Mining Site Primer

Tools for Assessment & Cleanup
of Abandoned Mine Sites

Overview

- Types of environmental problems
- Objectives
- Assessments
  - Approaches
  - Tools
- Cleanup
  - Approaches
  - Considerations

NECR Mine U Waste Rock

Personal Objectives

- Collect data that drives need for action
- Select appropriate actions with ecological restoration in mind
- Choose off-site disposal as LAST RESORT
- Collect data that maximizes effectiveness of on-site technologies

Problems

- Mines pose potential exposures to persons living working or recreating in the vicinity of contamination.
  - Primarily, we are concerned with inhalation and ingestion of soils and dust contaminated with heavy metals
    - Arsenic
    - Lead
    - Mercury
    - Radium
    - Sometimes Uranium
    - Eco & and plant toxins like zinc and cadmium
  - Some cases, acidic drainage is a problem as well (Why?)
- Mines represent loss of ecological function and opportunities for restoration.

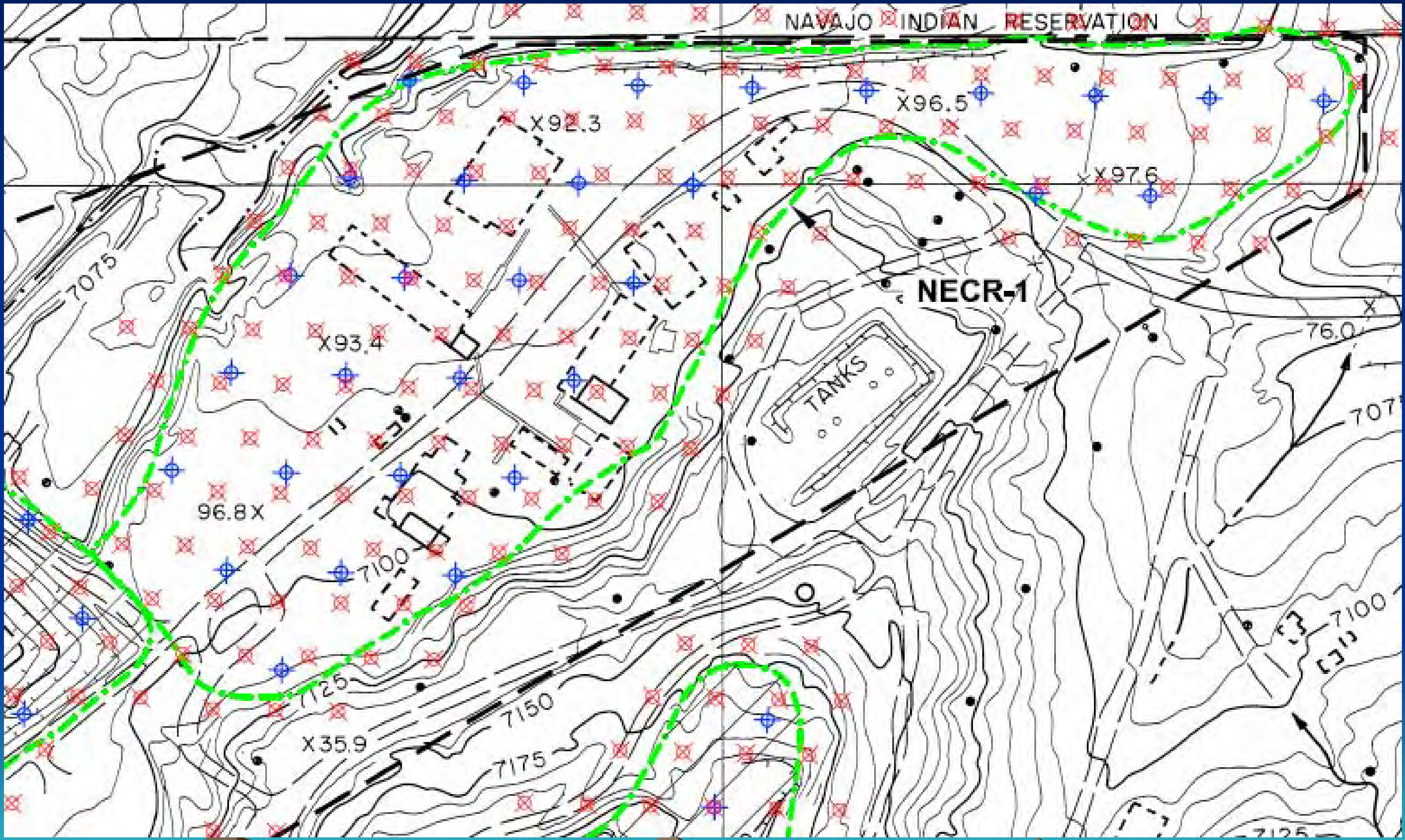
Objectives for Mine Cleanup & Assessment

- Mitigate public health threats posed by heavy metals and/or radiologicals at abandoned mines
- Use the best science to develop protective and cost-effective solutions that are applicable at multiple sites
  - Re-consider traditional cleanup goals and techniques based on estimates of material risk (bioavailability), ecological benefit, & and potential environmental costs

Assessment of contaminants in Soil

- Start with traditional assessment approaches (SW-846 or MARSSIM)
- Use the DQO process…in particular…
  - Decide what needs to be done – write an *“if…then”* statement
  - Define the boundaries of the action (or actions)
  - Choose sampling approach
  - Choose statistical tests for each unit (UCLs? t-test? MARSSIM Sign test or WRS test?)
  - Determine the no. of samples by unit
  - Collect data, develop descriptive statistics, test assumptions
  - Use Visual Sampling Plan – it’s free
  - Get results and answer the *“if…then”* statement

VSP Sampling Design



The 95% UCL on the Mean

Decision Unit	Mean Ra (pCi/g)	Ra UCL 95% (pCi/g)	Comment
NECR – 1	**24.39**	**32.45** (App. Gamma UCL)	Data follow Gamma Distribution
NECR – 2	**27.95**	**50.29** (App. Gamma UCL)	Data follow Gamma Distribution
Ponds 1 & 2	**78.26**	**165.37** (Adj. Gamma UCL)	Data follow Gamma Distribution
Ponds 3/3a	**117.27**	**693.07** (99% Chebyshev (MVUE) UCL)	Data are lognormal
Sediment Pad	**60.51**	**108.96** (App. Gamma UCL)	Data follow Gamma Distribution
Sandfill 1	**9.77**	**15.22** (App. Gamma UCL)	Data follow Gamma Distribution
Sandfill 2	**9.96**	**17.70** (App. Gamma UCL)	Data follow Gamma Distribution
Sandfill 3	**31.00**	**60.60** (App. Gamma UCL)	Data follow Gamma Distribution
Ventholes 3 & 8	**26.88**	**297.53** (Adj. Gamma UCL)	Data follow Gamma Distribution
Trailer Park	**14.15**	**49.77** (App. Gamma UCL)	Data follow Gamma Distribution

Optimize your Sampling Design

- New sub-objectives if necessary
  - Start with soil sampling. Are other media appropriate?
- Site-specific cleanup goals
  - Dependent upon speciation and bioavailability
  - Understand background concentrations
  - May choose site-specific risk assessment
  - Use PRGs as a "point of departure"
    - Higher or lower values may be appropriate

Assessment Tools

- Collaborative sampling
  - Develop correlation between a lab method (accurate) and a field (fallible) method.
  - XRF for heavy metals
  - Radiological scanning?
  - Surrogate contaminant
  - Field chemistry

Collaborative Sampling

- May improve cost-effectiveness of sampling require a large number of samples, some may be replaced with less expensive measurements
- Assumes
  - Lab-based measurements are more expensive (n)
  - Field-based measurements are less expensive (n')
  - A strong-linear relationship exists between the two-types of measurements (constant residual variance r^2 value)
  - Mean is normally distributed

Examples of Collaborative Sampling Equipment

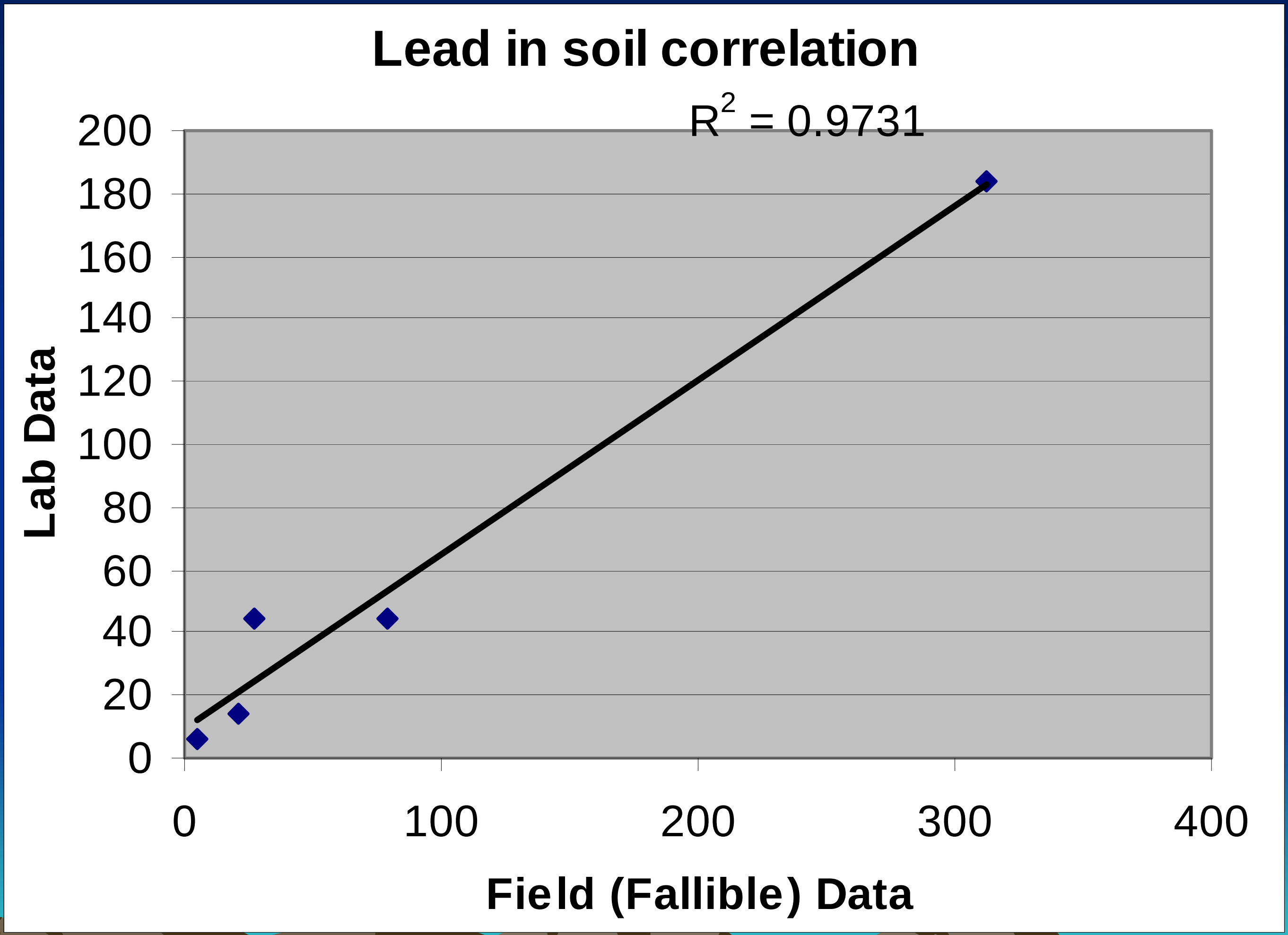
- X-ray fluorescence
- Direct measurements for radiation
- Mercury vapor analyzers

From the Field to the Hotel Room

Assessment Tools Continued

- Specialty sampling and analysis
  - Consider metal speciation (*e*⁻ microprobe analysis)
  - Consider bioavailability (*in-vivo* literature/*in-vitro* tests (PBET))
  - Consider leachability & or mobility testing (SPLP tests, Kd values)
  - Consider soil health, erosion parameters (TOC, bulk density) & rainfall intensity
  - Geotechnical testing (compaction, slope)
  - Treatability testing

Correlation?

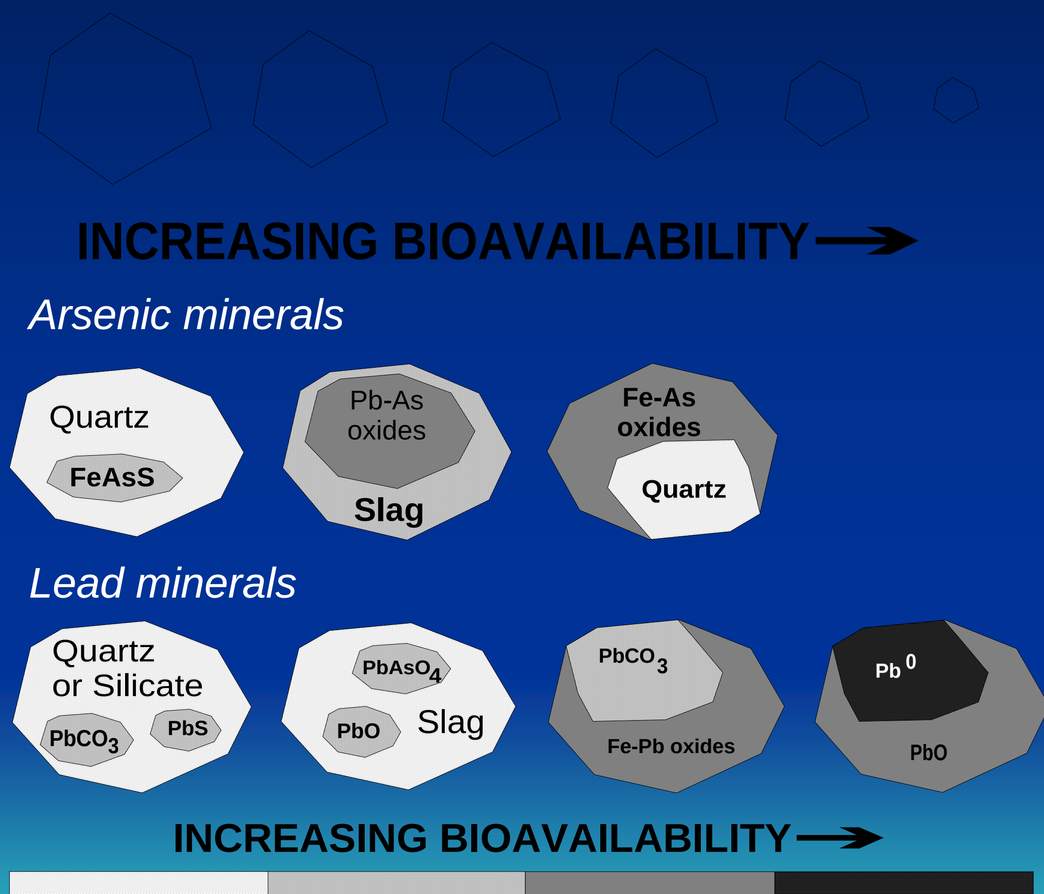


What is bioavailability?

- Bioavailability is the relative absorption of a chemical into the blood.
  - Risk assessment and cleanup goal determinations are typically based on animal toxicity data and epidemiological data
  - Absorption is dependent on chemical and physical form of the contaminant (e.g., species)

Bioavailability of Minerals

Arsenic or lead-containing particles (idealized particle size <1,000µm)



(*modified from Ruby et al. 1999*)

Examples of varying risk related to mine minerals

Risk of exposure to 500 mg/kg arsenic in soil and 0.01 mg/m3 arsenic in air over a lifetime

		Outdoor		Indoor	
Mining community	Ingestion	9.70E-07	*10 in 10,000,000*	1.90E-06	*2 in 1,000,000*
	Inhalation	2.60E-06	*3 in 1,000,000*	2.60E-05	*3 in 100,000*
	Total	3.60E-06	*4 in 1,000,000*	2.80E-05	*3 in 100,000*
Smelter community	Ingestion	9.70E-07	*10 in 10,000,000*	**1.20E-05**	***1 in 100,000***
	Inhalation	2.60E-06	*3 in 1,000,000*	**5.70E-05**	***6 in 100,000***
	Total	3.60E-06	*4 in 1,000,000*	**6.90E-05**	***7 in 100,000***

(*Adapted from* Murphy et al.1989)

Reconsidering Cleanup Goals

- Bioavailability in risk assessment
  - Removal objectives use Preliminary Remediation Goals (PRGs) for decision making in the “risk range” of contaminant concentrations
  - PRGs may not be an appropriate measure of risk at a mine site
    - Total metals may not be bioavailable
    - Risk assessment modeling traditionally assumes 80 to 100% absorption
- Consult your toxicologist

As Bioavailability Summary

Phase	Experiment	Test Material Number	Test Material Description	RBA	LB	UB	SE
II	2	2	Bingham Creek Channel	0.39	0.26	0.53	0.08
II	4	1	Murray Slag	0.55	0.38	0.73	0.10
II	6	1	Midvale Slag	0.23	0.17	0.30	0.04
II	6	2	Butte Soil 1	0.09	0.04	0.14	0.03
II	7	1	California Gulch Phase I Residential	0.08	0.03	0.14	0.03
II	7	2	California Gulch FeMnPbO	0.57	0.38	0.77	0.12
II	8	1	California Gulch AV Slag	0.13	0.07	0.19	0.04
II	9	1	Palmerton Location 2	0.49	0.34	0.66	0.10
II	9	2	Palmerton Location 4	0.61	0.44	0.80	0.11
II	11	1	Murray Soil	0.33	0.25	0.42	0.05
II	10	1	California Gulch AV Slag	0.18	0.15	0.22	0.02
II	10	2	NaAs (IV)	0.41	0.33	0.54	0.06
II	15	1	Clark Fork Tailings	0.51	0.42	0.62	0.06
II	15	2	NaAs (IV)	0.47	0.38	0.59	0.06
II	15	3	NaAs (Gavage)	0.50	0.41	0.63	0.07
III	1	1	VBI70 TM1	0.40	0.35	0.47	0.04
III	1	2	VBI70 TM2	0.42	0.36	0.49	0.04
III	1	3	VBI70 TM3	0.37	0.31	0.42	0.03
III	2	4	VBI70 TM4	0.24	0.20	0.28	0.02
III	2	5	VBI70 TM5	0.21	0.18	0.25	0.02
III	2	6	VBI70 TM6	0.24	0.19	0.28	0.03
III	3	1	Butte Soil 1	0.18	0.12	0.23	0.03
III	3	2	Butte Soil 2	0.24	0.20	0.28	0.02
III	4	1	Aberjona River Sediment - High Arsenic	0.38	0.36	0.41	0.02
III	4	2	Aberjona River Sediment - Low Arsenic	0.52	0.49	0.56	0.02
III	5	1	El Paso Soil 1	0.44	0.39	0.49	0.03
III	5	2	El Paso Soil 2	0.37	0.33	0.42	0.03
III	6	1	Soil Affected by CCA-Treated Wood Utility Poles	0.47	0.42	0.52	0.03
III	7	2	Dislodgeable Arsenic from Weathered CCA-Treated Wood	0.26	0.25	0.28	0.01

Ranges from 8-61% in 30 studies

Presented by B. Brattin, Summary of EPA *in-vivo* As studies

SUMMARY OF ARSENIC RBA VALUES

USEPA Default 80-100%

Range of observed = 8% to 61%

RBA (Point Estimate)	Fraction within Range
<25%	10/29 = 34%
25-50%	14/29 = 48%
50%-61%	5/29 = 17%

Presented by B. Brattin, Summary of EPA *in-vivo* As studies

Iron King Mine Site

- Iron King Mine Site is a large mine and smelter in Humboldt, AZ
- Runoff and erosion from the mine contaminated neighboring residences with arsenic
  - Arsenic is high in the region (above state and EPA guidelines for cleanup)

Bioavailability in Risk Analysis

- EPA found that all residences in the study exceeded PRGs (22 ppm – Reg 9 PRG)
- EPA found that background concentrations (35 ppm) exceeded PRGs
- EPA then considered bioavailability of arsenic as a means of reconsidering what the true protective level really is
  - Based on lines of evidence EPA selected a bioavailability default of 50% (departure from 80-100% typically used)

Arsenic in Ironite?

Ironite-Arsenic Example

- Ironite is a fertilizer derived from mining wastes
- Both the mining waste and the product are currently exempt from regulation as a hazardous waste under the Beville exemption.
- Ironite contains high levels of lead and arsenic, with arsenic levels typically ranging from 2600 – 5100 ppm.
  - EPA has reported to Congress on the Ironite Product

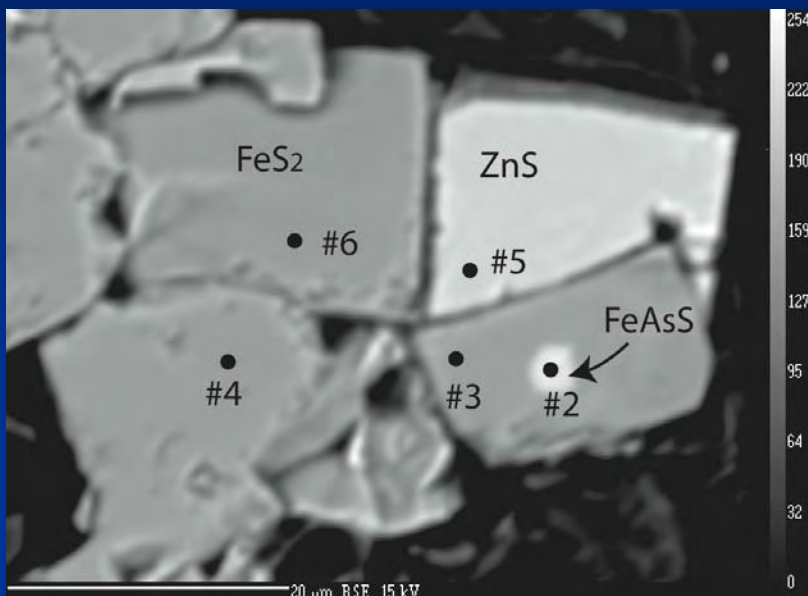
Approach and Performance Measures

- EPA reported a best estimate of 30% and a high end estimate of 45% for the RBA of arsenic in soil for the Ironite product (based on in-vivo & in-vitro respectively).
- Based on lines of evidence EPA tweaked the risk equations to include a bioavailability factor of 50%
  - Chose a cleanup goal of 80 parts per million instead of 22 ppm.

Electron Microprobe Analysis

- EPA Region 9 conducted speciation of As using an electron microprobe
  - Determined that As was present as arsenopyrite – a low bioavailability form of As
- Analysis provided confirmation that primary species in soil samples is in fact arsenopyrite.

Arsenopyrite in Soil at Iron King



Questions?

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