Phytostabilization of Mine Tailings: Metal Speciation and Dust Suppression

International Symposium on Emerging Issues in Environmental and Occupational Health: Mining and Construction in Transition Economies

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Director, University of Arizona NIEHS Superfund Research Program

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Superfund Research Program

Director: Dr. William A. Suk

The purpose of the Superfund Research Program is to:

- support, promote, and acquire fundamental scientific and engineering knowledge that advances society's understanding of human health risks from exposure to hazardous substances;
- develop innovative technologies for the prevention of such exposures;
- train the next generation of scientists;
- translate results into applied research to be used for informing the risk assessment decision-making process.

The intent within this interdisciplinary framework is the prevention of disease and the protection of human health.

University - Driven

http://www.niehs.nih.gov/research/supported/dert/cris/programs/srp/

SRP Grantees and Where They Work

University of Arizona Superfund Research Program

Legend:

Purple: P42 Grantees

Pink: SBIR Grantees

Green: R01 Grantees

Blue: Superfund Sites where grantees are performing research

Orange: Collaborating institutions

http://superfund.pharmacy.arizona.edu/

Institute for Mineral Resources

Director: Dr. Mary Poulton

Lowell Institute for Mineral Resources

The Lowell Institute for Mineral Resources is a leading global center for mineral resources that bridges basic and applied research in the fields of science, social science, engineering, health, business, leadership, policy, and that works with leaders to adopt new ideas, policies, and technologies.

- Lowering fresh water use
- Lowering energy use / renewable energy
- Healthy and safe communities and workforce
- Improving our understanding of the global mineral resource inventory
- Smaller mining footprint
- Sustainable resource development
- Informing policy decisions
- Outreach and continuing education

http://www.imr.arizona.edu/

Center for Environmentally Sustainable Mining

Director: Dr. Raina Maier

Partnership Superfund Research Program & Lowell Institute for Mineral Resources → CESM Center for Environmentally Sustainable Mining

http://superfund.pharmacy.arizona.edu/content/center-environmentally-sustainable-mining-cesm

CESM Mission

CESM
Center for Environmentally Sustainable Mining

Through cooperation between industry and academia, the CESM is developing innovative solutions and education programs for the environmental and human and ecosystem exposure issues that arise in the mining industry.

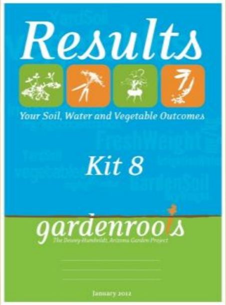
<u>**Current focal areas**</u>

- Dust characterization
- Dust control
- Remediation of mining wastes
    - tailings
    - waste rock
    - acid rock drainage
- Control of groundwater contamination
- Fate and speciation of metal(loid)s in mining wastes
- Education and analysis

Health worker trainings

Informational Materials

energy- water nexus



gardenroots
The Dewey-Humboldt, Arizona Garden Project

Mining Wastes

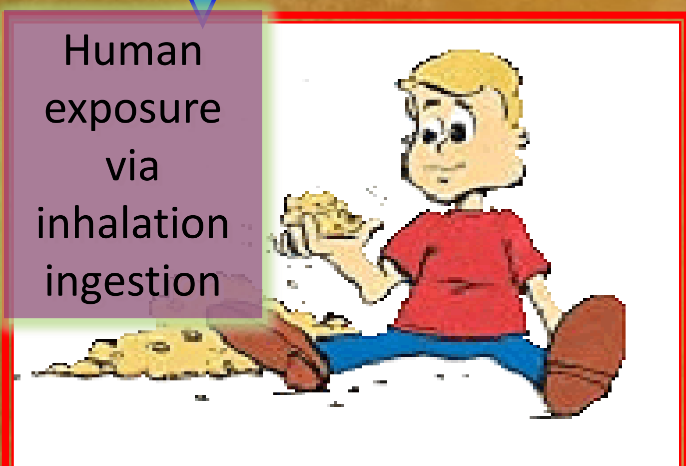
Metals
pH
No soil structure
Impacted microbial community
Limited vegetation

Arid and semi-arid mine tailings


Wind erosion


Water erosion


Recreational use


Human exposure via inhalation ingestion

Mining: A Global Environmental Contamination Issue

On a still day….

On a windy day….

A Case Study:
Iron King Mine-Humboldt Smelter Site

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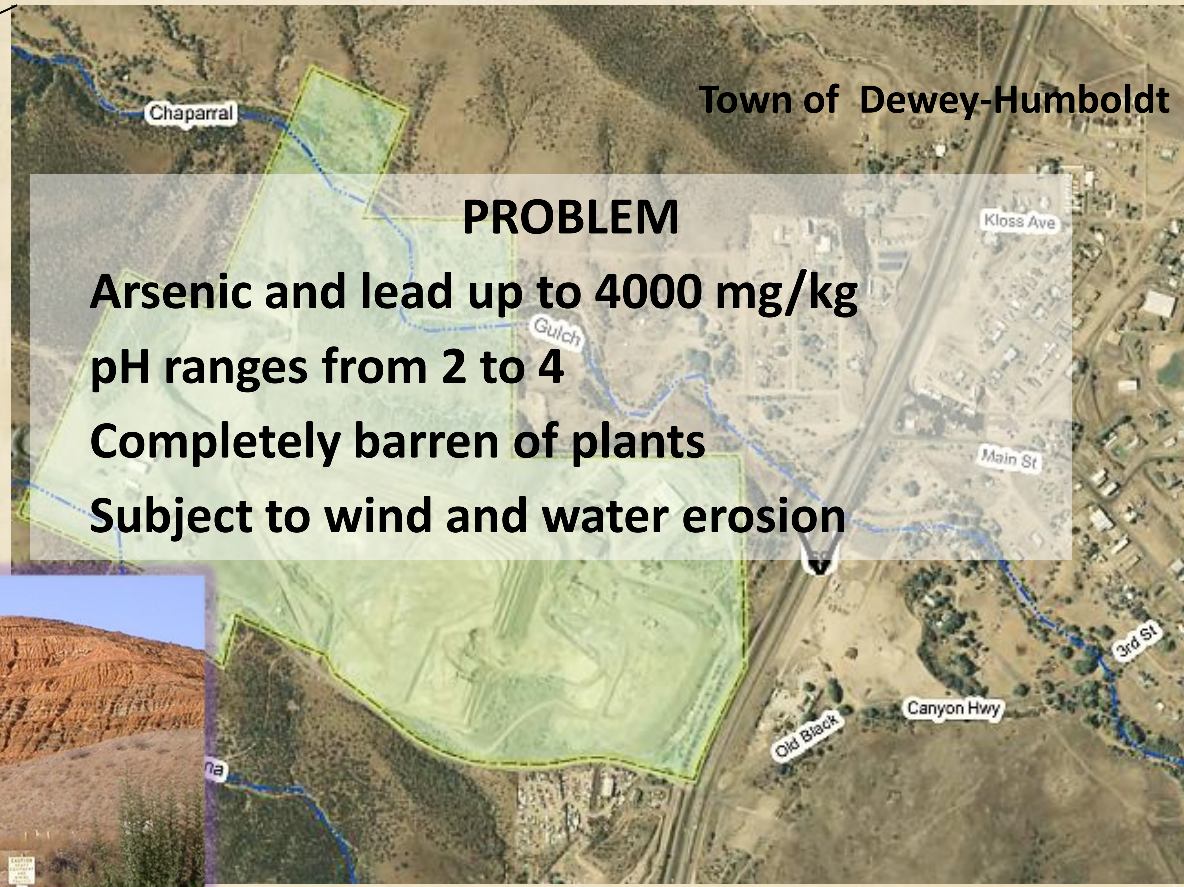
Listed as a Superfund Site by Environmental Protection Agency (EPA) in 2008.



PROBLEM

Arsenic and lead up to 4000 mg/kg

pH ranges from 2 to 4

Completely barren of plants

Subject to wind and water erosion

Mine operated 1904-1969; 3250 ft deep and 40 miles of shafts

A Solution: Assisted Phytostabilization

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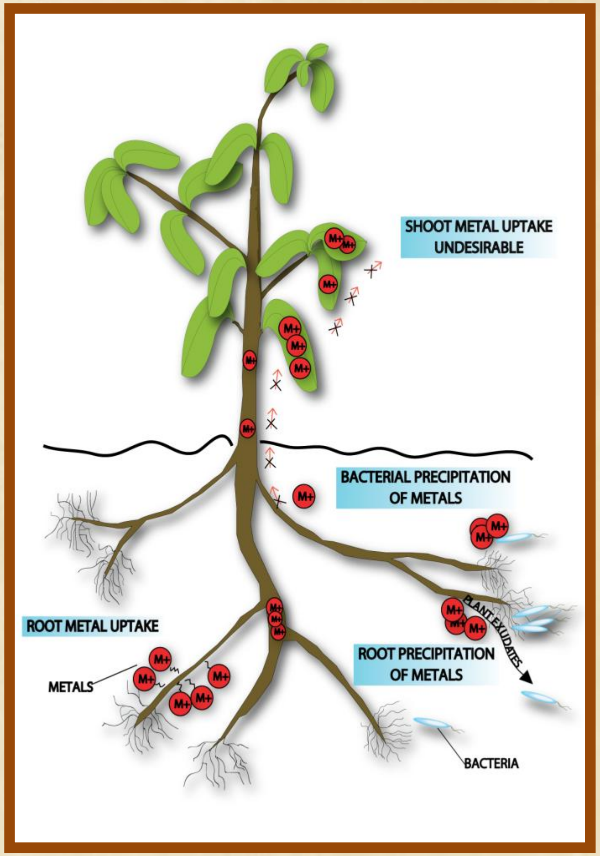
Stabilization of mine tailings against wind and water erosion using a vegetative cap to reduce the risk of human exposure to tailings contaminants.

Important parameters to evaluate:

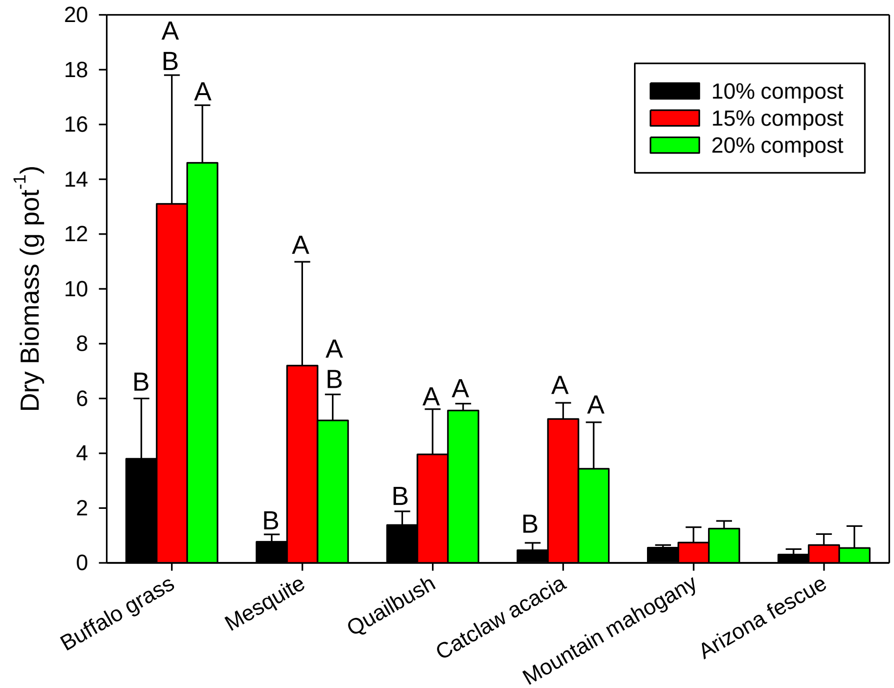
- identify suitable native plants
- establish minimum inputs required to assist plant growth and survival
- longevity and succession of vegetative cap
- metal speciation during revegetation
- evaluate reduction in erosion processes



Mendez and Maier, 2008. Environ. Health Perspec. 116-278-283

Greenhouse studies with Iron King tailings showed:

- 7/15 native species survived
- minimum 15% (w/w) compost amendment needed for direct planting



Buffalo grass

0% compost (w/w) 10% 15% 20%

Solís-Dominguez et al., Environ. Sci. Technol. 46:1019-27

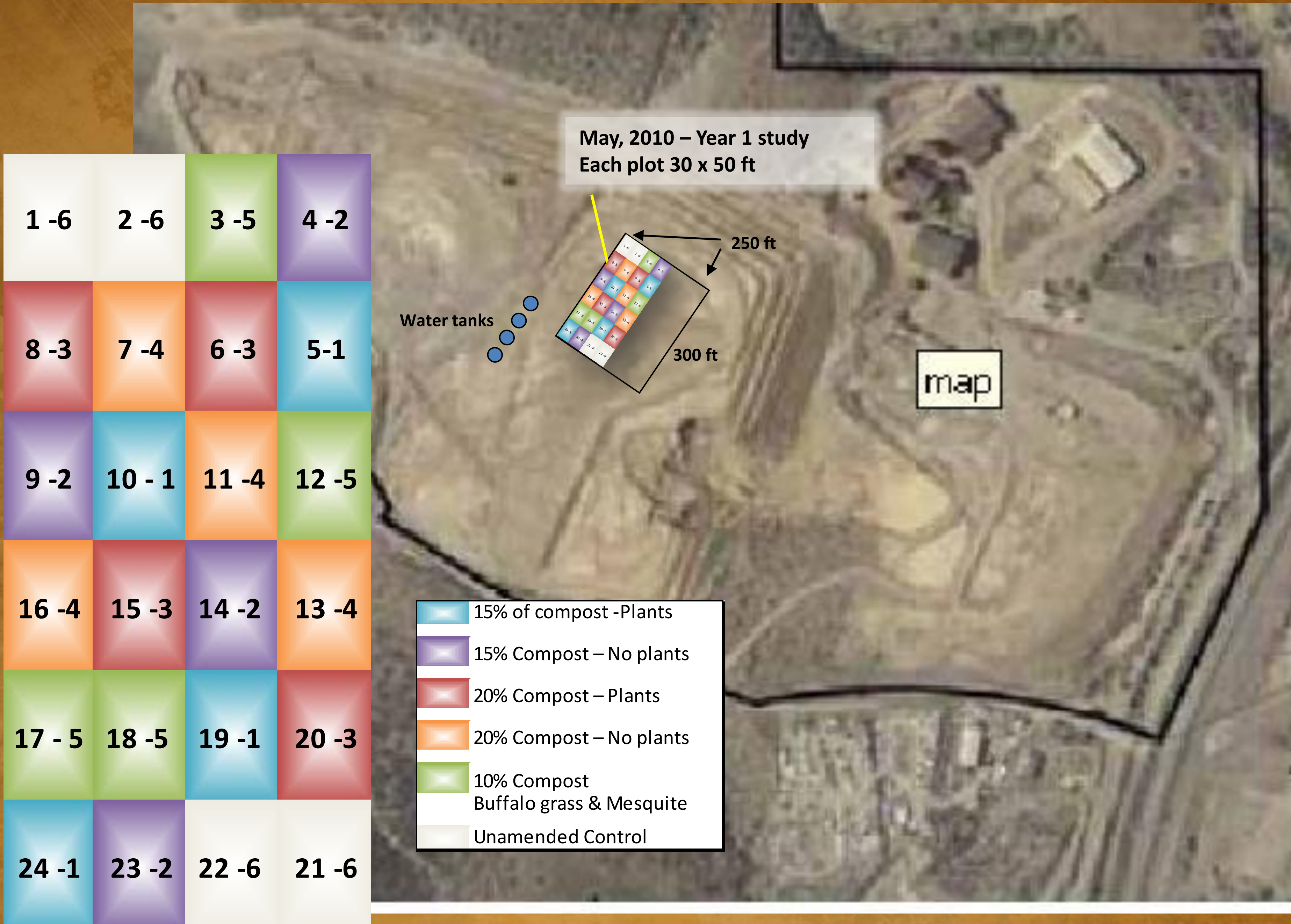
Field trial – initiated May 2010


Site preparation


OSHA-trained workers


Trial initiated

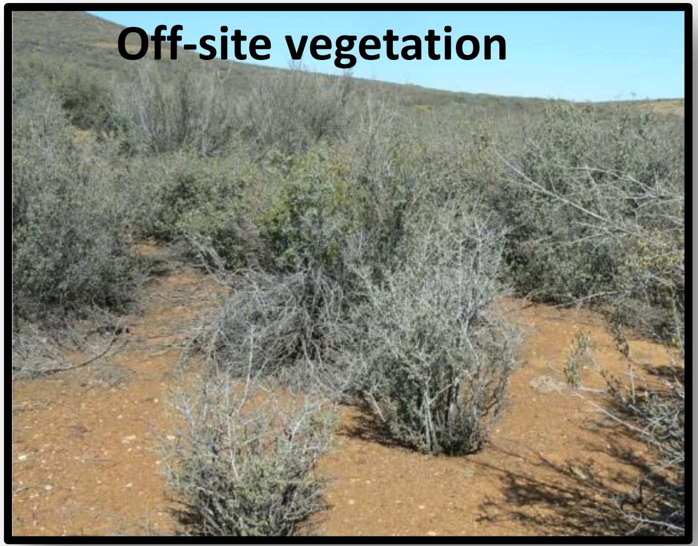

A windy day



1 -6
2 -6
3 -5
4 -2
8 -3
7 -4
6 -3
5-1
9 -2
10 - 1
11 -4
12 -5
16 -4
15 -3
14 -2
13 -4
17 - 5
18 -5
19 -1
20 -3
24 -1
23 -2
22 -6
21 -6
May, 2010 – Year 1 study
Each plot 30 x 50 ft
250 ft
300 ft
Water tanks
map
15% of compost -Plants
15% Compost – No plants
20% Compost – Plants
20% Compost – No plants
10% Compost
Buffalo grass & Mesquite
Unamended Control

Results

- Direct planting achieved a canopy cover similar to the surrounding area
- 15 and 20% compost amendment showed similar results



Buffalo Grass

Blooming and seeding after 17 months

Quailbush


April, 2010

September, 2011

September, 2011

Phytostabilization significantly impacts metal(loid) speciation

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Low microbial counts

Pb phases
Plumbojarosite
Anglesite
Galena

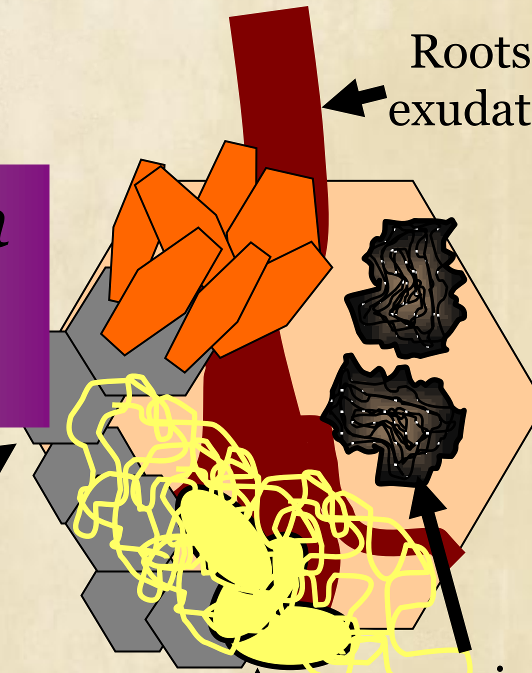
Zn phases
Goslarite
Zn-Fe sulfate
Sphalerite

As phases
Sorbed As(V)
Arsenopyrite

Also quartz, feldspar, Fe oxide, gypsum, clays

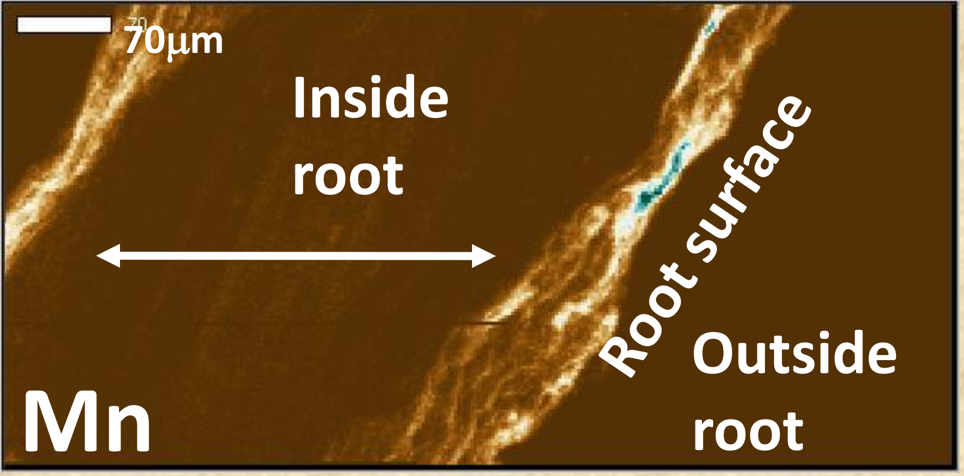
Phytostabilization

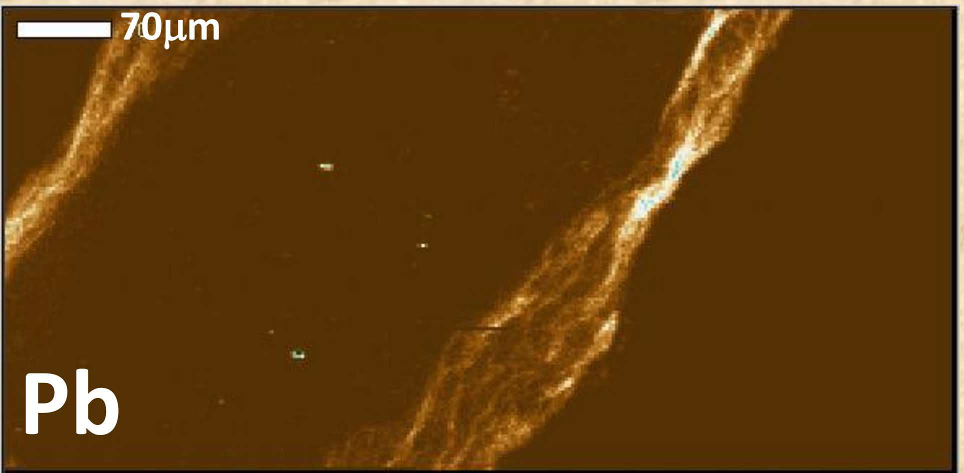
neo-formed colloids, precipitates/plaques (FeOx, MnOx)

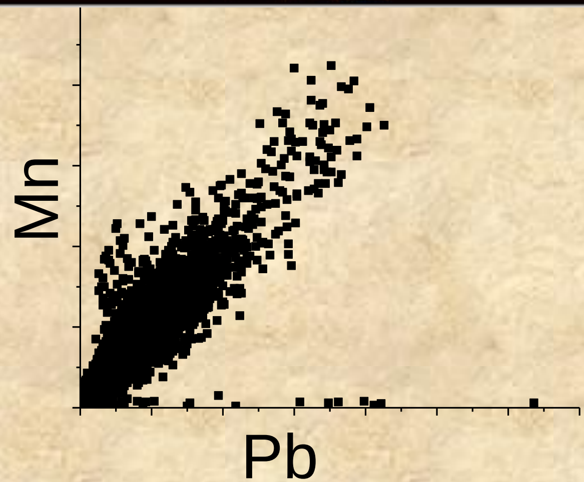


Form, fate **and** ***bioavailabily*** **of As, Pb, Zn**

Rhizostabilization



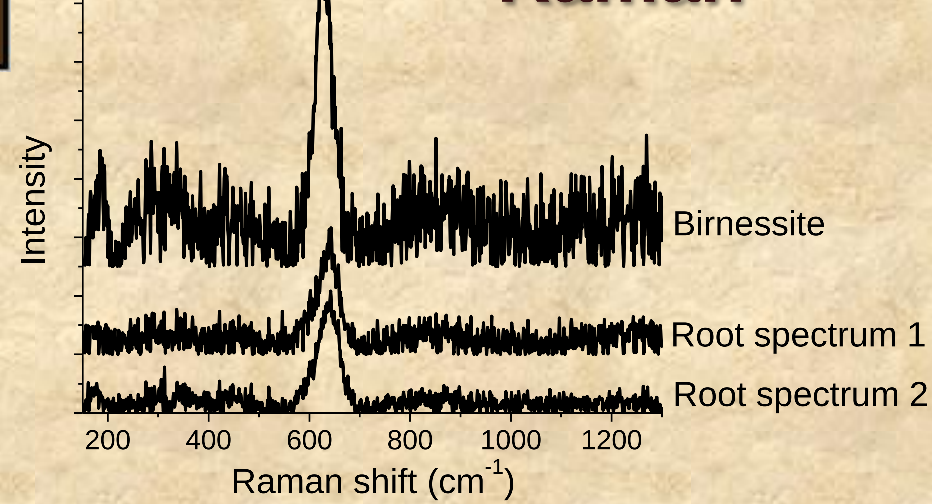




Mesquite root grown in tailings with 10% compost addition (wt/wt)

- Root-microbe-metal interaction affects Pb speciation.
- Biogenic birnessite formation at root surface.

Raman



Characterizing dust and reducing dust emissions

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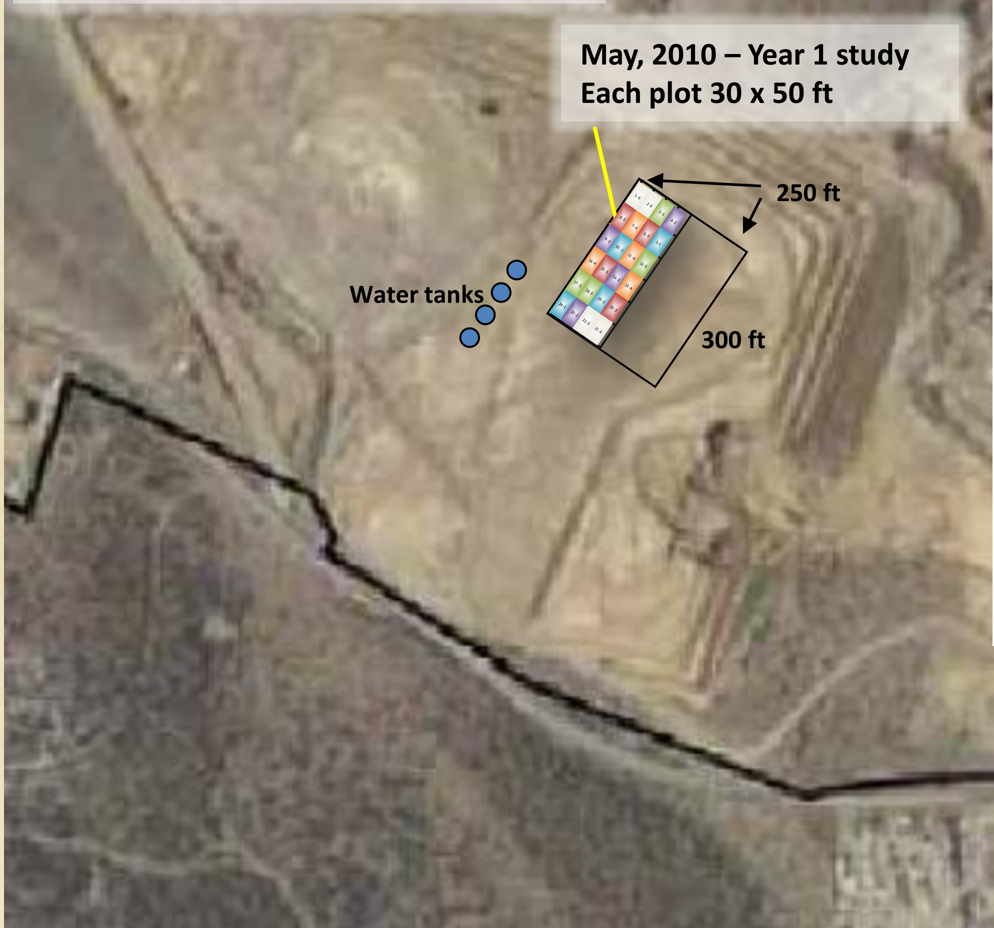
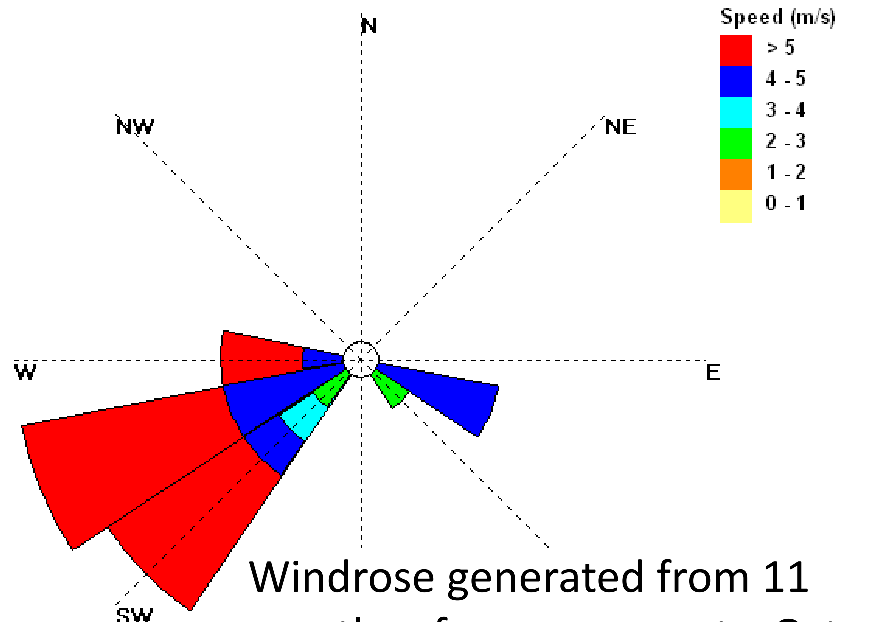
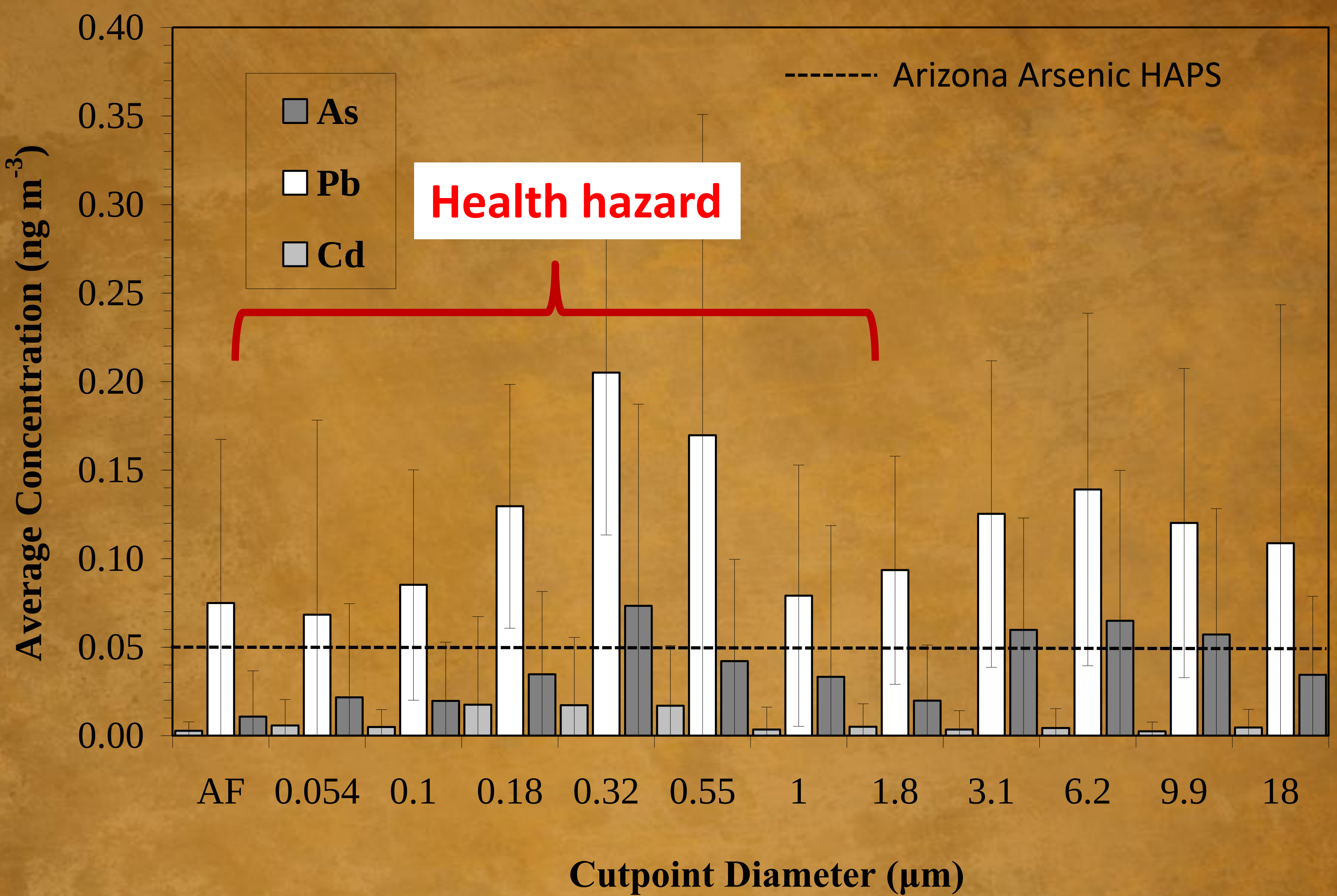
Risk Reduction?



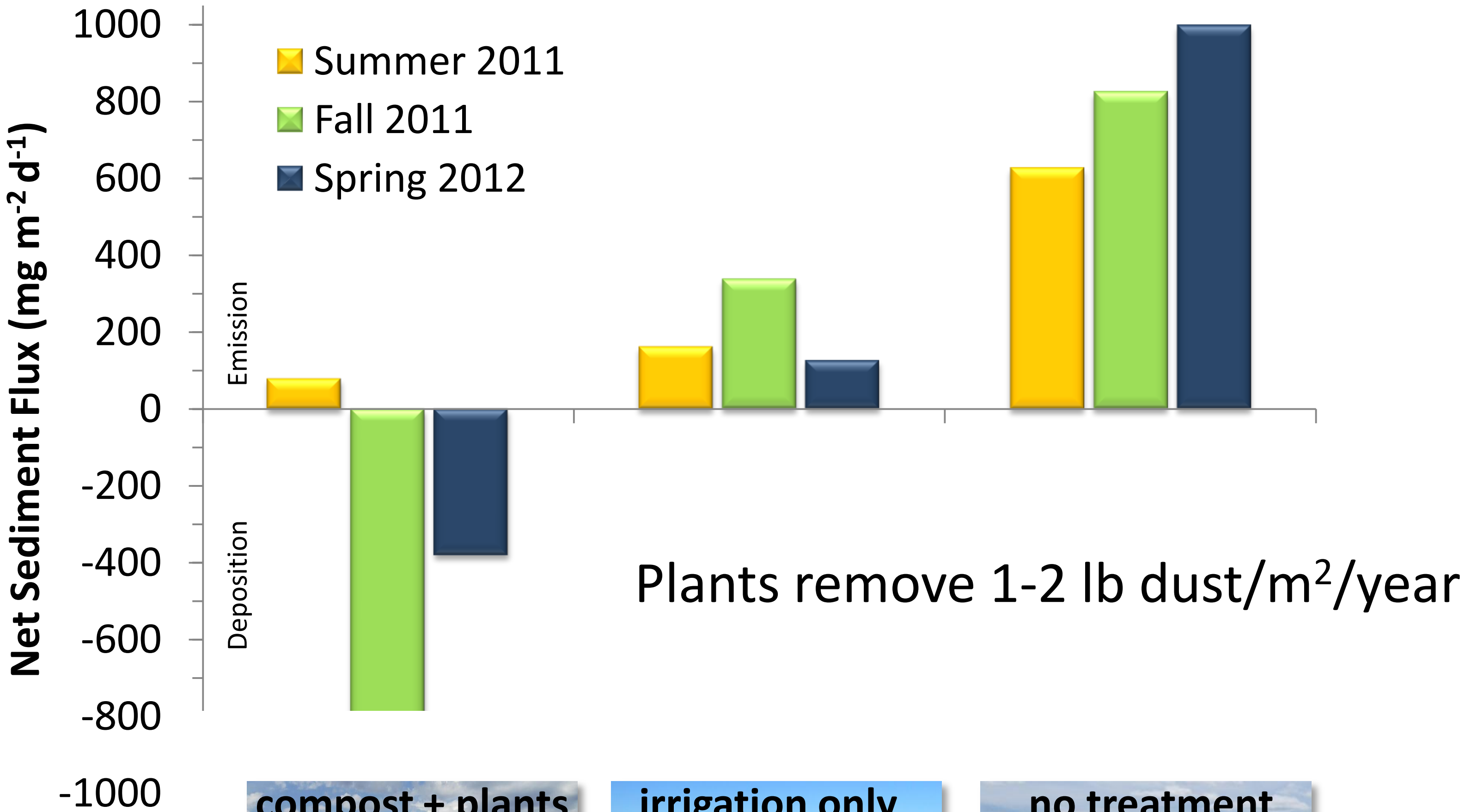


Windrose generated from 11 months of measurements, Oct 2008 to Aug 2009

Annual averaged metal concentrations Oct. 2008 to Aug. 2009



Plants Reduce Particulate Generation and Emissions



Conclusions

Assisted phytostabilization has potential as a cost-effective and acceptable remediation strategy for mine tailings

Phytostabilization appears to promote incorporation of toxic metals into stable mineral phases – lowering bioaccessibility

Phytostabilization appears to reduce emissions of small diameter particles which pose the greatest health risk.

Major information gaps

Are vegetative caps viable over the long-term?

Do normal successional plant processes take place? Does metal uptake into shoot material occur in successional plants?

Do tailings transition into soil-like materials?

Does speciation of tailings metals in the rhizosphere change in the short- or long-term?

What impact might this have on metal mobility and bioavailability?

What is the long-term relationship between vegetative cover and particulate emissions?

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You can follow the field study:

http://cals.arizona.edu/crops/irrigation/azdrip/BostonMill/IK/photolog.htm

Or write me and I will send you the link: rmaier@ag.arizona.edu

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The University of Arizona

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