The University of Arizona DUST Superfund Center: Mining Dust as a Complex Environmental Exposure

Solutions for Healthier Communities and Cleaner Mining

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National Institute of Environmental Health Sciences
Superfund Research Program Award P42ES004940

The U.S. Southwest has a rich history and legacy of hardrock mining

Here and across the globe we are seeing:

- increasing temperatures
- growing dust transport exacerbated by increased drought and wildfire events

That amplify historically under-appreciated inhalation exposure pathways

Globally, mining is responsible for 12% particulate matter health impacts

International Resource Panel. Global resources outlook 2019: United nations Environment Programme

One-third of the globe consists of arid environments vulnerable to dust exposure

Understanding dust exposure requires a new paradigm

Dust is often treated as inert

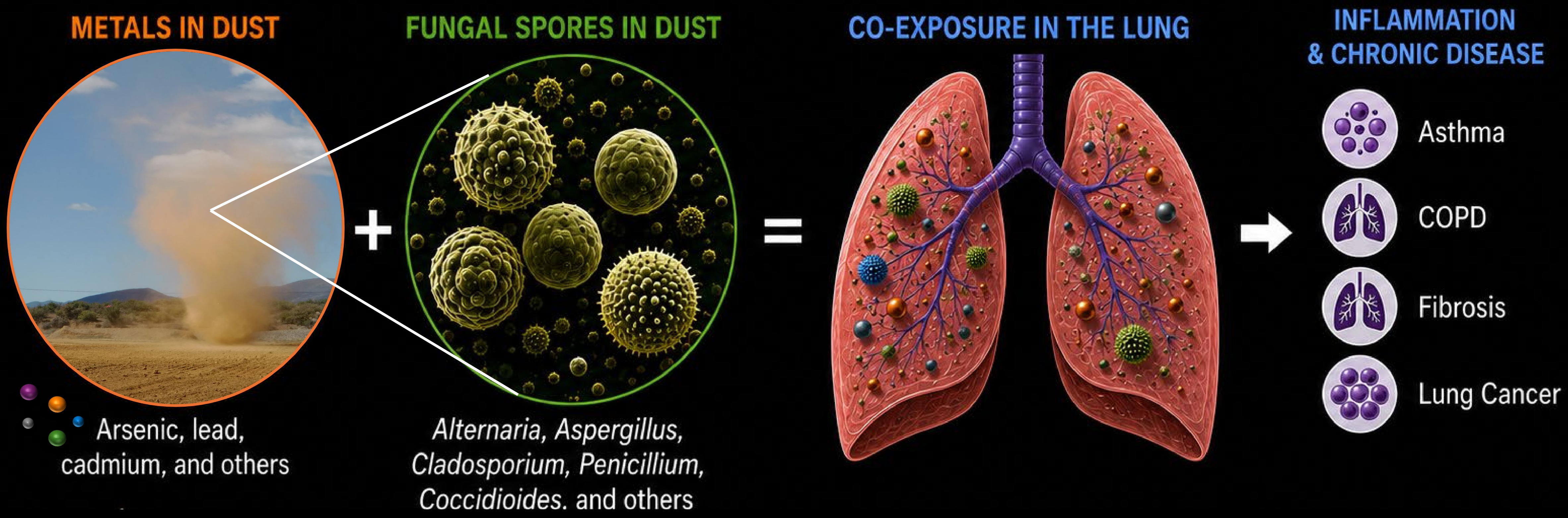
- EPA regulates on size alone (PM2.5 and PM10)

But in reality, dust is chemically and biologically active

- It contains metals/metalloids of differing bioavailability
- It contains microbiota including fungal spores

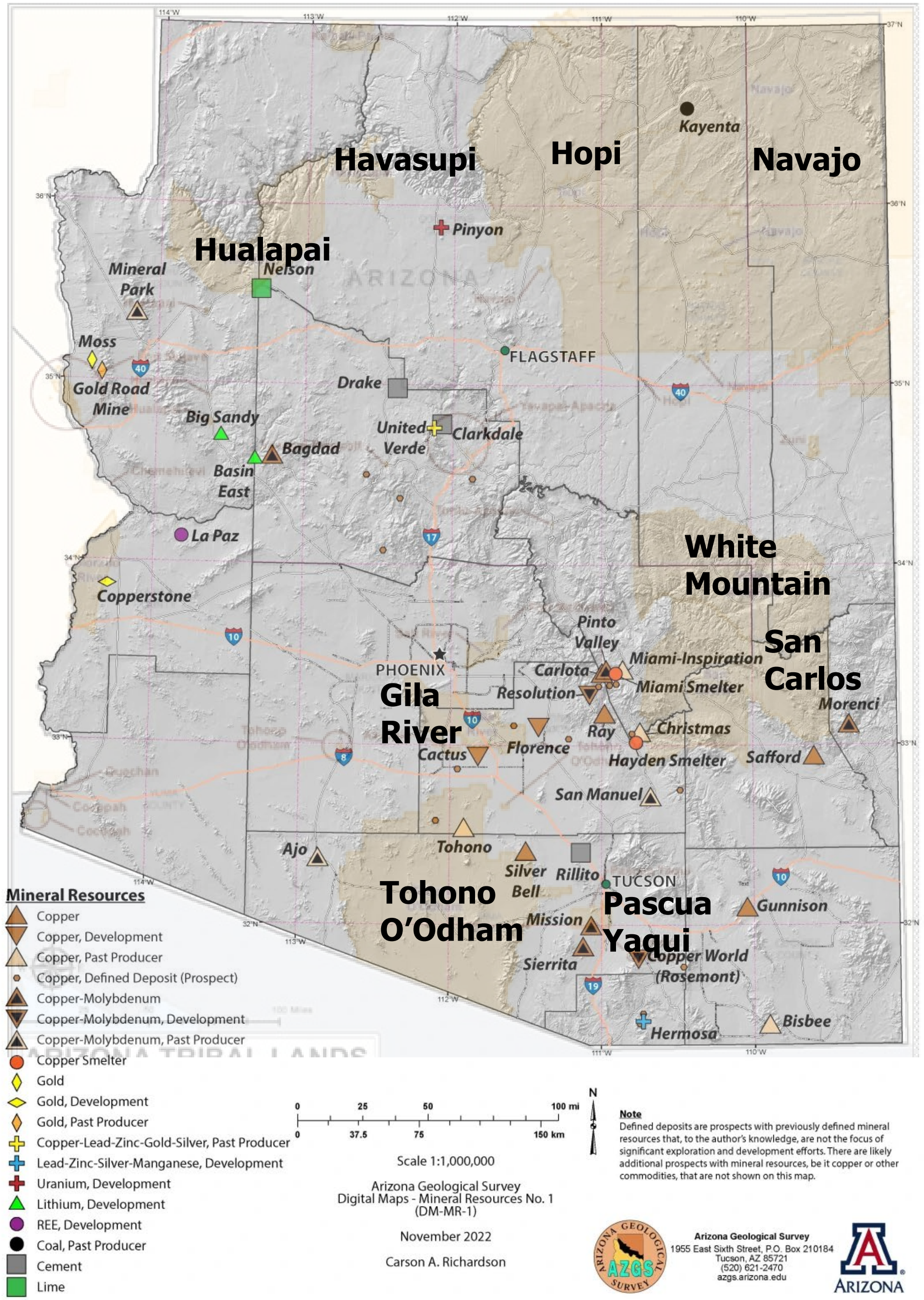
We believe exposure risk depends not only on particle size — but on particle content

What happens when toxic metals and immune-active fungal spores arrive in the lung together?

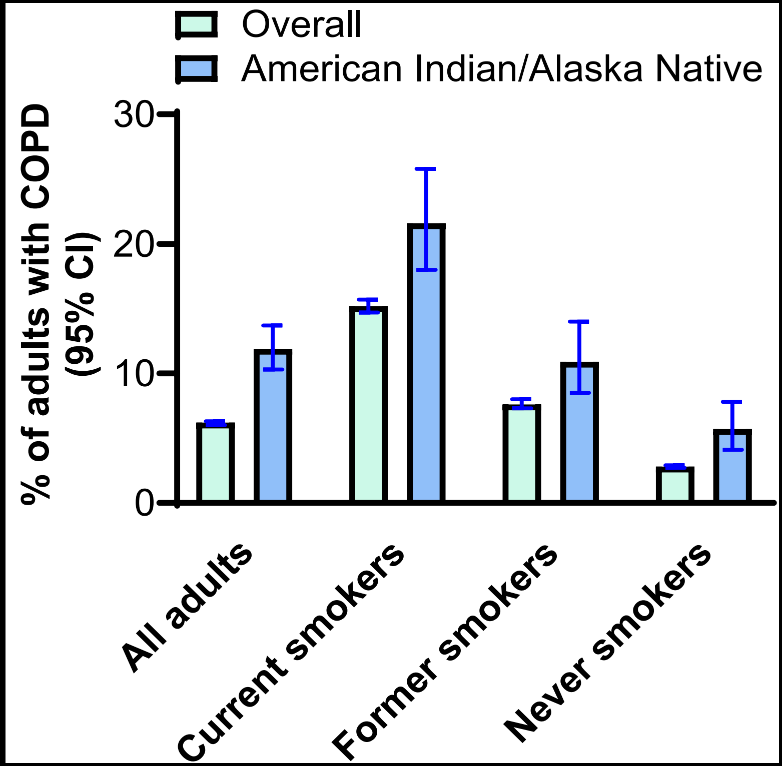


Understanding the complexity of dust is necessary
to protect human health and improve air quality standards

Arizona major mines and tribal lands



Arizona's mining legacy overlaps with Tribal lands, creating a unique opportunity to study dust exposure in communities with an elevated burden of respiratory disease



Higher COPD prevalence in American Indian/Alaska Native adults

These overlapping environmental and health challenges motivate the DUST Center's research

The University of Arizona Superfund Center - 37 years of success

- Arsenic focused
- Contributed to reducing the drinking water MCL from 50 to 10 ppb
- Have demonstrated that arsenic inhalation exposure in arid environments may be as important as drinking water exposure

Challenges moving forward:

- Current air quality standards focus on particle size rather than toxic content
- Critical gaps in our understanding of inhalation toxicology
  - consideration of mixed metals
  - consideration of fungal spores

The DUST Center 2025-2030

Drylands as dust sources

Understanding exposure

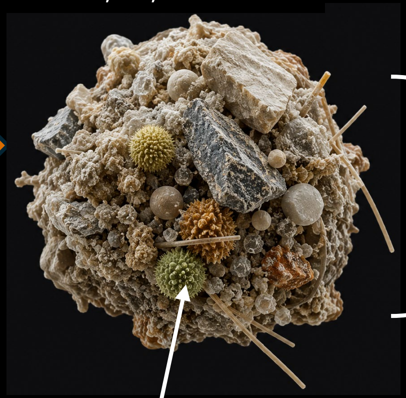
Serious health impacts

Tactics for mitigation, remediation, and resource recovery

1. ENVIRONMENT
Mining waste

2. EXPOSURE
Complex Dust

Metals: As, Pb, Cd etc.



Particulate size

Fungal Spores & other Biologicals

3. BIOLOGICAL RESPONSE
Lung Exposure & Disease

Inflammation

Epithelial Injury

Immune Dysfunction

Fibrosis & Chronic Disease

4. SOLUTIONS & TRANSLATION

Remediation

Stabilize soils, reduce dust, restore landscapes

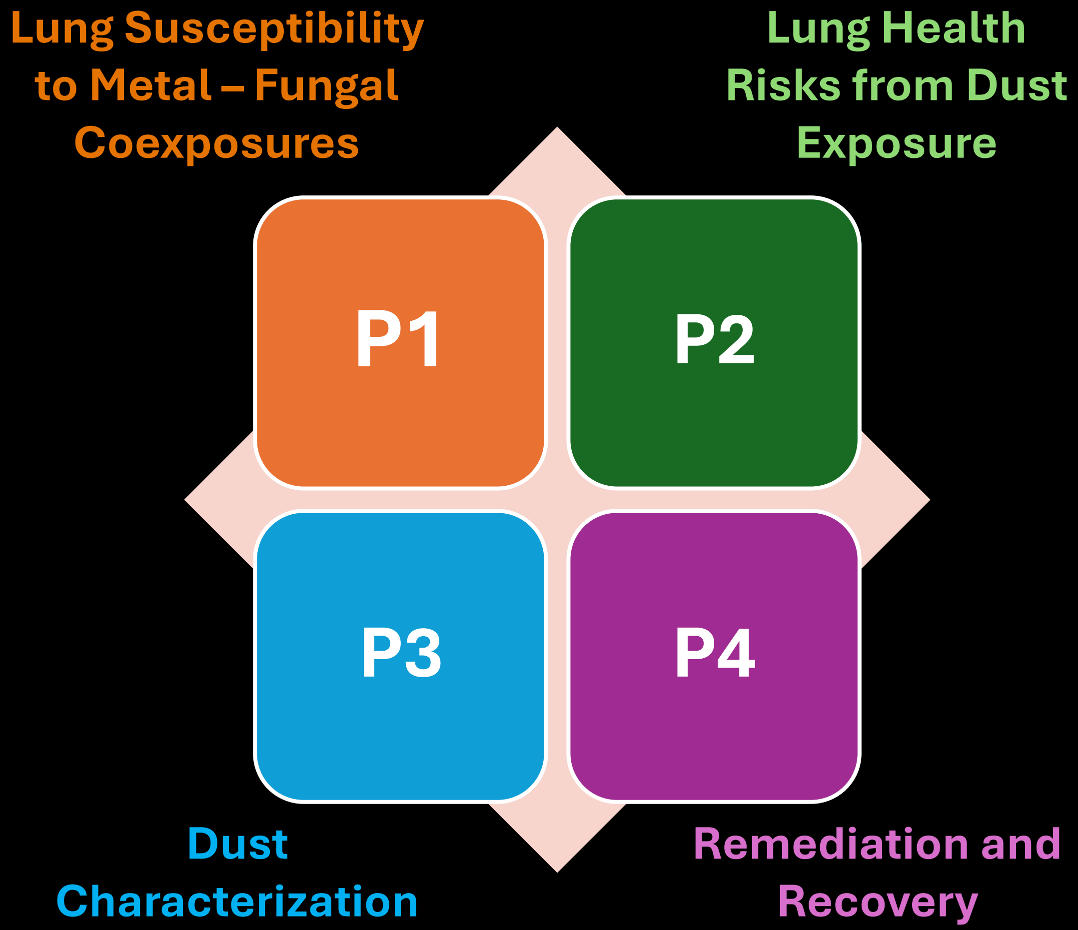
Resource Recovery

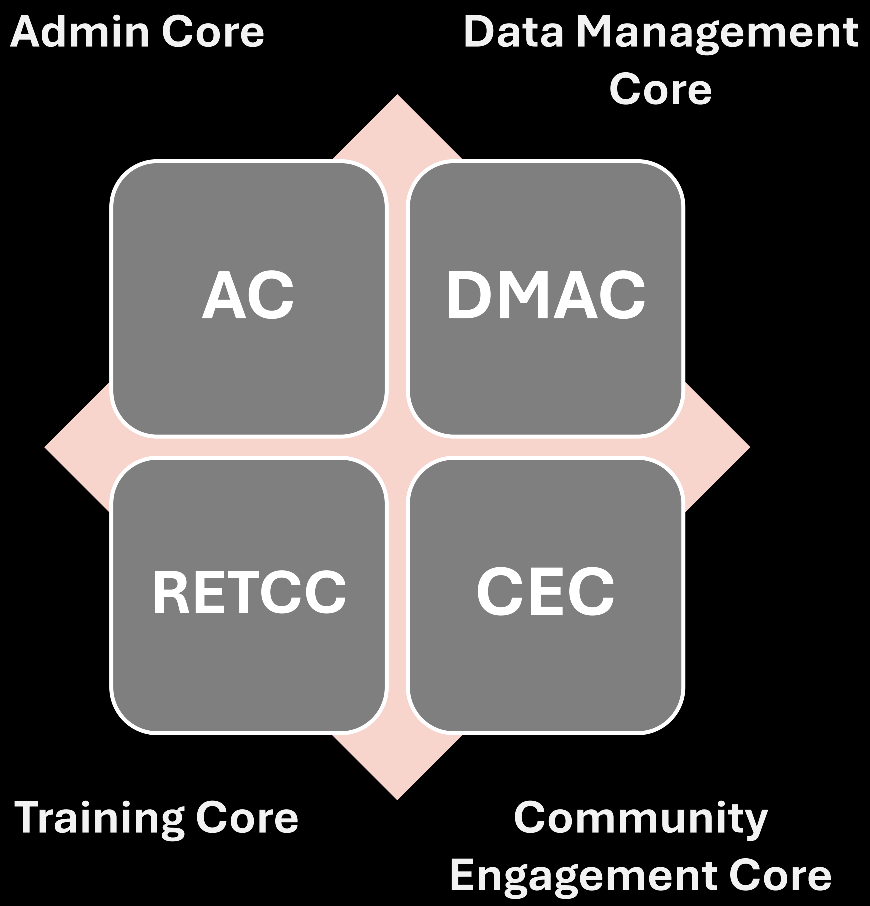
Recover valuable metals, reduce waste, provide clean water

Communities

Air monitoring, risk communication, policy & prevention

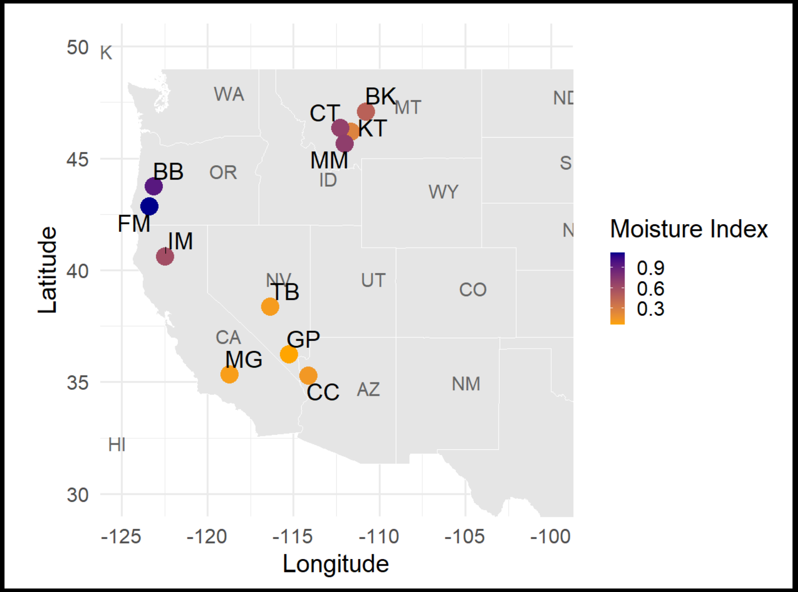
Projects and Cores

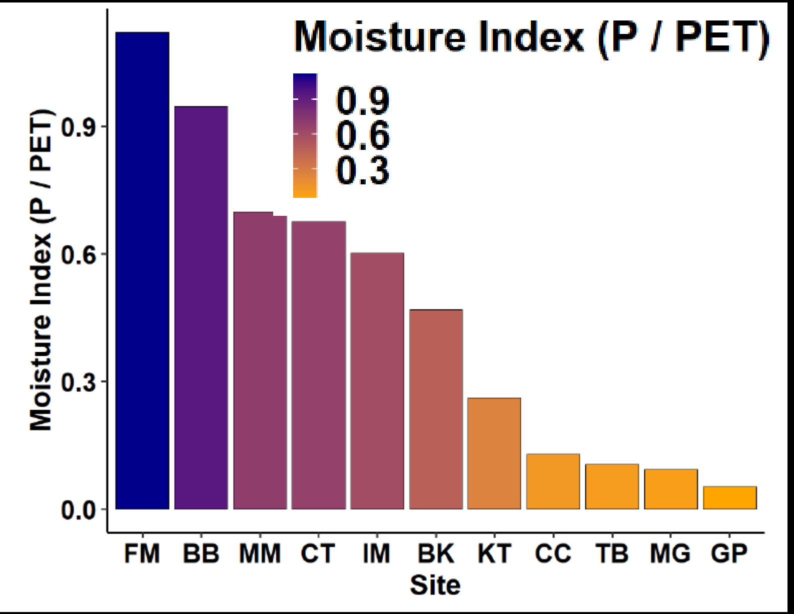




Before predicting health effects, we first have to understand how dust changes in the environment (Project 3)

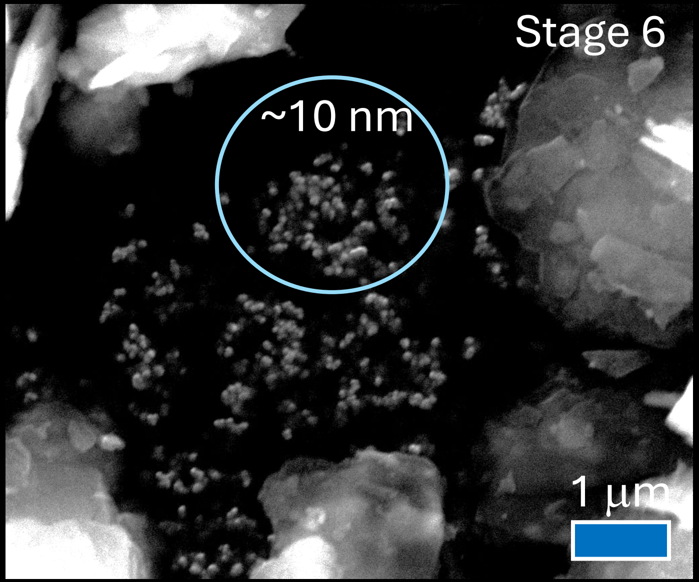
- What are the impacts of climate and wildfire disturbance on the composition of PM in tailings and tailings-impacted soils?
- How does environmental weathering affect the molecular speciation of As and Pb in this PM?
- How bioaccessible is the As and Pb in this PM?
- Does As molecular speciation enable prediction of its bioaccessibility in lung fluid?

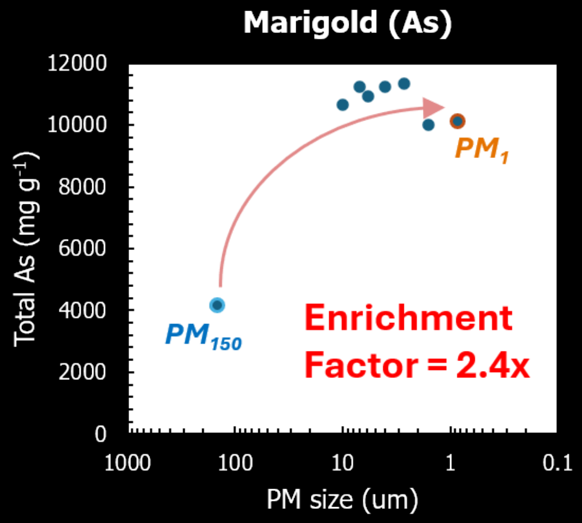


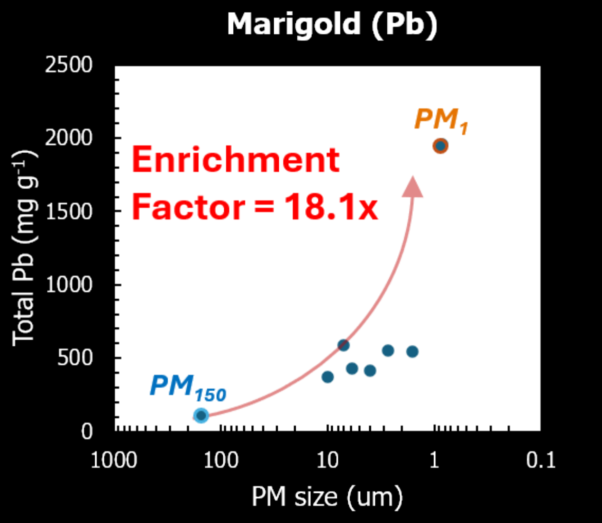


Comparison of a wet and a dry site

Marigold, CA – Dry Site







[As] PM_{150} >4000 mg g^{-1}

[As] PM_1 >10000 mg g^{-1}

[Pb] PM_{150} ~100 mg g^{-1}

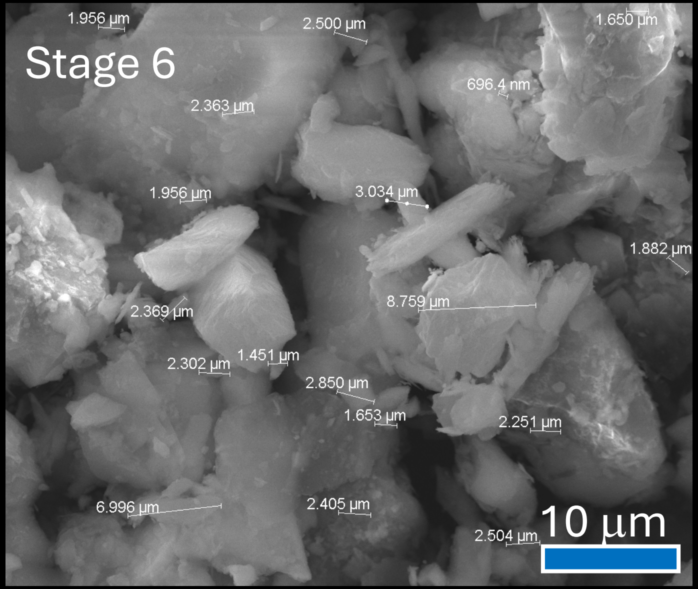
[Pb] PM_1 ~2000 mg g^{-1}

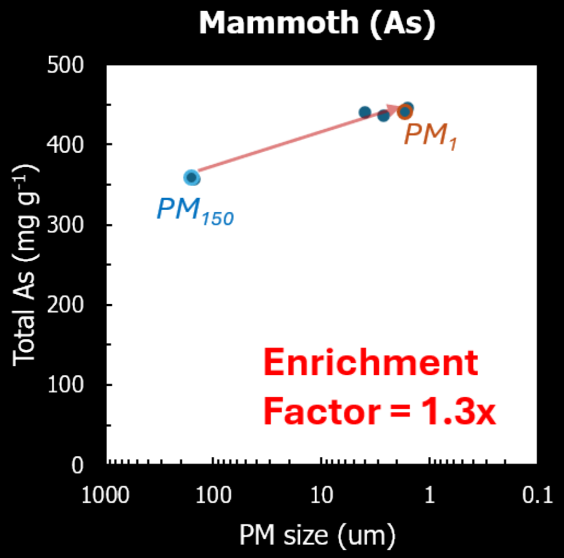
Key Findings:

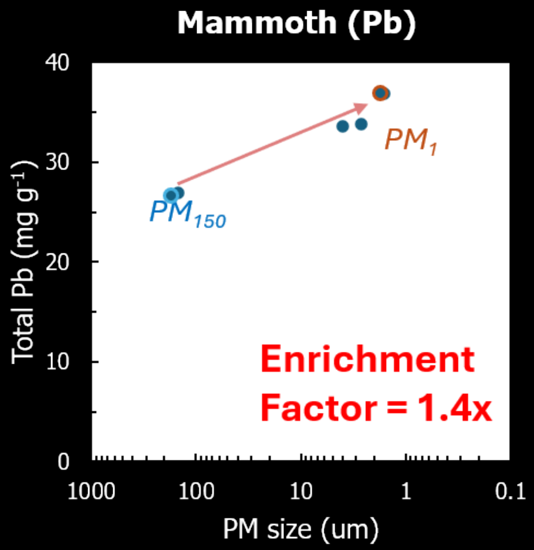
- PM is substantially enriched in As and Pb as size decreases
- As species shifted from As-Jarosite to As-Ferrihydrite with decreasing size

Shows molecular-scale control of weathering-derived PM enrichment

Mammoth Mine, MT – Wet Site







[As] PM_{150} = 357 mg g^{-1}

[As] PM_1 = 446 mg g^{-1}

[Pb] PM_{150} = 26.9 mg g^{-1}

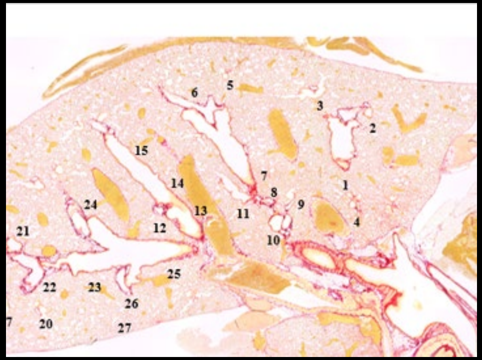
[Pb] PM_1 = 36.9 mg g^{-1}

Key Findings:

- Finer PM is enriched in As and Pb, but less than the dry site
- For As, there is depletion of arsenopyrite and increase in As-ferrihydrite and arseniosiderite

What are the unique risks to lung health from inhalation exposure to mining dust? (Project 2)

- **Chronic lung diseases** - among top five causes of death for Native American persons living in Arizona
- **Arsenic and mining waste exposures** - associated with increased asthma, emphysema, pneumonia, COPD, cancer, and idiopathic **pulmonary fibrosis**
- **Animal models** - arsenic exposure induces **lung fibrosis** in rats and mice

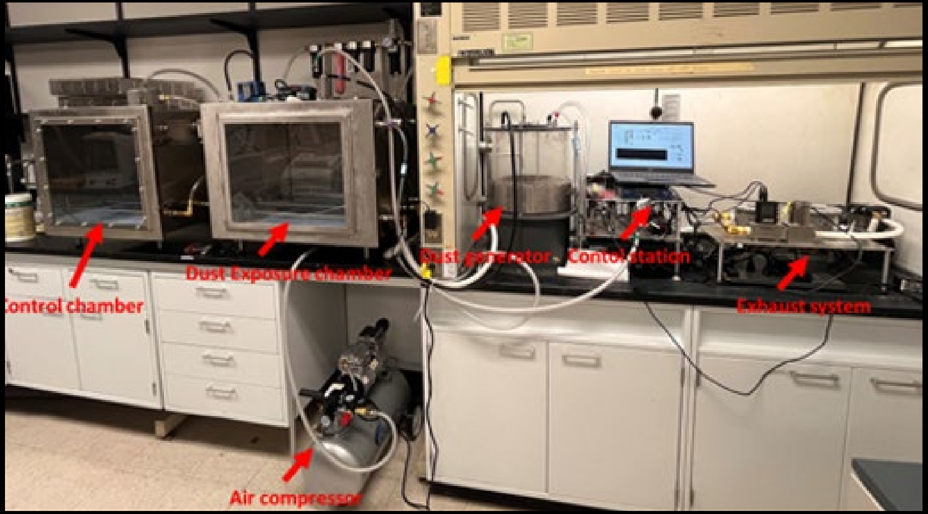


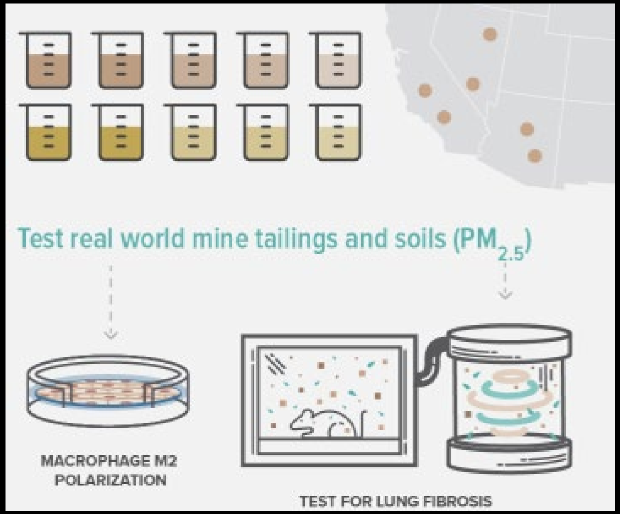
Knowledge gaps

- What arsenic species are more bioavailable/toxic via inhalation?
- What types of dusts are more dangerous?
- What lung regions are more sensitive?
- Exacerbated by co-exposure to mold?
- Relationships with co-exposure to other metals?
- Synergy with drinking water arsenic?
- Molecular mechanisms?
- Species difference?

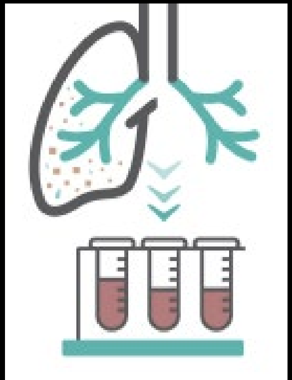
Dust inhalation toxicology, arsenic toxicokinetics, and risk factors for dust-induced lung fibrosis

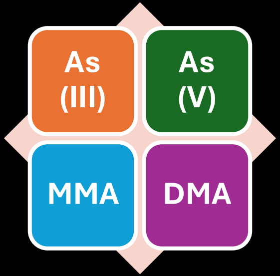
Exposure scenarios

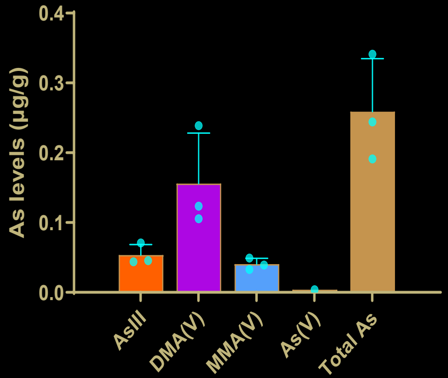




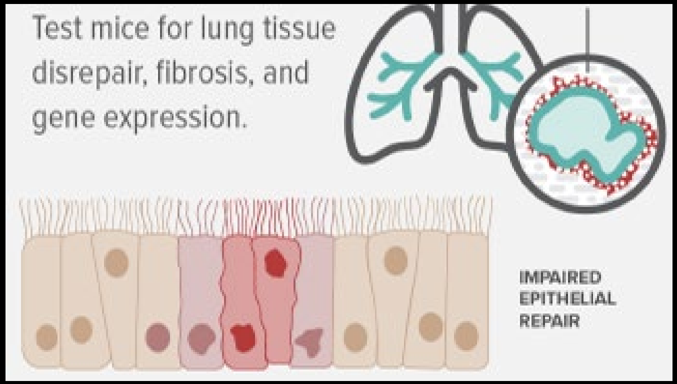
Toxicokinetics







Toxic endpoints



Risk prediction

Do dust-associated metals make the lung more susceptible to fungal disease? (Project 1)

DUST EXPOSURES

Mining Operations

Mining Wastes

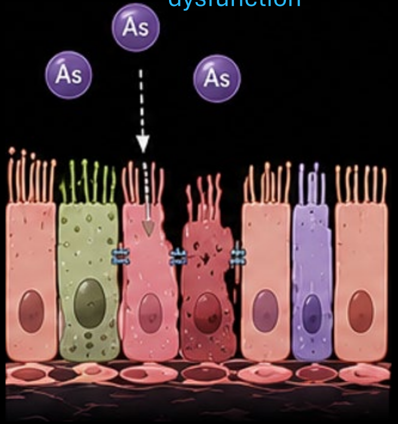
Construction

Metals and Molds

As Cu Pb Zn

METAL EXPOSURES DAMAGE THE AIRWAY LINING

Epithelial barrier dysfunction

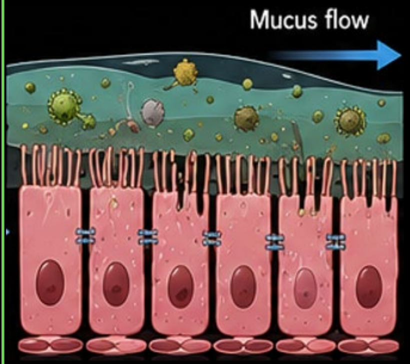


- Tight junction disruption
- Increased permeability
- Oxidative stress and DNA damage
- Inflammation and cell death

Ciliated cell
Goblet cell
Basal cell
Club cell
Tight junction

IMPAIR MUCOCILIARY CLEARANCE

Reduced mucociliary clearance



- Cilia dysfunction or loss
- Reduced mucus production
- Abnormal mucus (increased viscosity, decreased clearance)
- Trapped articles and microbes

INCREASE MOLD SUSCEPTIBILITY

Fungal adhesion, colonization and invasion

- Fungal adhesion
- Epithelial invasion
- Fungal colonization and growth
- Persistent inflammation

RESULTING IN PULMONARY DISEASE

Chronic inflammation

Asthma

Recurrent fungal infection

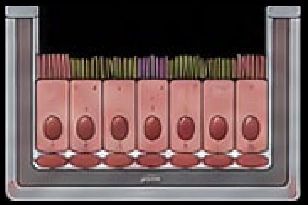
Remodeling

Fibrosis

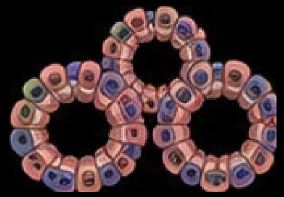
An integrated approach to study how toxic dust and mold affect the lung
(*in vitro, ex vivo, in vivo* and multi-omics approach)

In vitro response models

Mechanistic studies in airway epithelial systems



ALI culture



Lung organoids

Challenges:

Metals

As Cu Pb Zn

+

Mold

In vivo mouse models

Validate mechanisms and disease outcomes

Challenges:

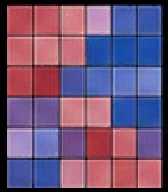
Metals

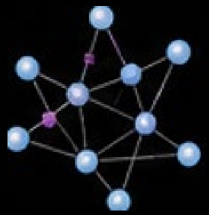
As Cu Pb Zn

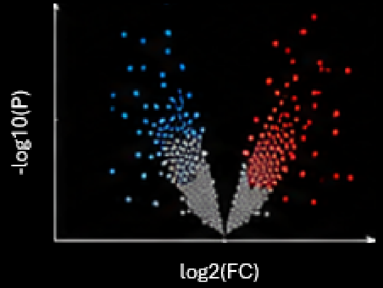
+

Mold

Multi-omics integration & experimental validation



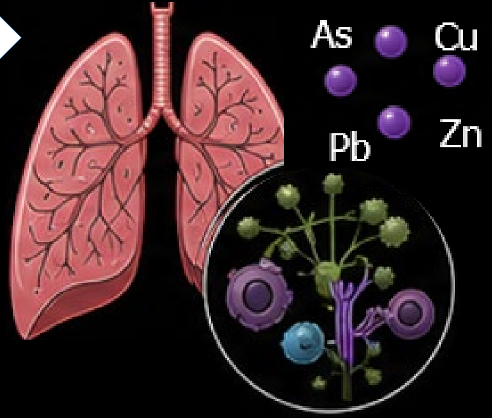




- Integrate scRNA-seq & RNA-seq
- Pathway analysis
- Experimental validation

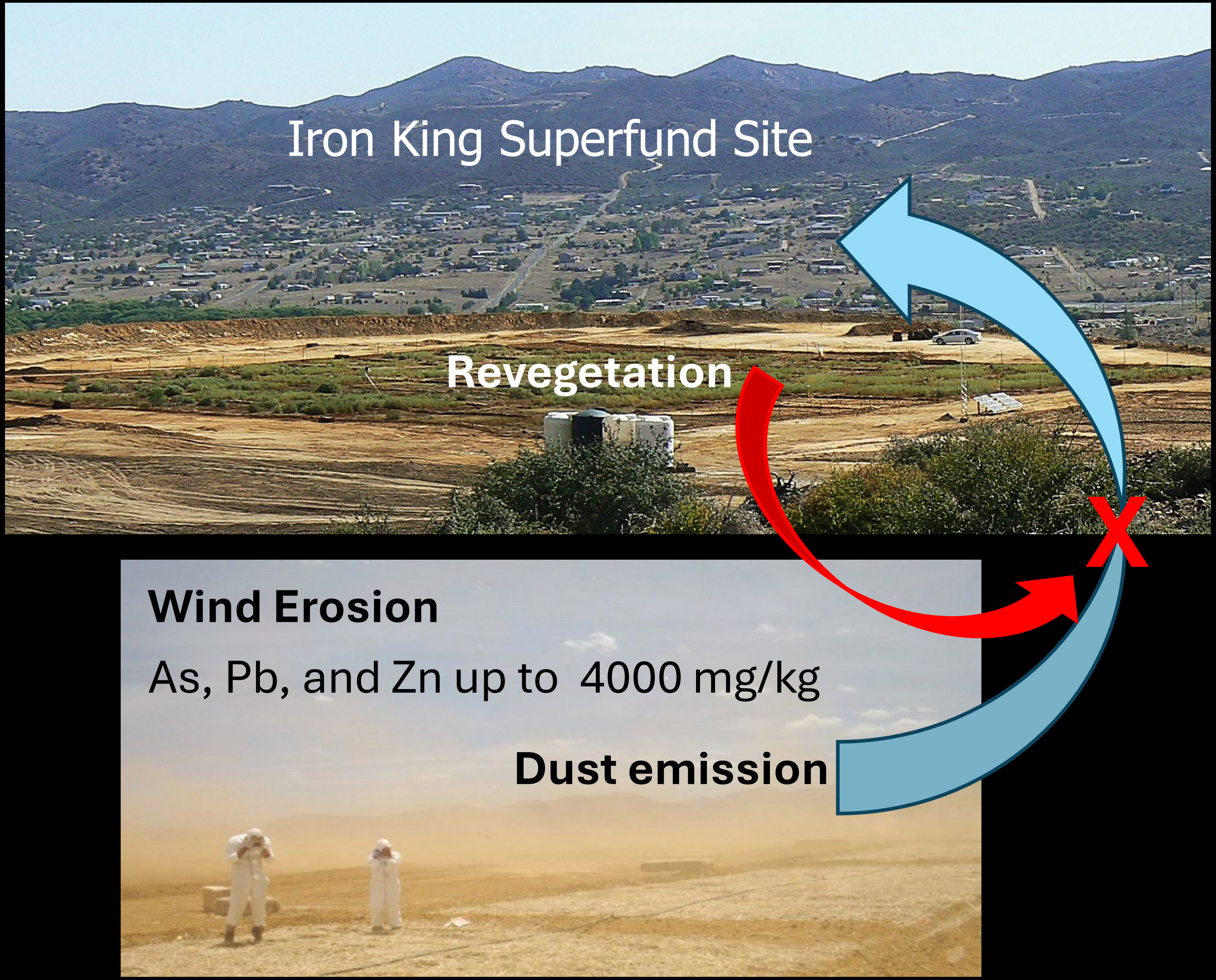
Integrated outcomes

- **Define how toxic dust:**
  - ✓ **damages the airway**
  - ✓ **promotes mold infection**
- **Identify biomarkers of lung disease**

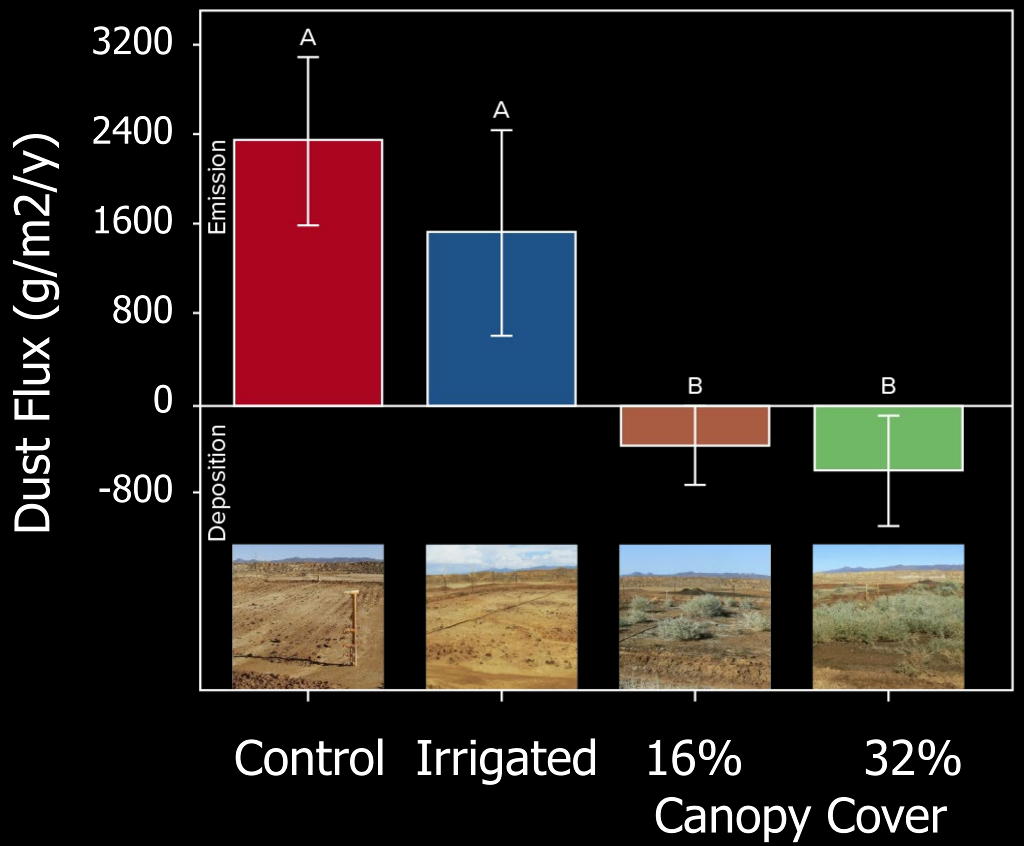


The best exposure is one that never occurs (Project 4)

Historically, mine wastes were viewed solely as liabilities. We view them as opportunities for both exposure reduction and strategic metal recovery



Revegetation reduces dust



Preventing Exposure

Precision remediation through spatial mapping using drone-based

- LiDAR
- hyperspectral imaging
- landscape-scale assessment

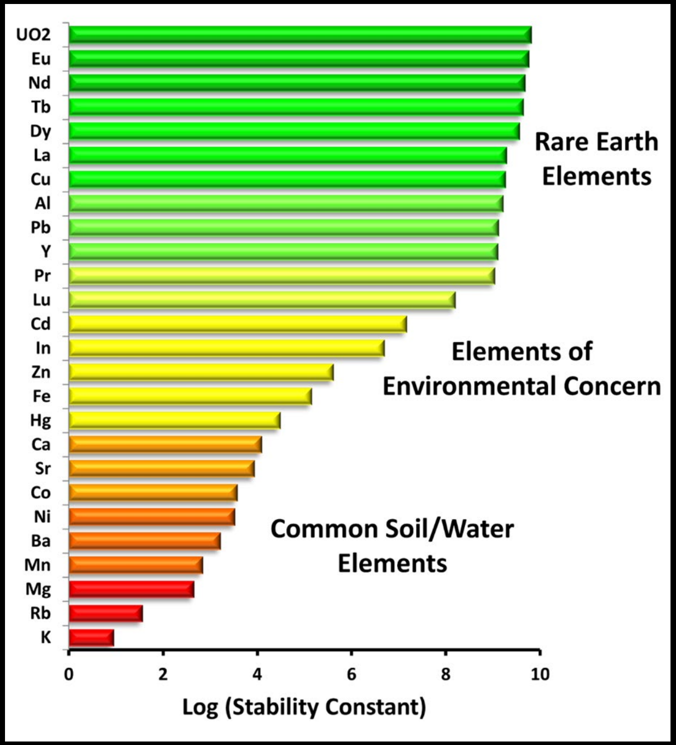
Lab-Scale Testing

Field-Scale Testing

Recovering Resources

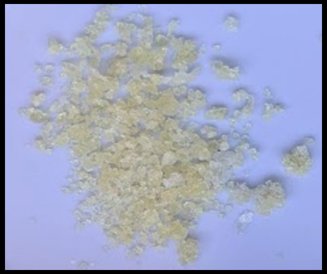
- Mine tailings and acid mine drainage are a valuable secondary resource stream
- Exploitation of these resources will reduce both environmental exposures and pressure for new extraction

Rhamnolipids are selective for uranium and REE



We are functionalizing beads with rhamnolipids to create hydrogels that can be packed into columns

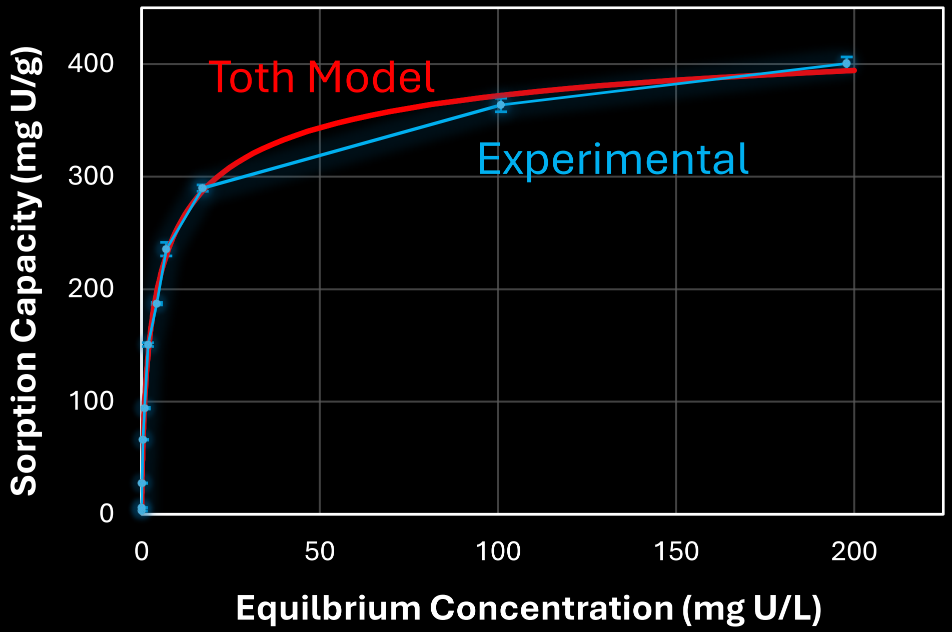
Polyacrylamide beads



Rhamnolipid-functionalized beads

Functionalized beads after uranium capture

Sorption capacity is 400 mg U/g hydrogel



Community Engagement and Research Translation

Community partnerships shape our science questions, sampling strategies, and translation priorities

Representative examples:

Working with the Cottonwood community

gardenroots
Cottonwood, the Heart of Verde Valley, AZ

Community concern:

Can recycled copper slag used in Cottonwood create harmful dust exposures?

Our response:

- Measured metals in raw and reclaimed slag
- Measured respirable dust
- Reported results back to participants

Findings and Impact:

- Raw slag had significantly higher Al, As, Cd, Cu, Mn, and Pb than repurposed materials
- Raw slag dust (PM<10) had higher concentrations for all metals except Pb, which was significantly lower
- Community members have received their results with applicable risk-based comparative values
- Data are informing community decisions

Photo of historic copper slag pile and processing equipment in Cottonwood, Arizona. Courtesy Lois Polashenski

Working with the Black Mesa Community

Community concern:

Dust in the air at Black Mesa near the Peabody Coal Mine

Our response:

- Supported 7 community listening sessions
- Presented findings to the Navajo Nation Resources and Development Committee
- Led a series of community discussions about particulate matter monitoring

Findings and Impact:

- Established first PM monitoring in June 2026. Six more sensors to be installed over the next 3 months
- Students are creating culturally informed educational materials for community members and tribal college students
- Partnership with UA EHS-RISE undergraduate summer research experience for Indigenous scholars

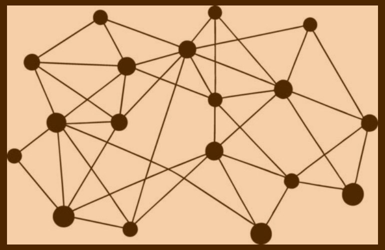
Dust in the air at Black Mesa near the Peabody Coal Mine


Community discussions about PM monitoring

Data Management – AI-Enabled Environmental Health Science

Project 1
(omics)

Center Data Hub



Project 2
(lung injury)

Project 3
(dust characterization)

Project 4
(remediation)

Data Infrastructure
Secure data repository for sharing Center data

AI Analytics
AI-assisted analysis of molecular data

Research Translation
Plain language summaries for communities and policy-makers

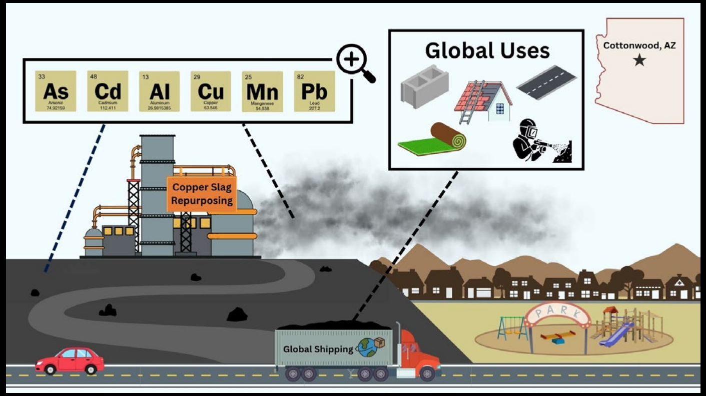
AI-Enabled Discovery
AI-enabled mapping of metal-fungal co-exposure

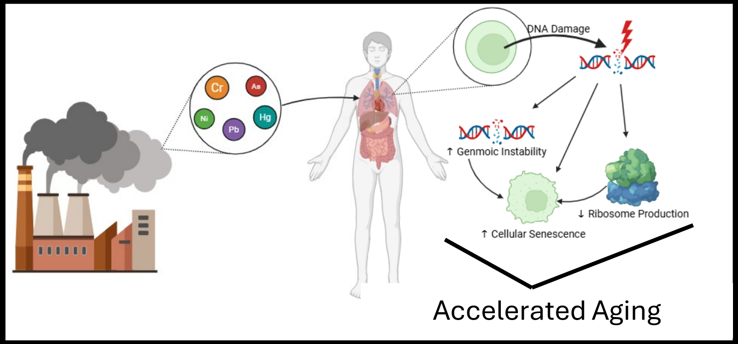
Integrating data, accelerating discovery, and improving research translation

Research Experience & Training Coordination Core

UArizona trainees at December 2025 Superfund Annual Meeting, College Station, Texas. From left to right: Xenia De Gracia Medina, Diksha Manhas, Andreanna Roros, Lois Polashenski, and Kelsey Graves.

Gaining information design expertise and experience - examples of Trainee visual abstracts





We train scientists to:

- work across biomedical, environmental, and engineering disciplinary boundaries
- care about research translation and community engagement

The Future of Dust Research

Today's standards ask: **How much dust is in the air?**

Tomorrow's standards should ask: **What makes the dust hazardous?**

- Metals
- Fungal spores
- Particle chemistry
- Bioaccessibility
- Biological activity

Our goal is to redefine what we mean by hazardous dust—and in doing so, better protect communities while creating a more sustainable future for mining.

University of Arizona DUST Center Team

Project 1

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