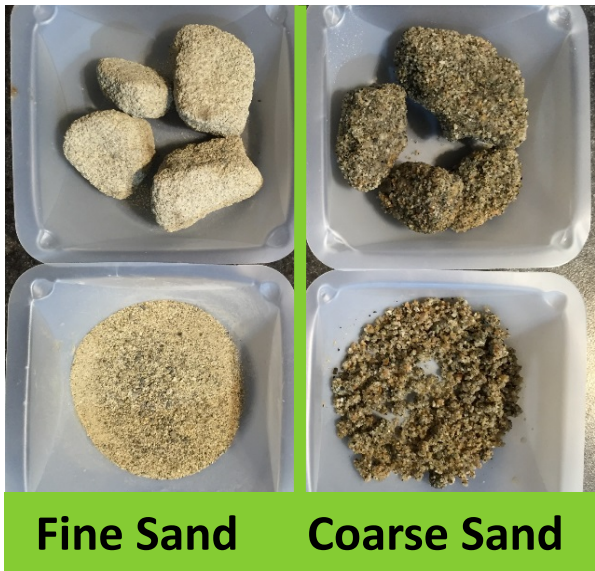
Sustainable Solutions – Stabilization of Metals in Soil

PI: Malcolm Burbank, BioCement Technologies, Inc

Microbial Induced Calcite Precipitation by Indigenous Soil Bacteria

- Targeted Metals: Lead, other metals (e.g., barium, cadmium, cobalt, manganese, strontium and zinc). Also stabilizes uranium.
- Innovation: Simultaneously alter engineering characteristics of soil/sand while reducing the mobility of metals. Stable over geologic time. Process is carbon neutral to carbon negative.
- Status: BioCement is commercially available. Currently testing the use of BioCement to treat munitions-impacted soil.



BioCement

Phone: 509-607-2406
Email: burbankm@cdmsmith.com

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Assessing Effectiveness of Mercury Methylation

PI: Heileen Hsu-Kim
Duke University

Biogeochemical Framework to Evaluate Mercury Methylation Potential During in-situ Remediation of Contaminated Sediments

Assessing Effectiveness of Mercury Methylation

PI: Heileen Hsu-Kim, Duke University

Biogeochemical Framework to Evaluate Mercury Methylation Potential

- Targeted Metals: Mercury
- Innovation: Establishing biogeochemical indicators for methylmercury production to improve the effectiveness of in situ remediation.
- Status: Conducting lab sediment microcosm experiments simulating a range of conditions relevant to mercury-contaminated Superfund sites.
- Relevant Publications:
  - Wyatt et al., Environ Sci Technol, 2016
  - Kucharzyk et al., Environ Sci Process Impacts, 2015
  - Ticknor, et al., Environ Eng Sci, 2015
  - Pham et al., Environ Sci Technol, 2015 (DGT sampling)

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Biogeochemistry: Bioavailability Assays at Clear Creek, CO

PI: Jim Ranville
Colorado School of Mines

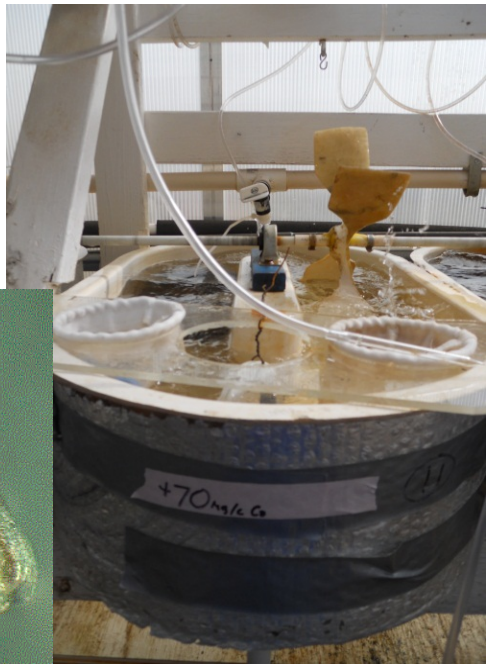
Investigating Biogeochemical Controls on Metal Mixture Toxicity Using Stable Isotopes and Gene Expressions

Biogeochemistry: Bioavailability Assays at Clear Creek, CO

PI: Jim Ranville, Colorado School of Mines

Biogeochemical Controls on Metal Mixture Toxicity

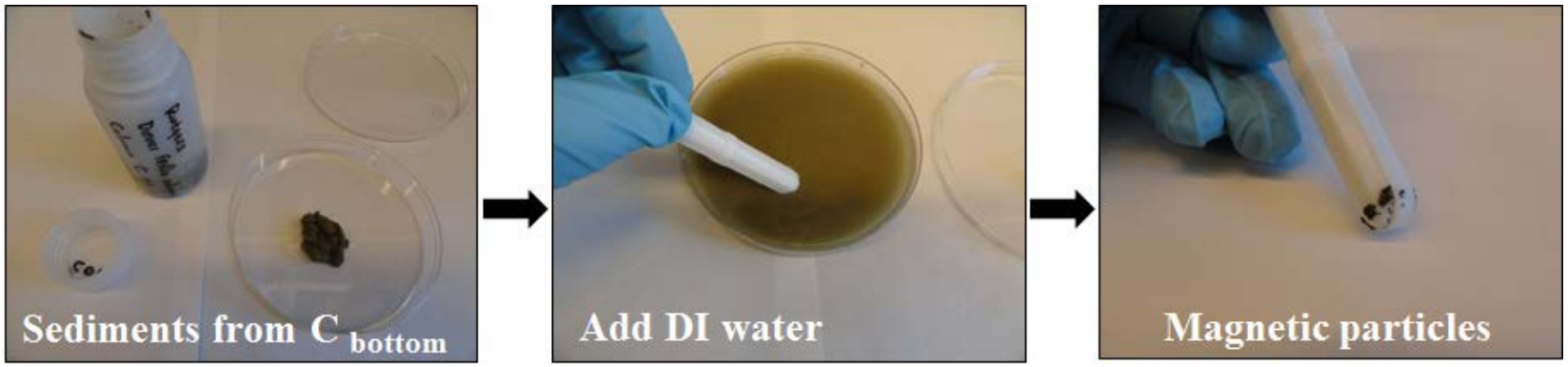
- Targeted Metals: Metal mixtures (lead, copper, zinc, nickel, iron)
- Innovation: Organism & community-level studies, genomic bioassays, & bioavailability studies. Applying concepts to study remediation effectiveness; simulated recovery experiments.
- Status: Field testing in metals-contaminated stream at North Fork Clear Creek Superfund site in CO.
- Relevant Publications:
  - Traudt et al., Environ Toxicol Chem, 2017
  - Cadmus et al., Environ Sci Technol, 2016
  - Traudt et al., Environ Toxicol Chem, 2016

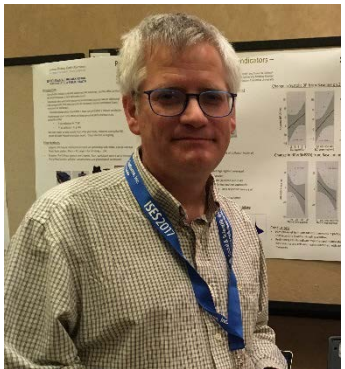


Enhanced Remediation at Contaminated Sites in the U.S.

PI: Benjamin Bostick, Steven Chillrud, Columbia University

Enhanced Remediation at Contaminated Sites in the U.S. –
Focusing on Arsenic for SRP, but also working with Mn



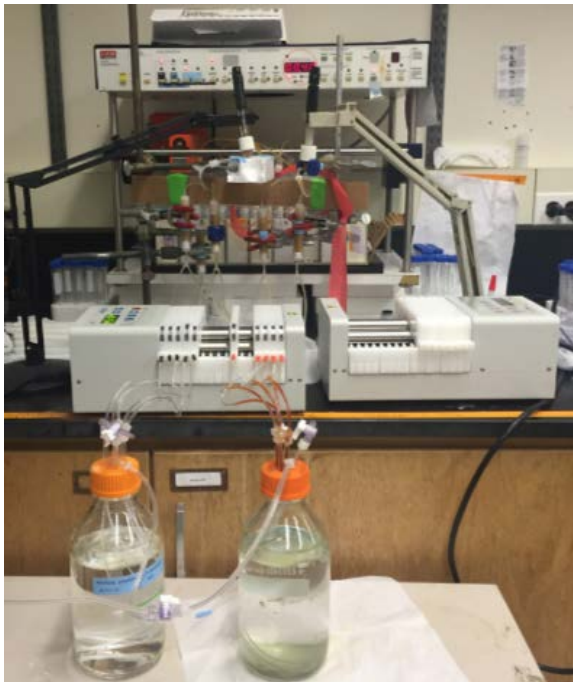


Enhanced Remediation at Contaminated Sites in the U.S.

PI: Benjamin Bostick, Steven Chillrud, Columbia University

Enhanced Remediation of Arsenic at Contaminated Sites in the U.S.

- Targeted Metals: Arsenic, Manganese.
- Innovation: Developing enhanced remediation technology that produces magnetite in situ → forms reactive barrier that sustains low As both in laboratory and in field trials.
- Status: Lab and field-based studies; pilot at US Geological Survey site on Cape Cod, Lot 86 Superfund site at North Carolina State University. First field-scale test of nitrate-Fe(III) injections for As remediation.
- Relevant Publications:
  - Sun et al., Environ Sci Technol, 2016
  - Sun et al., J Hazard Mater, 2016



Protecting Water from Mine Waste

PI: Jose Manuel Cerrato
University of New Mexico

Immobilization of Uranium, Arsenic, and Co-occurring Metals in Mine Wastes

Developing cost-effective remediation strategies that immobilize metals and prevent degradation of community water sources.

Protecting Water from Mine Waste

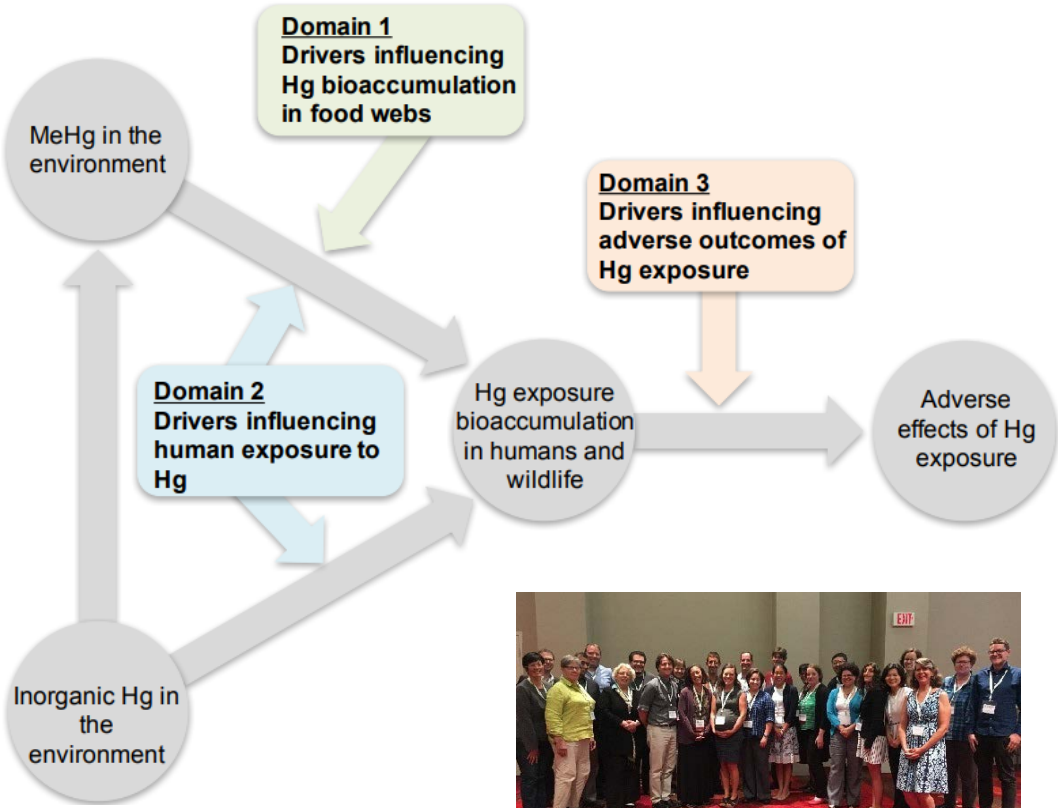
PI: Jose Manuel Cerrato, University of New Mexico

Immobilization of Uranium, Arsenic, and Co-occurring Metals in Mine Wastes

- Targeted Metals: Uranium, arsenic, metal mixtures (Mo, Se, V)
- Innovation: Studying reaction mechanisms involving metal mixtures of ubiquitous secondary mineral phases and the adsorption of locally abundant iron oxides that may help reduce exposure risks to human health. Engineering phytoremediation strategies using biogeochemistry and reactive transport modeling. Manipulating rhizosphere environment to alter microbiome-plant interactions controlling uptake of metals in surface water systems downstream of mine waste sites.
- Status: Recently funded, in-vitro and greenhouse experiments; working at Jackpile-Paguate Uranium Mine - Laguna Pueblo, New Mexico.

Outreach Activities: Informing Policy

- International Conference on Mercury as Global Pollutant (ICMGP): Science Informs Policy Questions
  (Celia Chen, Dartmouth SRP Center)
  - Workshop focused on Hg production & fate in response to multiple environmental factors
  - 4 synthesis papers expected to be published in early 2018
  - Synthesis reports currently available on ICMGP website
    (http://mercury2017.com/program/synthesis-effort/)

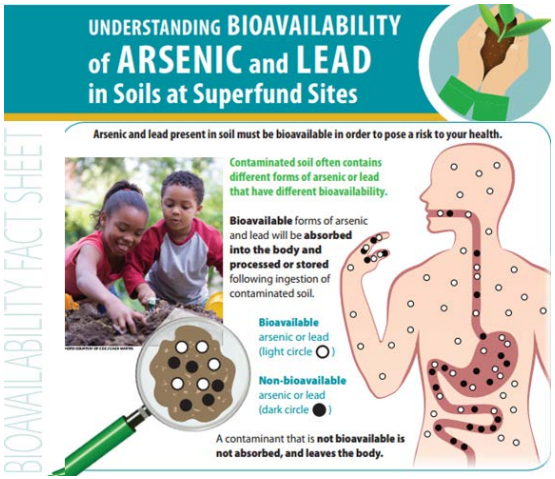


Outreach Activities: Meetings and Partnerships

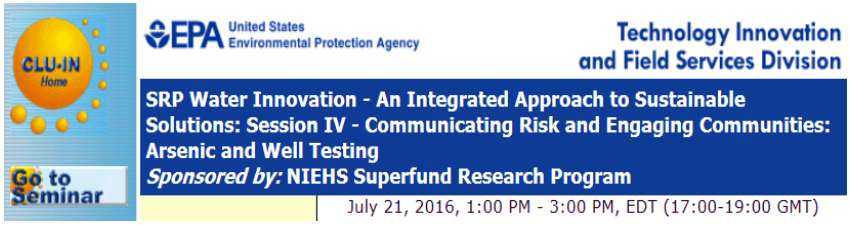
- Sustainable Mining Meetings
  (Raina Maier, University of Arizona SRP Center)
  - 2014 and 2016 meetings established the Pan-American Hub for Sustainable Mining
  - "Compatible" with community, environment, and industry interests

- Partnership with mining companies
  (Raina Maier, University of Arizona SRP Center)
  - Testing cost-saving techniques for stabilizing waste using phytostabilization
  - Identifying biogeochemical values that define a sustainable reclaimed ecosystem, and developing metrics of minimum quality standards for capping material to sustain plant growth

Outreach Activities: Metal Bioavailability



- Bioavailability Fact Sheet
  (U North Carolina, Chapel Hill, U Arizona, U.S. EPA)
  - Created simple factsheet to explain metal bioavailability to the public
- Arsenic and Well Testing Webinar
  (UNC-CH, Columbia, Dartmouth, U Arizona)
  - Well testing for As
  - Communication / engagement



- GardenRoots Project
  (Monica Ramirez-Andreotta, U Arizona)
  - Community-Engaged Research/Citizen Science project
  - Collecting garden soil for As analysis, safe gardening seminars
  - Factsheets and personalized results

gardenroots
A Citizen Science Garden Project

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Additional/Former
SRP Metals Remediation and Related Research

National Institute of Environmental Health Sciences
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Superfund Research Program Metal / Metalloid Remediation Research

The National Institute of Environmental Health Sciences (NIEHS) Superfund Research Program (SRP) funds university and small business multidisciplinary research on human health and environmental issues related to hazardous substances. SRP was initiated under the Superfund Amendments and Reauthorization Act of 1986. The central goal of SRP is to understand and break the link between chemical exposure and disease. Teams of diverse professionals develop, test, and implement unique, solution-oriented approaches to address complex environmental health problems. The following are recent and current SRP grants developing new remediation and detection strategies for heavy metals and metalloids. For more information about the SRP, visit http://www.niehs.nih.gov/srp.

Amendments for Metals / Metalloids	
Enhanced Remediation of As Contamination in the U.S. * **Benjamin Bostick, Columbia University** **Phone: 845-365-8659** **Email: bostick@ldeo.columbia.edu** **P42ES010349**	Removal of Arsenic and Heavy Metals from Drinking Water John Lovell, ADA Technologies, Inc Phone: 303-792-5615 Email: john.lovell@adatech.com R44ES011885
Immobilization of Uranium, Arsenic, and Co-occurring Metals in Mine Wastes * **Jose Manuel Cerrato, University of New Mexico** **Phone: 505-272-1299** **Email: jcerrato@unm.edu** **P42ES025589**	Activated Carbon as a Multifunctional Amendment to Treat PCBs and Mercury* Richard Luthy, Stanford University Phone: 650-723-3921 Email: luthy@stanford.edu R01ES016143
Development of in-situ Mercury Remediation Approaches Based on Methylmercury Bioavailability* Upal Ghosh, University of Maryland – Baltimore County Phone: 410-455-8665 Email: ughosh@umbc.edu R01ES024284	Sequestration and Immobilization of Metal and Metalloid Contaminants in Sediments Peggy O'Day, University of California – Merced Phone: 209-228-4338 Email: poday@ucmerced.edu R01ES016201

Other Phytoremediation Work

- Endophyte Assisted Phytoremediation of Arsenic
  (PI: Michael Blaylock, Edenspace)
- Phytoextraction of Cadmium from Plant Trichomes Expressing a Stabilized Antibody
  (PI: Ryan Shepherd, Phyllotech)
- Nano-scale Mechanisms of Metal(loid) Rhizostabilization in Desert Mine Tailings
  (PI: Jon Chorover, University of Arizona)

Other Bioremediation Work

- **Microbial Communities that Bioremediate Chemical Mixtures (PI: Lisa Alvarez-Cohen, University of California, Berkeley)***

•As, TCE, BTEX mixtures

- Novel Mechanism of Uranium Reduction Via Microbial Nanowires (PI: Gemma Reguera, Michigan State University)
- In Vivo Characterization of Bacteria-mediated Extracellular Reduction of Chromium (PI: Peter Lu, Bowling Green State University)
- Chemical Mapping of Chromate Uptake, Localization, and Reduction in Remediating Bacteria (PI: Joseph Irudayaraj, Purdue University)

***Currently Funded**

Other Amendments / Capping

- **In-situ Mercury Remediation based on Methylmercury Bioavailability**
  (PI: Upal Ghosh and Cindy Gilmour, University of Maryland – Baltimore County)*

- Sub-Micrometer Zero Valent Metal for in situ Remediation of Contaminated Aquifers
  (PI: John Freim, OnMaterials)

  •Cr (VI), As, and heavy metals

- Sequestration & Immobilization of Metal/Metalloid Contaminants in Sediments
  (PI: Peggy O'Day, University of California – Merced)

***Currently Funded**

Drinking Water

- **Anode Modification to Target Pb Removal for Drinking Water Purification using Inverted Capacitive Deionization**
  (PI: Lindsay Boehme, PowerTech Water, LLC)*
- Removal of Arsenic and Heavy Metals from Drinking Water
  (PI: John Stanley Lovell, ADA Technologies, Inc.)
- Iron-Based Adsorption Technology for Removing Arsenic from Water
  (PI: Margaret Lengerich, HMSolutions)
  → Spin off from Brown SRP Center work with Joseph Calo

***Currently Funded**

Detection/Sensing Technologies

- **Low-cost, Easy-to-use Test for Lead Concentration in Drinking Water**
  (PI: Lihua Zhang, Intelligent Optical Systems, Inc)*

- **Graphene-based Nanosensor Device for Rapid, Onsite Detection of Dissolved Lead in Tap Water**
  (PI: Ganhua Lu, NanoAffix Science, LLC)*

- **Lipid Enhanced Nano-Sensors (LENS) for Pb & Hg Detection in Water**
  (PI: Steven Lenhert, Zansors, LLC)*

- Catalytic DNA Biosensor for Toxic Metal Ions
  (PI: Yi Lu, ANDalyze [formerly Dzymetech], Inc.)

***Currently Funded**

Detection/Sensing Technologies, Cont.

- **Gold Nanoparticle-based Mercury Analyzer for On-site Measurement of Soil & Sediment***
  (PI: Jay James, Picoyune)

- Field-ready and Rapid Trace-level Detection & Speciation of Arsenic in water
  (PI: Merwan Bernhabib, OndaVia, Inc)
  - **Se, Cr, Pb, V**

- Real-Time Monitoring of Bioremediation
  (PI: Duncan Hitchens, Lynntech, Inc)

- Catalytic DNA Biosensor for Toxic Metal Ions
  (PI: Yi Lu, ANDalyze (formerly Dzymetech), Inc.)

***Currently Funded**

SRP R01 Research Aims

Specific Aim 1: Develop in situ remediation tools for Hg and MeHg impacted sediments

Specific Aim 2: Fill key knowledge gaps needed to develop a biogeochemical model for MeHg production and degradation in contaminated sediments and soils

Next Up…

In Situ Activated Carbon Amendment for Sediment and Soil Mercury Remediation

Dr. Cynthia Gilmour

Team: Upal Ghosh and James Sanders (UMBC)
Dwayne Elias (UT, ORNL)

Acknowledgement: Adeline Lopez, MDB, Inc.