Human Health Aspects of Mineral Deposits and Mining

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USEPA Human Health Environmental Criteria

Element	Human Health	
Media	Residential Soil	Drinking Water
Units	mg/kg	µg/L
Al	77,000	200
As	23	10
Cd	70	5
Cr	280	100
Cu	3,100	1,300
Fe	55,000	300
Hg	6.7	2
Mn	1,800	50
Mo	390	
Ni	1,600	
Pb	400	15
Se	390	50
U	230	30
V	78	
Zn	23,000	5,000

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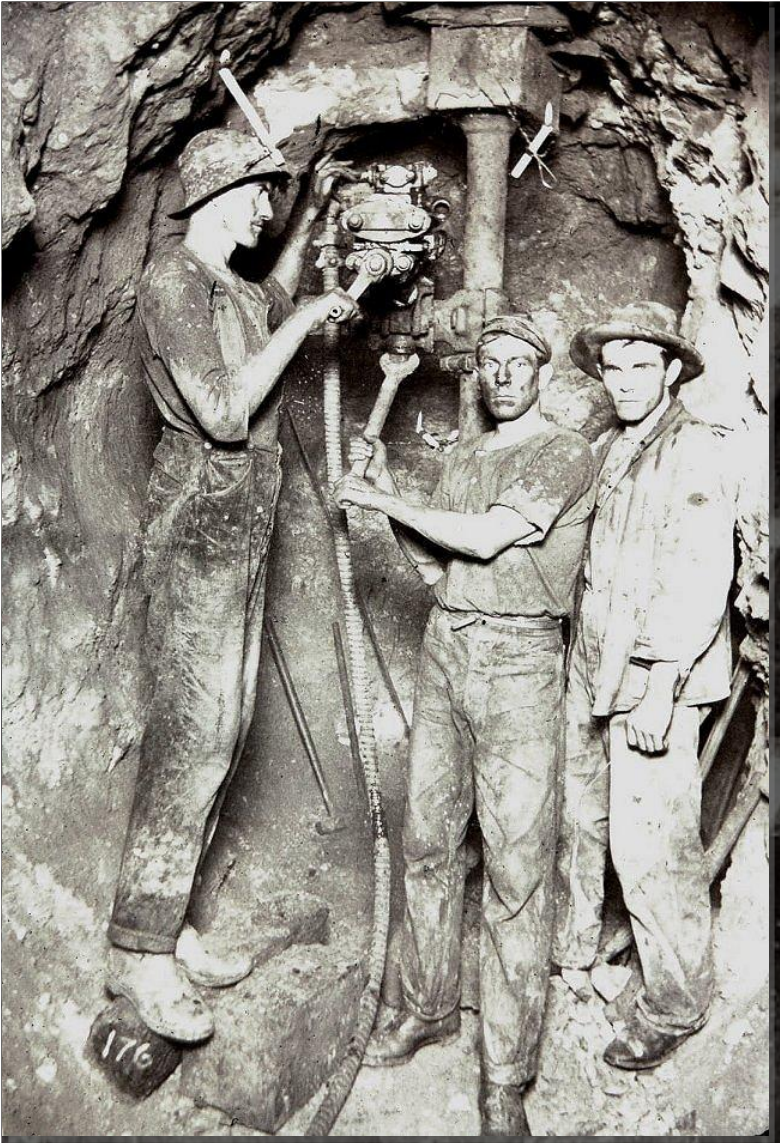
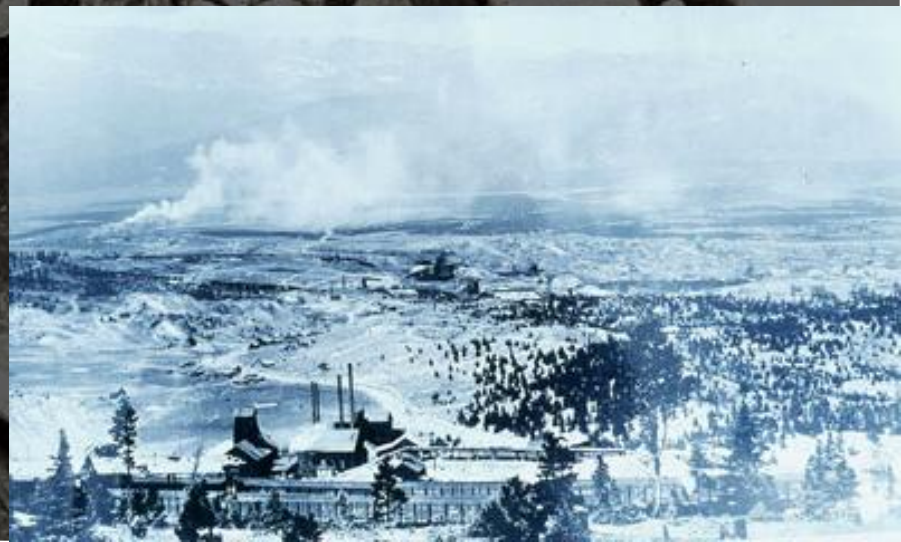


Historical mining

- Occupational exposures at time of mining
  - Silicosis, asbestosis, etc.
- Environmental exposures (past and current)
  - Heavy metals in mine wastes, smelter emissions, soils, drinking water



ZAMBIA: Kabwe, Africa's most toxic city

Photo: Nebert Mulenga/IRIN

Women in Kabwe 'mining' zinc in the rubble of what was once Africa's biggest lead mine

KABWE, 9 November 2006 (IRIN) - Kabwe, home to 300,000 people, is Africa's most polluted city and has gained the dubious distinction of being ranked as the world's fourth most polluted site, according to a survey published by the Blacksmith Institute, a New York-based organisation monitoring pollution in the developing world.

In this toxic environment, Christine Mupika, barefooted and without any protective clothing, is just one of many scavenging Kabwe's open quarries and old dump sites near the city centre every day for metals, coal and zinc to sell by the roadside. Her high-risk occupation earns her about US$0.25 for 25kg of zinc and around $1.25 for the same quantity of coal; income derived from scrap metal

IRIN

humanitarian news and analysis

a project of the UN Office for the Coordination of Humanitarian Affairs

Mining, processing in developing countries

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The World's Most Polluted Places

From lead in the soil to toxins in the water and radioactive fallout in the air, The Blacksmith Institute has created a list of the world's worst ecological disaster areas

Story | All Best and Worst Lists

La Oroya, Peru

BACK NEXT

5 of 10 | View All

Pollution from the mining and processing operations of Doe Run Peru has led to dangerously high concentrations of lead in children's blood in La Oroya.

MATHEW BURPEE

MORE

Number of people potentially affected: 35,000

Type of pollutant: Lead, copper, zinc and sulfur dioxide

Source of pollution: Heavy metal mining and processing

Lead is the contaminant that shows up most frequently on Blacksmith's list because the toll it takes on children can be so devastating. In La Oroya, a mining town in the Peruvian Andes, 99% of children have blood levels that exceed acceptable limits, thanks to an American-owned smelter that has been polluting the city since 1922. The average lead level, according to a 1999 survey, was triple the WHO limit. Even after active emissions from the smelter are reduced, the expended lead

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A town left to die

Thursday, November 18, 1999

By ANDREW SCHNEIDER
SEATTLE POST-INTELLIGENCER SENIOR NATIONAL CORRESPONDENT

LIBBY, Mont. -- First, it killed some miners.

Then it killed wives and children, slipping into their homes on the dusty clothing of hard-working men.

Now the mine is closed, but in Libby, the killing goes on.

The W.R. Grace Co. knew, from the time it bought the Zonolite vermiculite mine in 1963, why the people in Libby were dying.

But for the 30 years it owned the mine, the company did not stop it.

Neither did the governments.

Not the town of Libby, not Lincoln County. Not the state of Montana, not federal mining, health and environmental agencies, not anyone else charged with protecting the public health.

Here is what is killing people in Libby:

Along with the enormous deposits of vermiculite in the earth of nearby Zonolite Mountain are millions of tons of tremolite, a rare and exceedingly toxic form of asbestos.

Potential health issues related to mining and mineral processing

- Can vary substantially depending upon
  - the commodity and deposit geology
  - mining and processing methods used
  - whether best environmental engineering practices were/are followed
- Many (but not all) mining-affected areas with health concerns are legacies of historical mining
- Modern engineering practices, if implemented properly, eliminate or greatly diminish potential environmental, health concerns

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Mineralogical controls on toxicity of geologic materials

- Particle mineralogy, size, shape, chemical composition, surface freshness
- Particle solubilities and chemical reactivities in body fluid(s) encountered along exposure pathways
- Chemical form of potential toxicants as they are released from the earth materials into the body fluids (i.e., oxidation state has strong influence)
- Overviews, and references therein:
  - Plumlee and Ziegler, 2003, 2006 online, *Treatise on Geochemistry*, vol. 9
  - Plumlee, Morman, and Ziegler, 2006, in *Medical Mineralogy and Geochemistry*, Min. Soc. Am., Geoch. Soc. Reviews in Mineralogy and Geochemistry, v. 64

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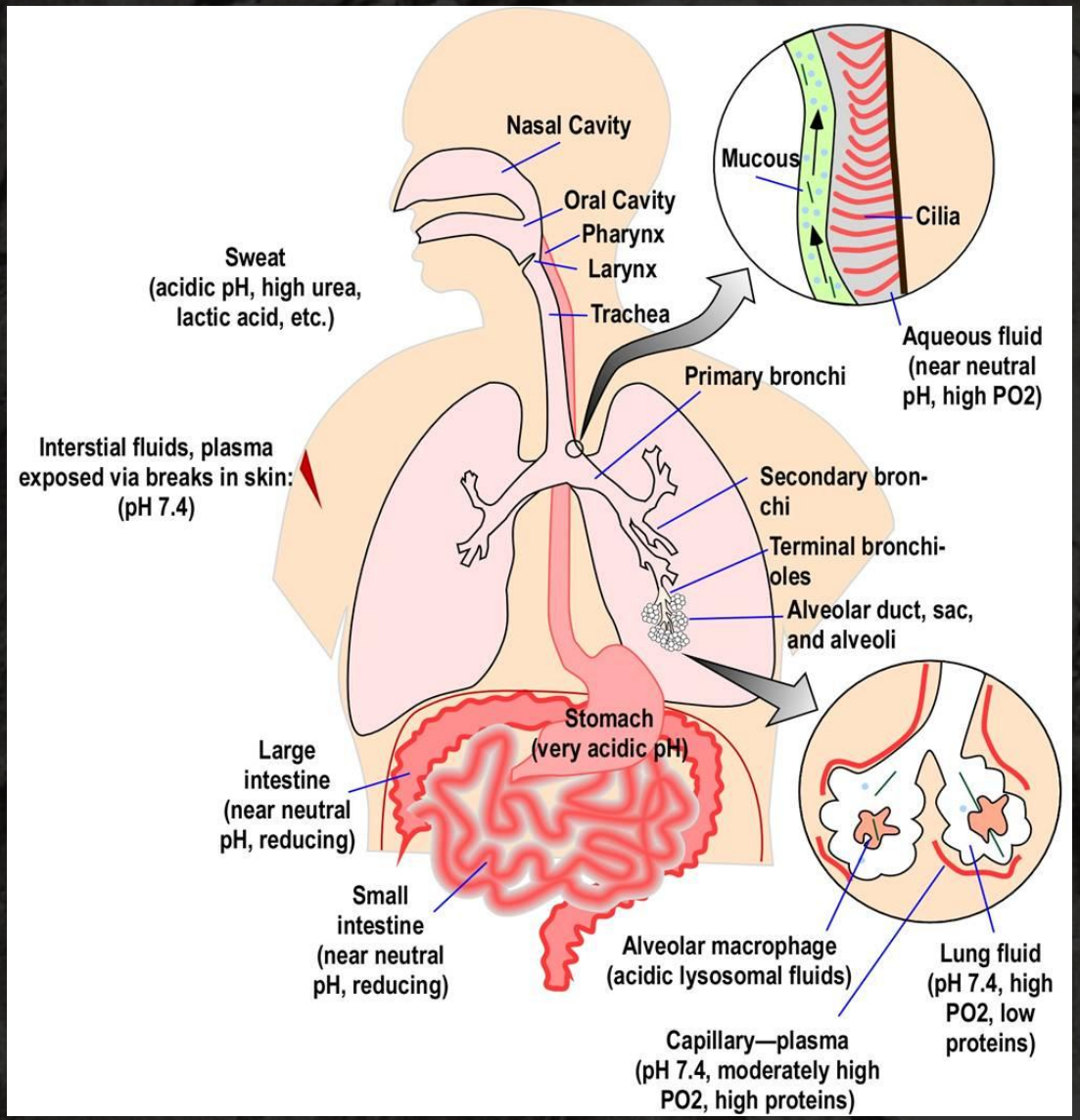
Bioaccessibility in the Human Body



- Need to consider specific biochemical environments
- Stomach is acid; intestines are near neutral
- Digestive track
- Lungs
- Blood

From: Plumlee et al. (2006) Reviews in Mineralogy and Geochemistry, v. 64.

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Asbestos: Mineralogy

- Asbestos is an industrial term applies to several minerals
  - Serpentine-group: Chrysotile (most commonly mined and used in USA and Canada)
  - Amphibole-group: tremolite, actinolite, amosite, crocidolite, anthophyllite (mined from South Africa and Australia)
- Fibrous, resistant to chemicals and heat

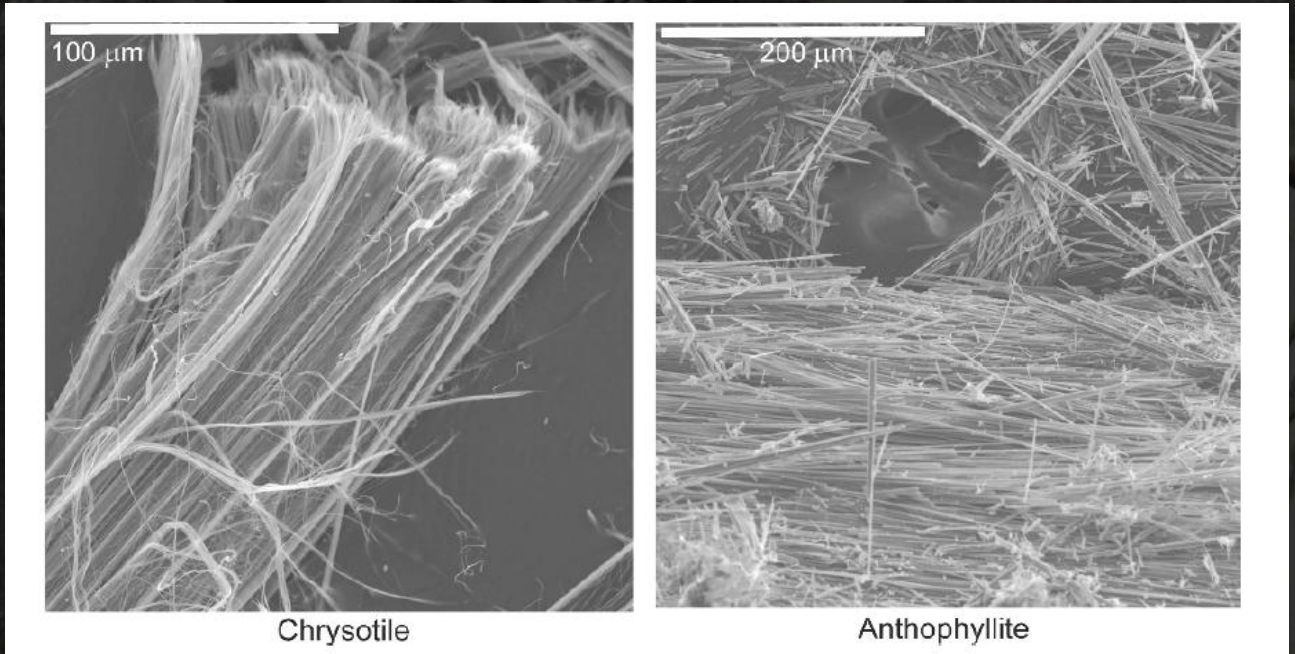

Figure 3. Scanning electron microscope (SEM) photomicrographs showing examples of chrysotile and anthophyllite asbestos, each once mined from veins within regionally metamorphosed ultramafic rock.

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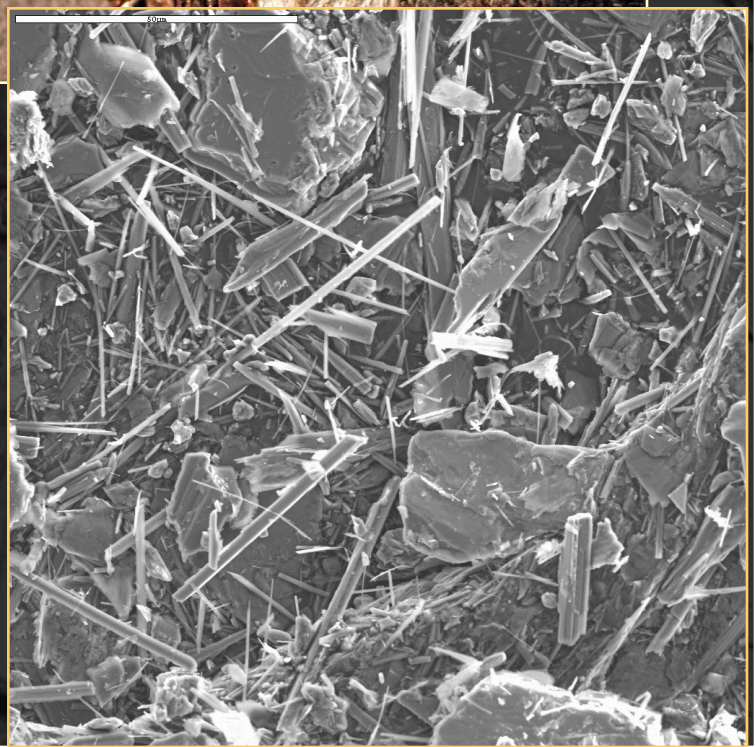
Asbestos-containing Mineral Deposits

- Serpentinites and other ultramafic-hosted deposit types
- Some marble deposits
- Talc deposits formed by regional metamorphism of dolostones (NOT hydrothermal talc deposits)
- Skarn deposits hosted by contact-metamorphosed dolostones
- Metamorphosed iron formations (crocidolite deposits: W. Australia & South Africa)
- Alkalic intrusive (i.e., Libby, MT) or carbonatite-hosted deposits

Van Gosen, B. (2007) The geology of asbestos in the United States and its practical applications: Environmental & Engineering Geoscience, Vol. XIII, p. 55–68.

Libby, Montana

- Fibrous and asbestiform amphiboles are common trace minerals in the vermiculite mined at Libby
- High incidences of mesothelioma, other cancers, and asbestosis among vermiculite miners and mill workers, their families, and the general public in Libby (population ~2,500)
- Clear cases of mesothelioma from environmental exposures



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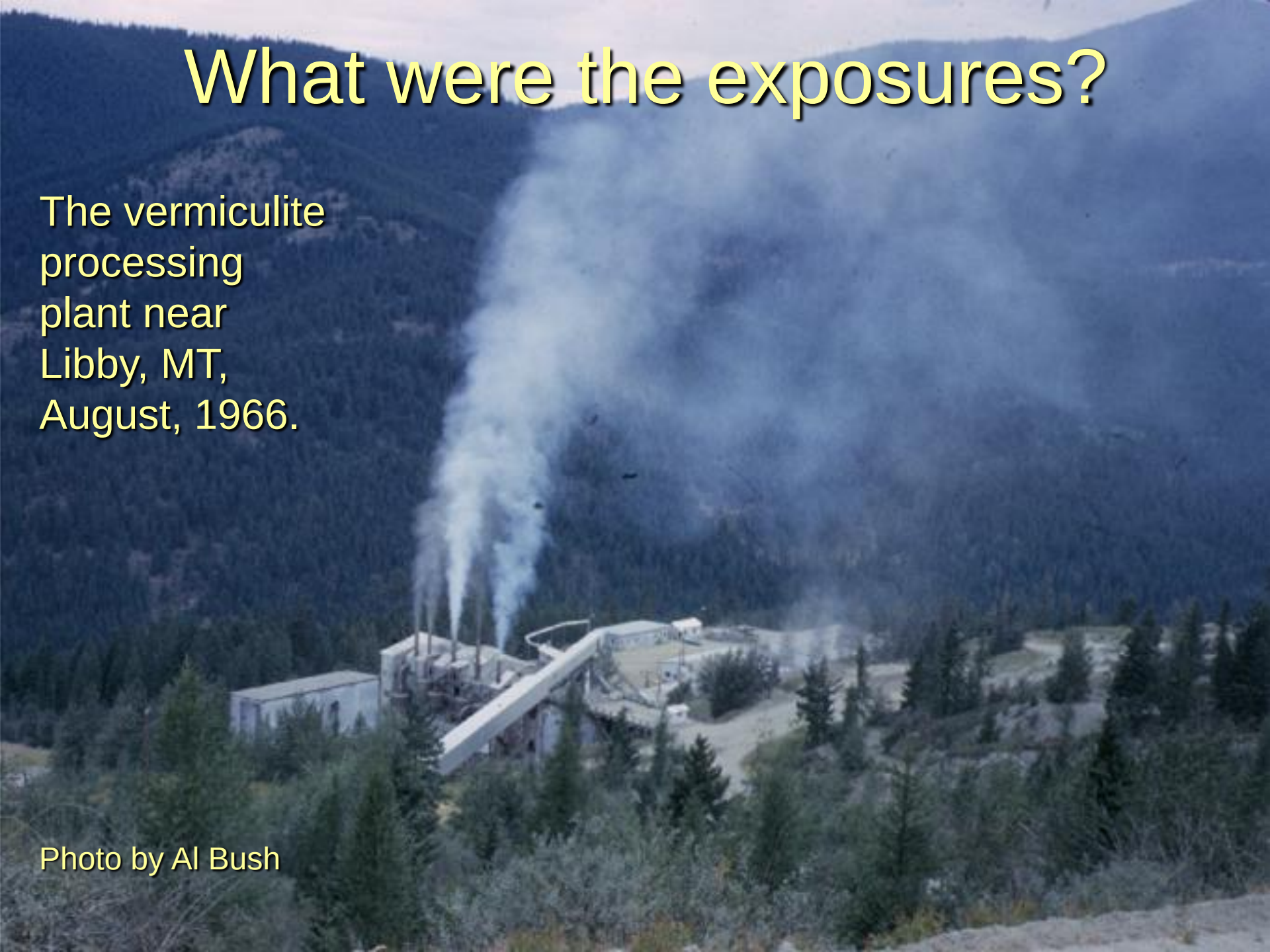
What were the exposures?

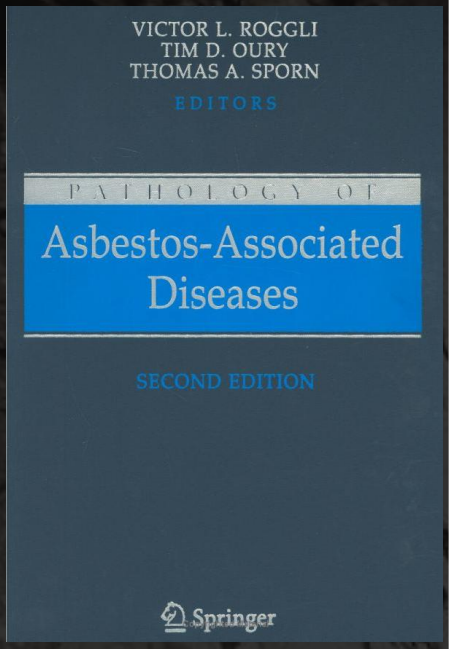


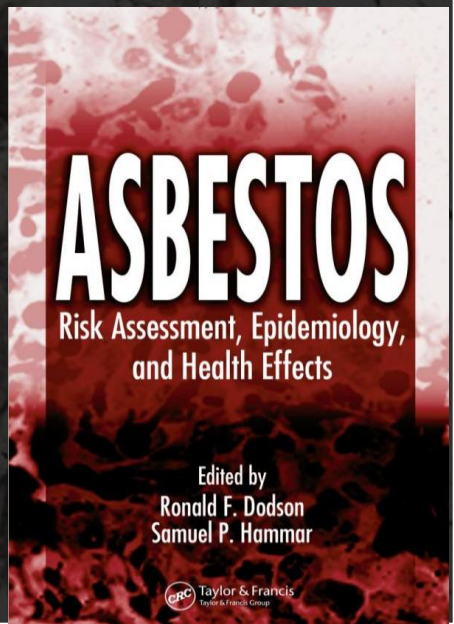
The vermiculite processing plant near Libby, MT, August, 1966.

Photo by Al Bush

Many aspects of asbestos toxicity are still debated

- Amphibole asbestos more carcinogenic than chrysotile asbestos?
- Relative toxicity of short versus long fibers?
- Disease endpoints for the various fibers?
- Toxicity of non-”asbestos” compositions, acicular crystals, elongate cleavage fragments?
- Health risks of exposures to natural occurrences of asbestos (NOA)?
- Toxicity of “weathered” asbestos in soils?





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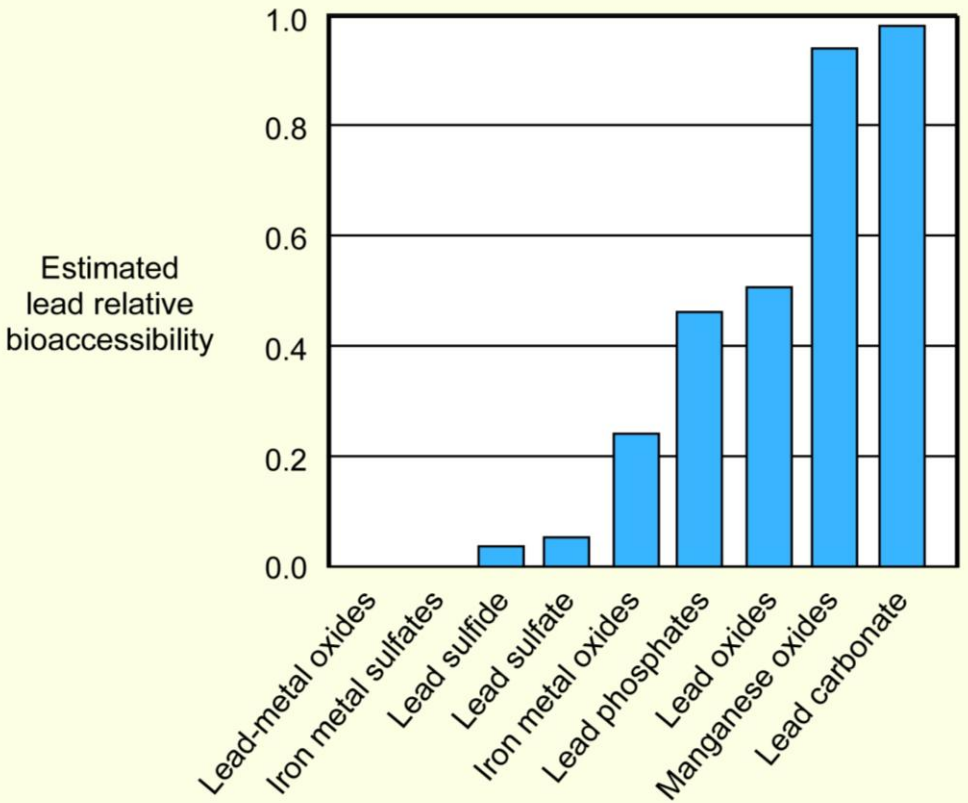
Bioavailability of Lead

- Fed juvenile swine feed spiked with various types of mine waste and lead compounds and monitored blood lead levels.
- Bioavailability of lead in digestive system:

  Cerussite ($PbCO_3$) > Anglesite ($PbSO_4$) > Galena (PbS)



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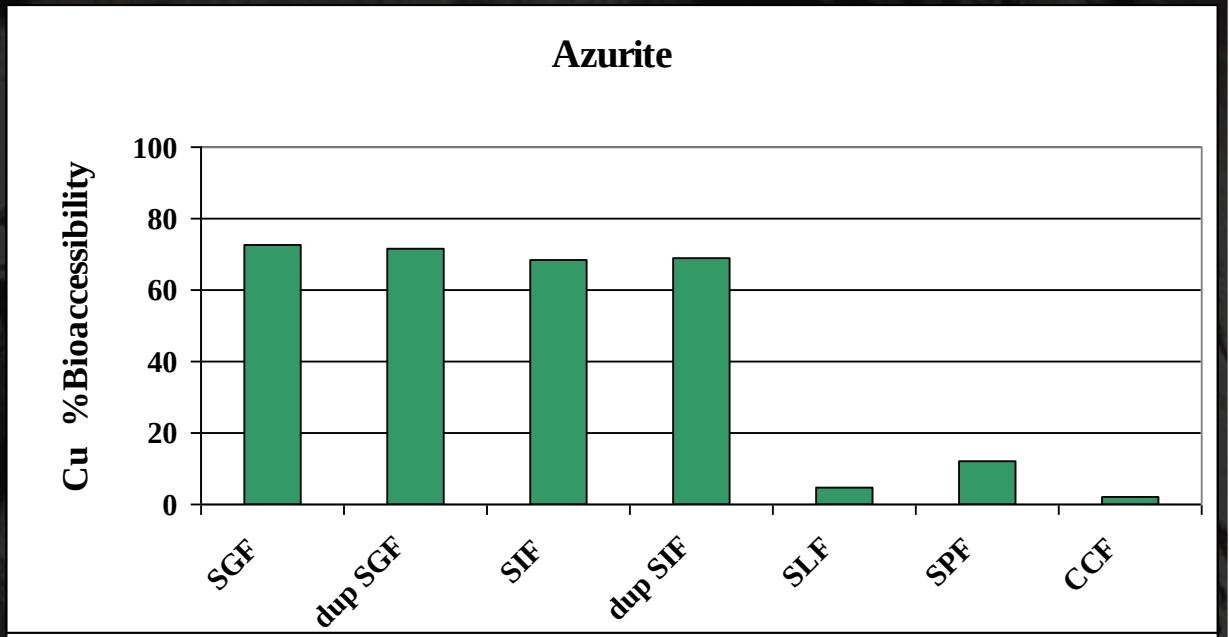
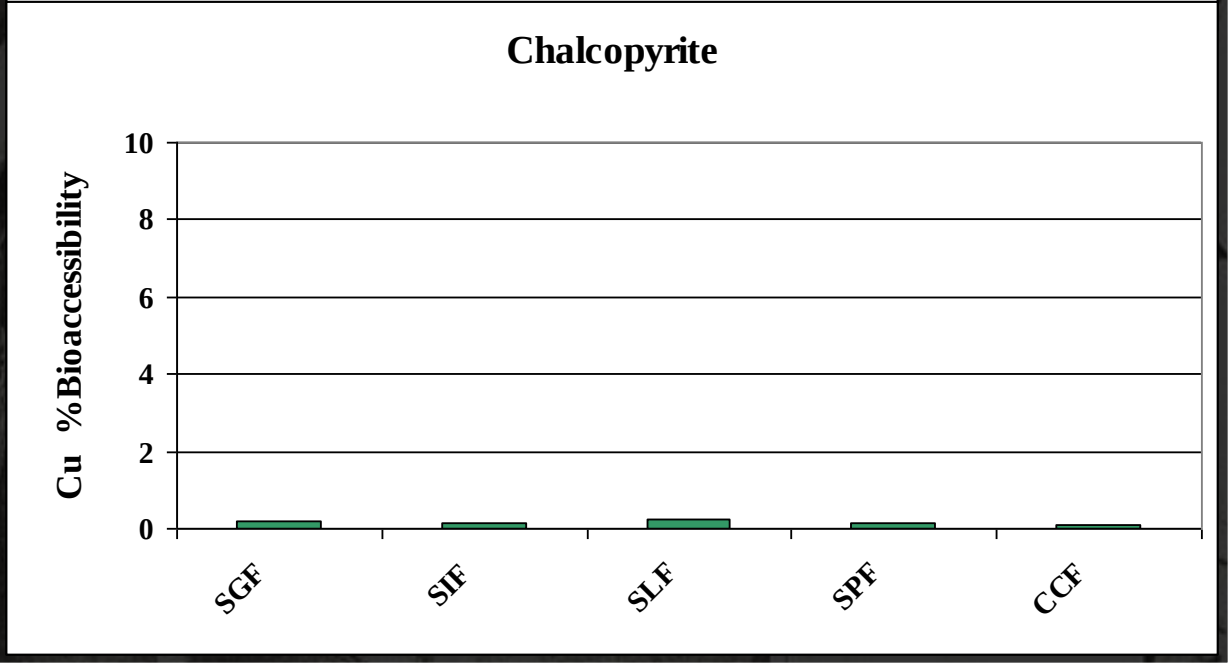
From Casteel et al. (2006)

Copper Availability from Copper Minerals

- SGF: Simulated Gastric Fluid
- SIF: Simulated Intestinal Fluid
- SLF: Simulated Lung Fluid
- SPF: Simulated Phagolysosomal Fluid
- CCF: Carrier Cell Fluid





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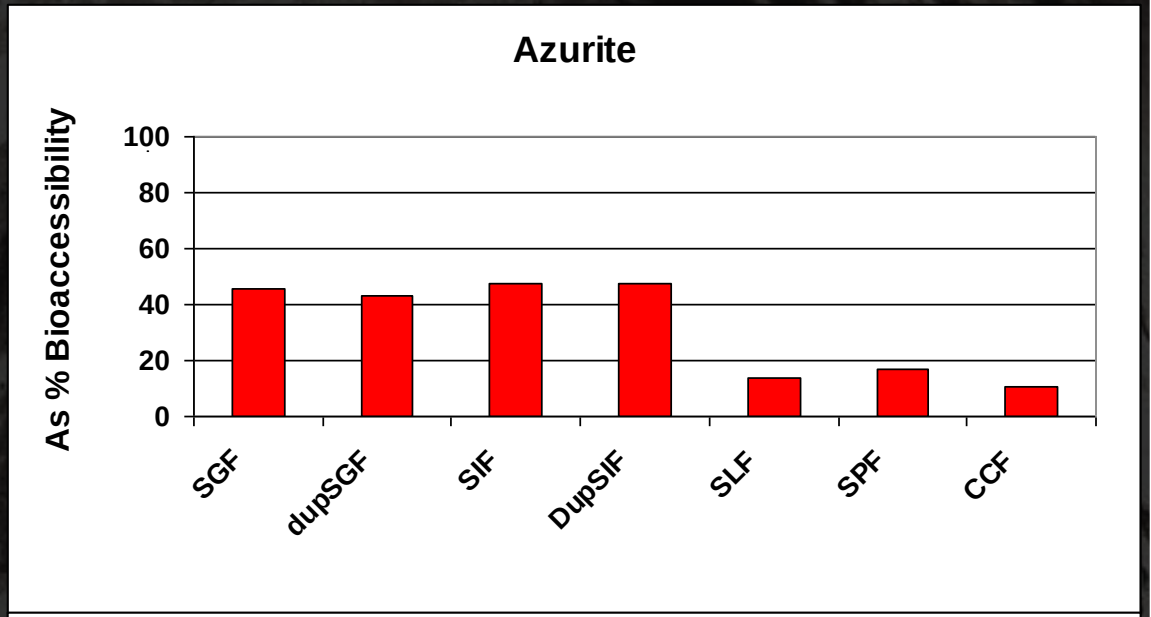
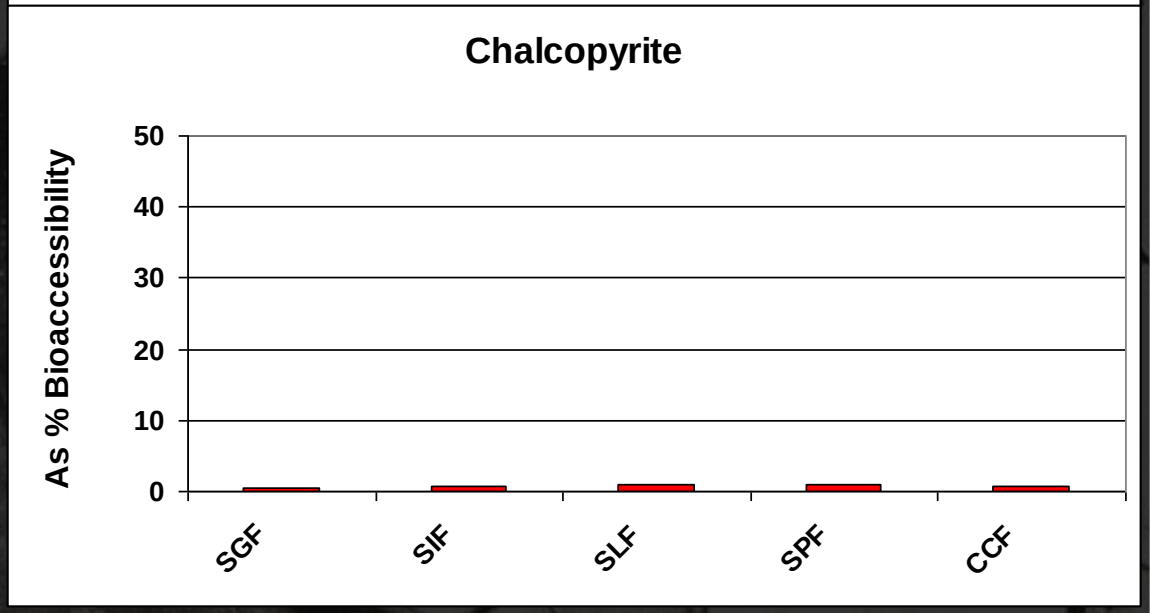
Arsenic Availability from Copper Minerals

- SGF: Simulated Gastric Fluid
- SIF: Simulated Intestinal Fluid
- SLF: Simulated Lung Fluid
- SPF: Simulated Phagolysosomal Fluid
- CCF: Carrier Cell Fluid





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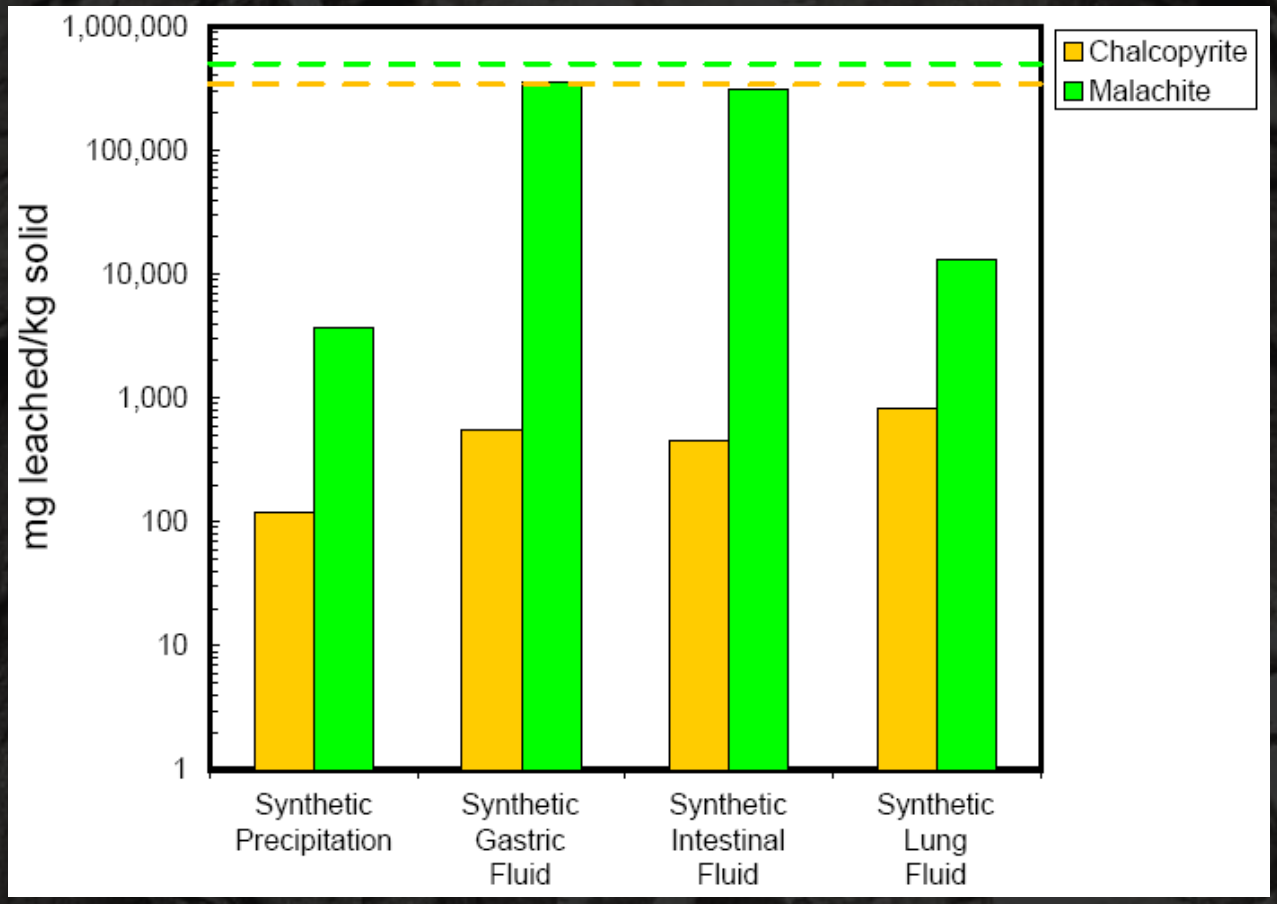
Copper Availability



- Leachability of various copper minerals was evaluated in environmental (EPA Method 1312) and synthetic human settings
- Permits assessment of complex mine wastes.

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An independent U.S. interagency assessment of mining-related engineering, environmental, and health issues, Marinduque Island, Philippines

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AFTP

Department of Mining & Geological Engineering

Futures Group

University of the Philippines 1908


Marcopper tailings causeway
Botilao
Lusok
Mogpog River Basin
Butan Sapa
Maguila-guila dam
1996 Dredge Channel
Mogpog
Mogpog River
San Antonio Pit
Sta. Cru
Marcopper
Boton
Boac
Tapian Pit
Bol River
Ogbac
Hina-pulan
Makulapnit River
Makulapnit dams
5
Boac River Basi
06/09/2003

Marinduque public health concerns attributed to copper mining

Based on reported case-based health studies in the area south of Calancan Bay:

- Elevated blood-lead cases in some children (10-20 µg/DL blood lead)
  - Review of analytical labs indicates possible QA/QC concerns with blood lead analyses
- "Arsenic poisoning" (3 cases, incl. fishermen and a family member)?
- Possible effects of other heavy metals associated with mine wastes, mine-affected waters?

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Possible sources of lead?

- Limited tailings samples compared to paint chips, soil from school in village of several children with elevated blood lead (10-20 µg/DL)

	Lead (ppm)
Marcopper tailings (bulk)	12-25 ppm
Tailings black sand	240 ppm
School soil	4 ppm
Paint chips from school window shutters, flower pots, multi-use area	1.4 to 13570 ppm
EPA IEUBK-based action levels, residential soils	150 – 1500 ppm (400 ppm play yard)
Canadian residential soil guidelines	140 ppm

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Health Team Medical Assessment

- Lead and arsenic are low in the samples of tailings, mine wastes, ground waters and surface waters analyzed
- Other population-based problems may act as contributing or confounding factors to human health effects from the mine tailings.
  - Widespread anemia
  - Nutritional deficiency
  - Immunological diseases

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Examples of mining-related health concerns from heavy metals

Kabwe, Zambia

- Lead-zinc ores, enriched in arsenic, vanadium, and cadmium, were mined from the early 1900's to 1994
- A mining city of 300,000 people grew up directly next to the mine workings, and smelter
- The city's population remains following cessation of mining
- Some 25,000 residents live adjacent to the mine's waste piles, and many build their houses out of sun-dried bricks made with mine wastes
- Another 150,000+ residents live around the mining camp, and flooding has brought mine wastes into the main canal running through town
- See http://www.agiweb.org/geotimes/jan08/article.html?id=nn_

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Kabwe, Zambia

- Abundant lead carbonate, lead sulfate, zinc silicates
- Limited amounts of sulfides
- These supergene Pb-Zn deposits have been labeled by some as "environmentally friendly" due to their lack of acid-generating potential, however….

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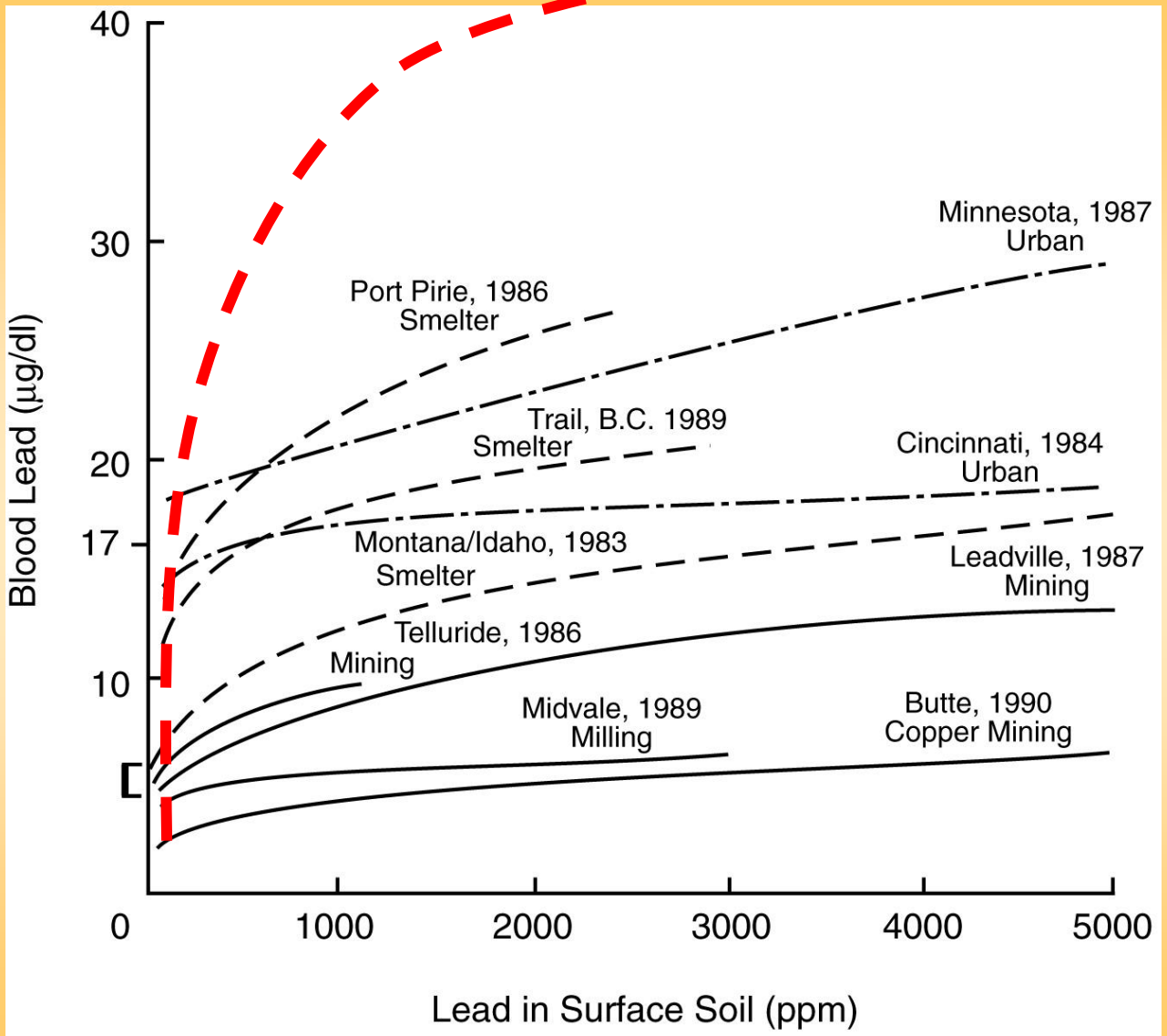
Estimated 30,000 Kabwe chilldren have severe lead poisoning, with many higher than 65 µg/dl



Kabwe? – speculative ….

Many different exposure pathways

Photo by Nebert Mulenga, IRIN

Many different exposure pathways

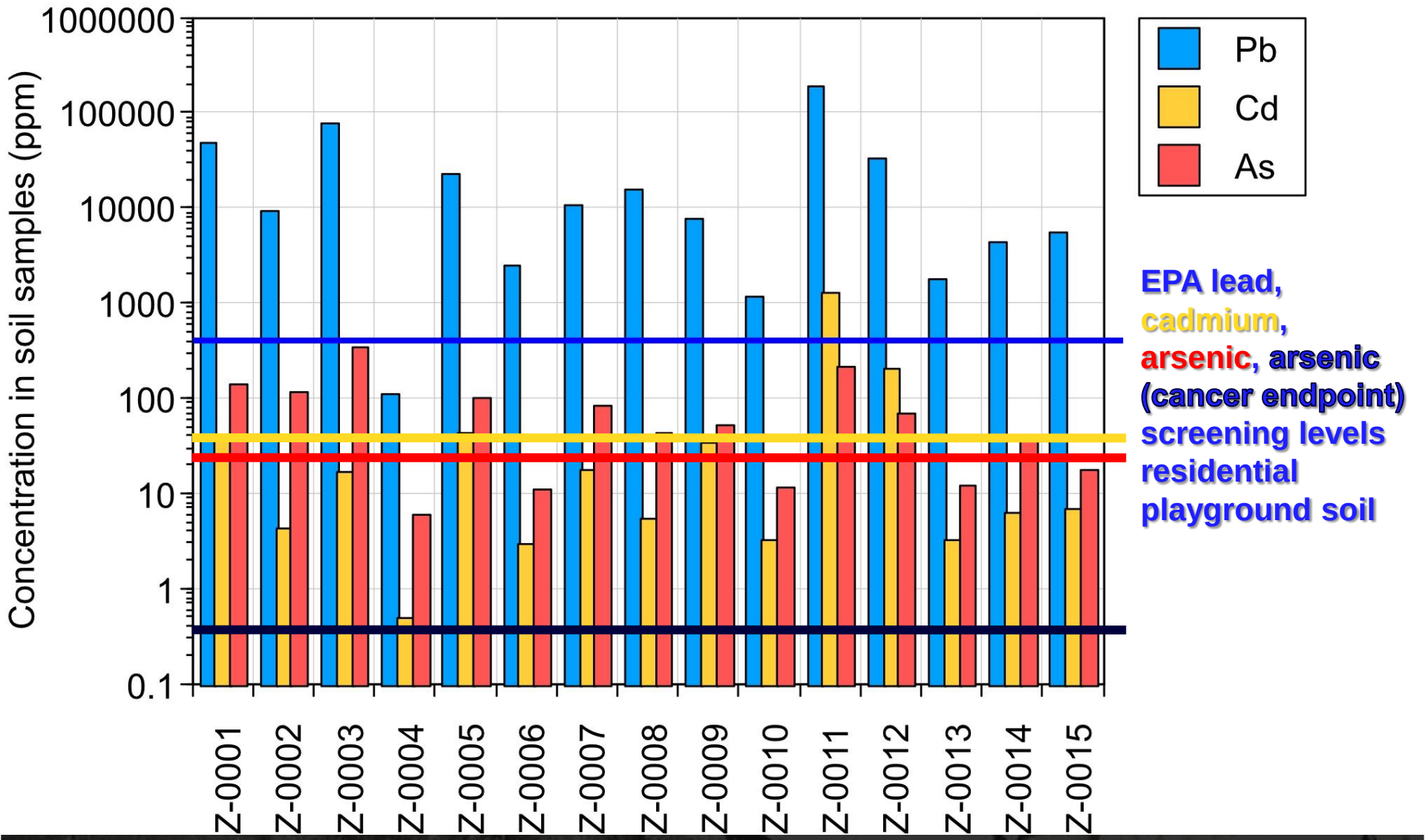
Photos from unpub. Water Management Consultants Report

“Edible” soils, consumed mainly by pregnant women

Photo from unpub. Water Management Consultants Report

Photograph 6.6 Soil being sold in Kabwe Main Market, showing typical size of lumps (100-150 g)

Lead, arsenic, and cadmium in Kabwe soils, mine wastes



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USGS unpub data

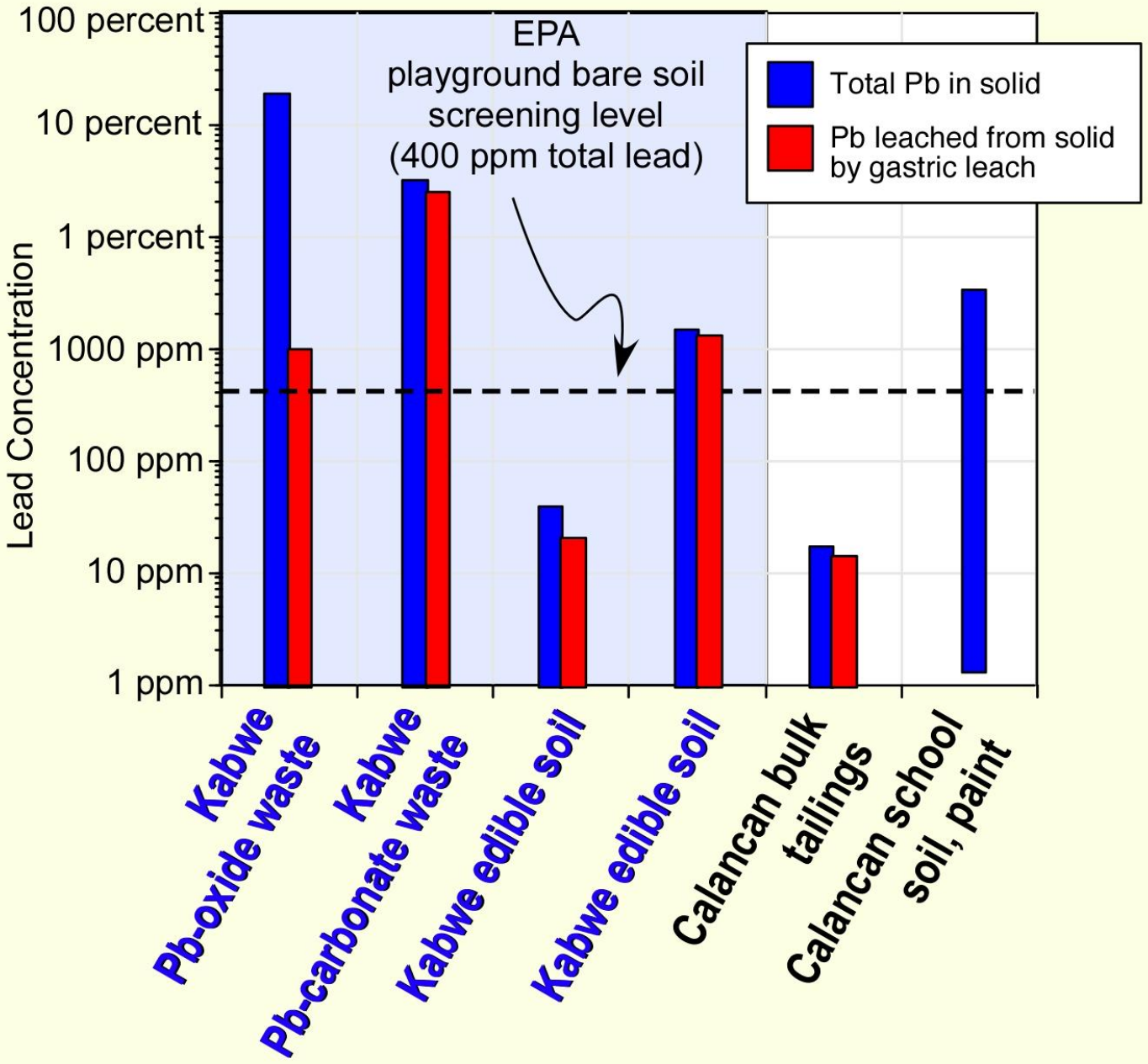
Simulated gastric fluid bioaccessibility tests of mine wastes

Plumlee et al., 2007, RIMG 64

SGF: 1.5 pH, HCl + glycine, Drexler and Brattin (2007) recipe

1 hour, 37°C

1:100 solid:liquid



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Windblown Dusts

Holden Mine, WA: US Forest Service photo, pre-remediation

http://www.fs.fed.us/r6/wenatchee/holden-mine/

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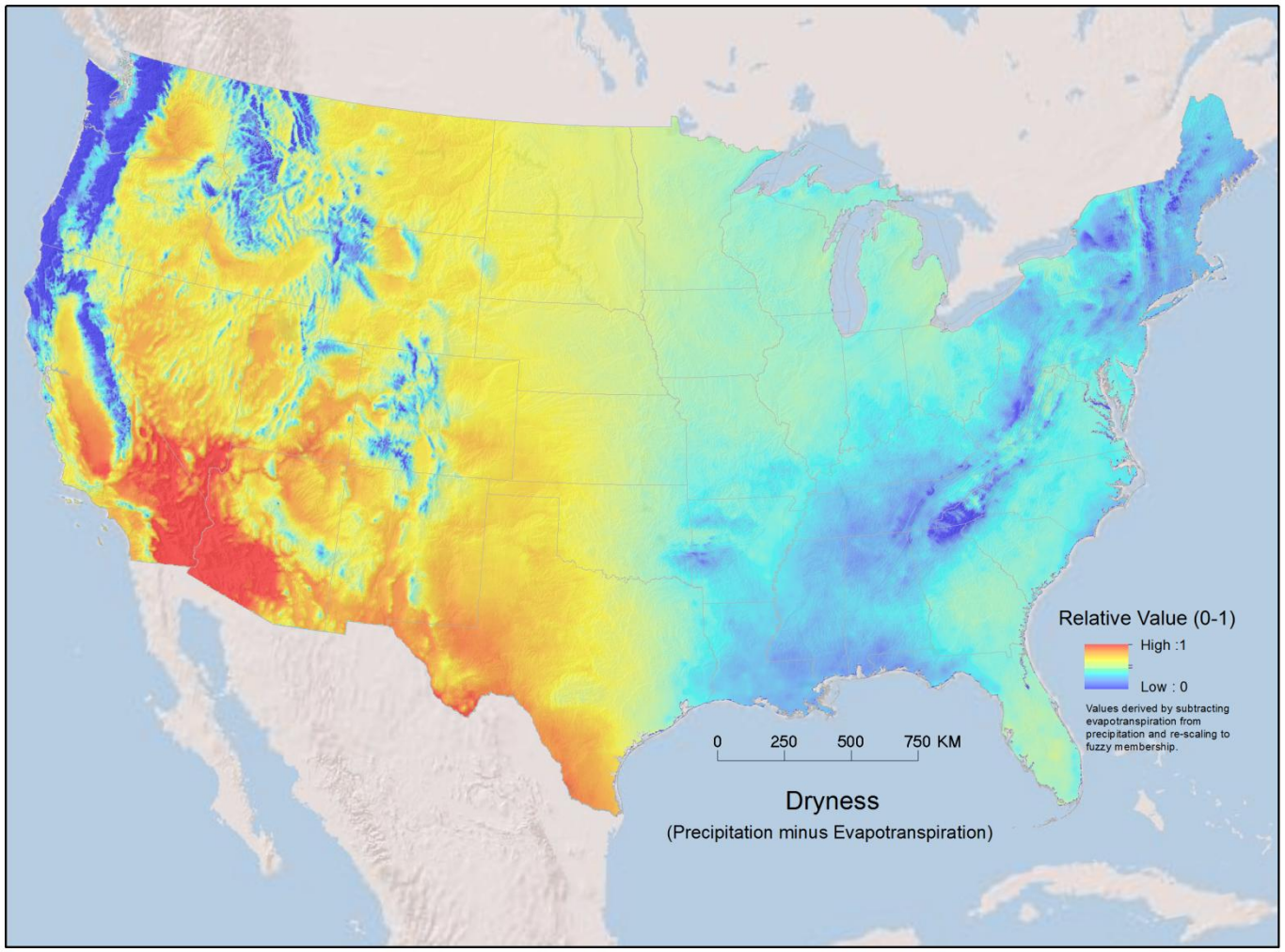
Humans & Windblown Dusts



- Throughout the United States, the ratio of evapotranspiration to precipitation varies greatly.

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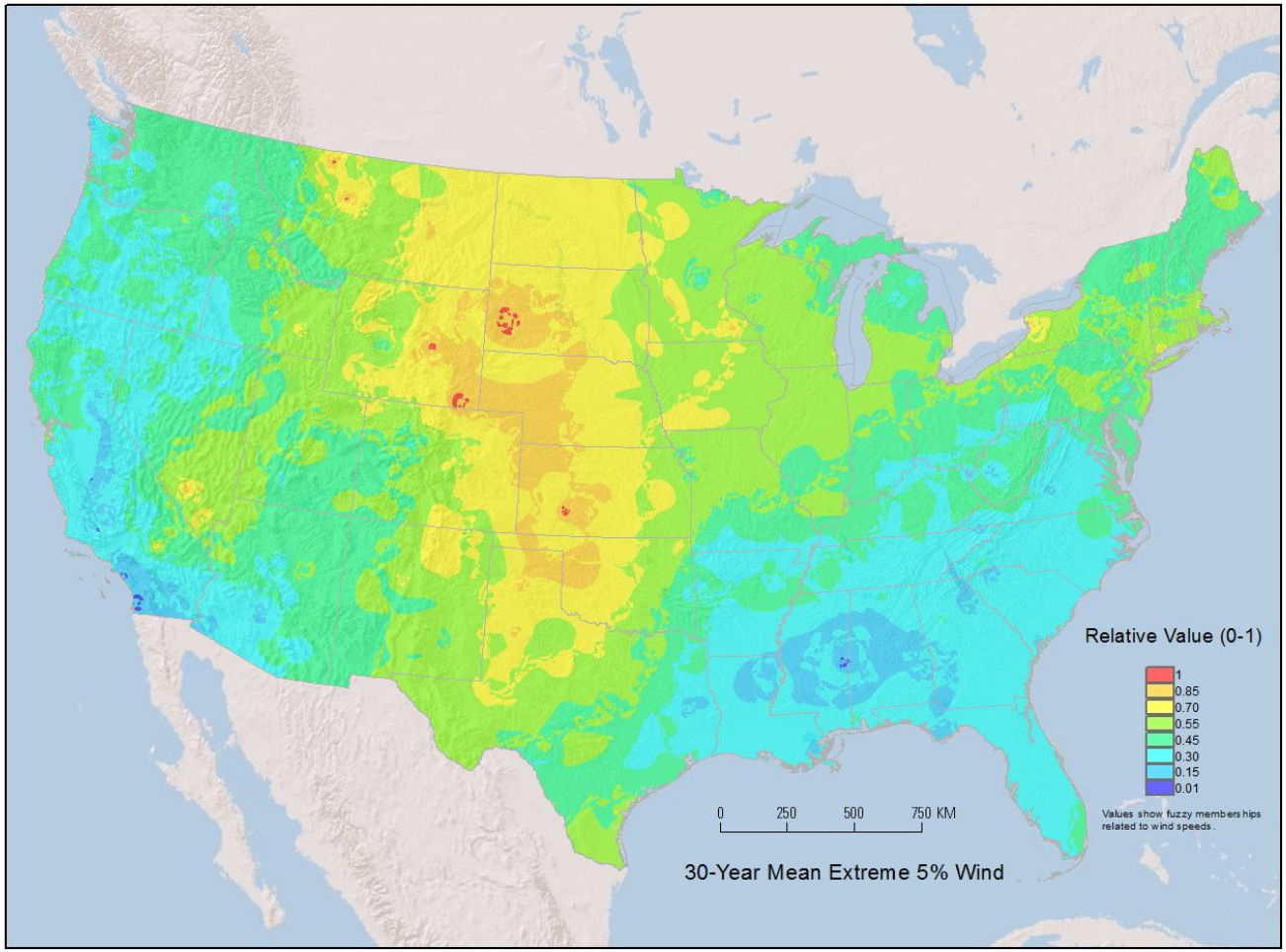
Humans & Windblown Dust Application



- Throughout the United States, the wind velocity also varies greatly.

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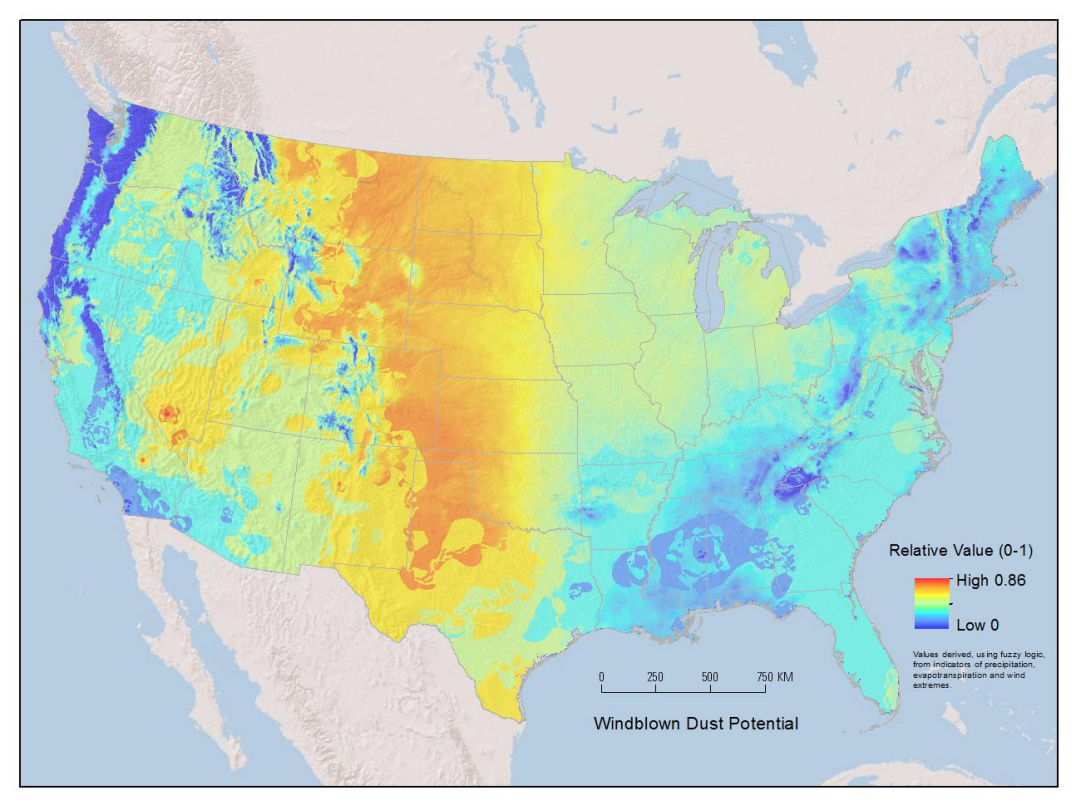
Humans & Windblown Dust Application



- The combination of evapotranspiration to precipitation and wind velocity may yield insights into high risk areas for windblown dusts.

Element	Human
Media	Residential Soil
Units	mg/kg
Al	77,000
As	23
Cd	70
Cr	280
Cu	3,100
Fe	55,000
Hg	6.7
Mn	1,800
Mo	390
Ni	1,600
Pb	400
Se	390
U	230
V	78
Zn	23,000

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The Medical Geology of Mineral Deposits

- Health issues clearly linked to or attributed to mining likely will continue, and increase in visibility
  - There are sites with well-documented, clear links
  - There are also sites where mining has been blamed but where clear links are tenuous
- Kabwe illustrates that potential environmental and health effects of mineral deposits, mining, and mineral processing must be examined holistically, not individually

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The Medical Geology of Mineral Deposits

Earth scientists working with health scientists to:

- Understand presence, form, abundance, size and morphology of potential toxicants in mineral deposits
- Understand potential biosolubility, bioaccessibility, bioreactivity of geologic materials in the body
- Identify deposit types that are more likely to have potential health impacts, so that the impacts can be anticipated and mitigated before they occur
- Assess potential exposure sources and pathways, both mining- and non mining-related
- Develop pre-mining health baseline assessments

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