Superfund Research Program (SRP) Funded Research in Metal/Metalloid Remediation Technologies

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National Institute of Environmental Health Sciences
Research Triangle Park, NC
SRP is Part of the National Institutes of Health

- **Fundamental Knowledge**
  - of living systems
  - ...with environmental exposures
  - ...including health effects, assessing risks, detection and remediation

- **NIH Research Mission**

- **Health Outcomes**
  - ...reduced illness & disability
  - ...caused by hazardous substances
  - ...relevant to Superfund stakeholders

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**National Institutes of Health**

Bethesda, MD

**National Institute of Environmental Health Sciences**

Research Triangle Park, NC

**Superfund Research Program (SRP)**

SARA Legislation
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.

**Biogeochemical Interactions:**
Affecting Bioavailability for in situ Remediation of Hazardous Substances (8)

**Multi-Project Centers:**
Health Effects, Risk, Detection & Remediation Research; Community and Stakeholder Outreach (23)

**Small Business Research:**
Remediation and Detection technologies (6)
SRP Research Portfolio (2017)

- Remediation
  - Physical/Chemical (7):
    - Barrier: 2
    - Chemical: 3
    - Electro/Thermal: 2
  - Biological (8):
    - Extraction: 3
    - Degradation: 5

- Monitoring & Modeling
- Toxicology
- Ecology
- Epidemiology
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.
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:**
  - Hammond et al., ES&T, 2018
  - Valentin-Vargas et al., SciTotEnv, 2018
  - Honeker et al., Micro Ecol, 2017
  - Santos et al., PeerJ, 2017
  - Gil-Loaiza et al., SciTotEnv, 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 stabilizes metals in soil

*Previously Funded
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.

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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:**
  – Pham et al., Environ Sci Technol, 2015 (DGT sampling)
Assessing Effectiveness of Mercury Methylation

PI: Upal Ghosh University of Maryland – Baltimore County and Cynthia Gilmour, Smithsonian)*

Development of in-situ Mercury Remediation Approaches Based on Methylmercury Bioavailability

Smithsonian Environmental Research Research Center
Assessing Effectiveness of Mercury Methylation

PI: Upal Ghosh, Cynthia Gilmour

Development of in-situ Mercury Remediation Approaches Based on Methylmercury Bioavailability

• **Targeted Metals**: Mercury

• **Innovation**: Developing in situ remediation tools for Hg and MeHg impacted sediments; developing a biogeochemical model for MeHg production and degradation in contaminated sediments and soils

• **Status**: field trial of in situ sorbent remediation using activated carbon in Berry's Creek, NJ

• **Relevant Publications**
  - Christensen, et al. Appl Env Microb 2018
  - Gilmour et al. Sci Tot Env, 2017
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**:
  - Meyer et al., Bull Env Con Tox, 2017
  - 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

Sediments from C_{bottom} → Add DI water → Magnetic particles
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., Chemosphere, 2016
  – 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

Avasarala et al. ES&T 2017
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**: Developing cost-effective remediation strategies that immobilize metals and prevent degradation of community water sources. Studying reaction mechanisms of metal mixtures and adsorption with iron oxides. Engineering phytoremediation/rhizosphere 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.

• **Relevant Publications**:
  – Avasarala et al., ES&T, 2017
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 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
Additional/Former
SRP Metals Remediation and Related Research

https://tools.niehs.nih.gov/srp/search/index.cfm
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

- Novel Rhamnolipid Surfactants for Recovery of Critical Elements and Remediation of Metal Contaminated Waste Streams  
  (PI: Chett Boxley, GlycoSurf, LLC; Raina Maier, University of Arizona)*

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

- 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)*

- **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
Multi-Disciplinary Centers – metals/mining

- University of Arizona: Risk and Remediation of Metal-Mining Wastes* (Center Director: Raina Maier)

- University of New Mexico: UNM Metal Exposure Toxicity Assessment on Tribal Lands in the Southwest (METALS) Superfund Research Program * (Center Director: Johnnye Lewis)

- Dartmouth College: Sources and Protracted Effects of Early Life Exposure to Arsenic and Mercury* (Center Director: Bruce Stanton)

- Columbia University: Health Effects and Geochemistry of Arsenic * (Center Director: Ana Navas-Ascien)

*Currently Funded
Questions?

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SRP Search Tool: https://tools.niehs.nih.gov/srp/search/index.cfm