WHEN BACKGROUND RISKS ARE IMPORTANT: METALS IN SOIL

Behrsing, T.; Davis, B.; Wade, M.; Eichelberger, J.
Department of Toxic Substances Control, CalEPA, Sacramento, CA, USA.

ABSTRACT

Naturally occurring metals in soils can be significant in risk assessment and risk management. USEPA has recommended including naturally occurring metals in risk assessments. Background issues are to be addressed in risk characterization, rather than in selecting chemicals of potential concern. This new approach presents a more thorough picture of risks and encourages transparency. However, it may generate confusion by reporting risks which will generally not be addressed in remediation because they stem from background. For some sites it is important to portray total risks from both anthropogenic and natural sources. Sites A, B, C, and D illustrate areas affected by mineralized soils, dredged material used to create land, drainage from mine tailings, or agricultural drainage. Site A was created by filling wetlands with sediments dredged from a bay. The sediments were impacted by drainage from mine tailings carried through a river system. Metal concentrations in original soils are generally much less than those detected in artificial fill soils. Arsenic (As) concentrations in original soils ranged from 2 to 21 mg/kg compared to 0.7 to 49 mg/kg in artificial fill. Manganese (Mn) ranged from 156 to 628 mg/kg in original soils and 27 to 13,559 mg/kg in artificial fill. Potential risks to human and ecological receptors from exposure to these fill soil metals can be significant. The cancer risk and hazard index (HI) for future residents are 6E-4 and 1.6 based on the 95th percentile As concentration, and 8E-4 and 2.2 assuming the maximum concentration. The Mn HI for future residents is 0.9 based on the 95th percentile and 7.5 based on the maximum. Ecological receptors may suffer harm from exposure to local background concentrations that are toxic. For example transport of fill material containing serpentine to areas where ecological receptors are adapted to lower metal concentrations can be deleterious. Addressing high risk estimates can be problematic through traditional remediation because of large areas. Awareness of the potential risk can suggest alternate mitigation measures such as land use restrictions.

INTRODUCTION

COMPARISON OF GUIDANCE ON METALS AND BACKGROUND				
GUIDANCE DOCUMENT	BACKGROUND EVALUATION METHOD	CHEMICAL OF POTENTIAL CONCERN SELECTION	RISK ASSESSMENT	RISK CHARACTERIZATION
USEPA 1989 Risk Assessment Guidance for Superfund	Sample areas not influenced by site contamination	Eliminate metal if consistent with background	Includes only selected metals	Includes only selected metals
DTSC 1997 Background Guidance	Pool all data and eliminate outliers representing contamination	Eliminate metal if consistent with background	Includes only selected metals	Includes only selected metals
USEPA 2002 Background Guidance	Sample areas not influenced by site contamination	Include metals irrespective of background	Includes metals irrespective of background	Identify site-related risk and background risk

Current U.S. EPA (2002) guidance recommends including metals, without regard to background, in risk assessments. Background issues are addressed during risk characterization rather than in COPC selection.

This newer approach presents a more thorough picture of risks, but may generate confusion by reporting risks from background which are not likely to be addressed during remediation.

This poster discusses examples of sites for which it is important to portray total risks from both anthropogenic and natural sources.

SITE A

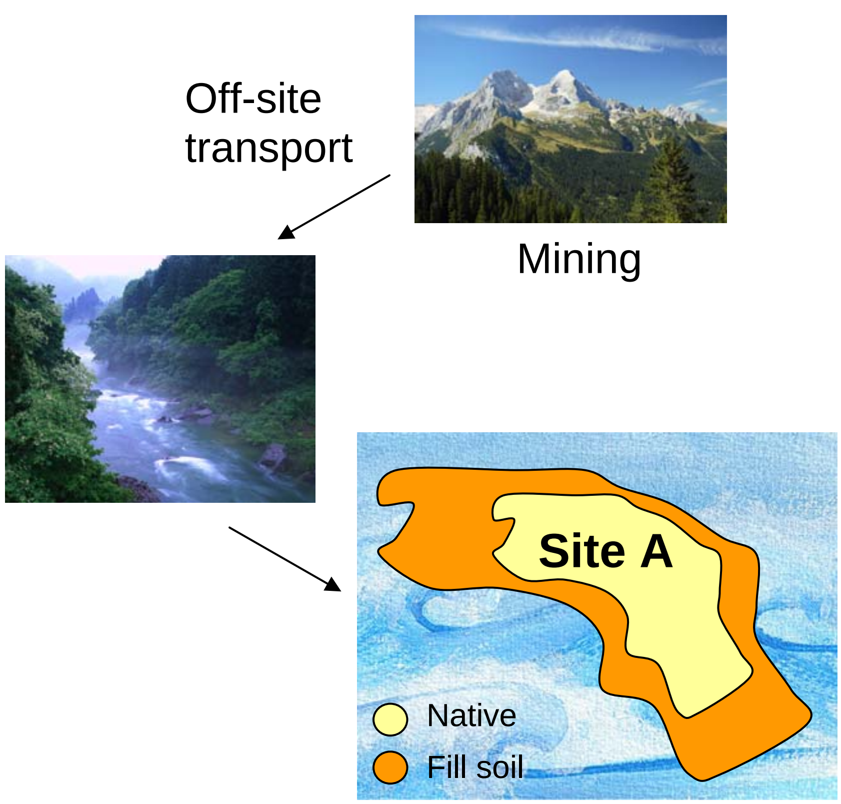
SITE: Natural island in California coastal area.

SOURCE OF METALS: Mining in the Sierra Nevada Mountains and dredging deposited silt.

HISTORY: Hydraulic extraction of gold in the mountains with mine tailings deposited in river systems.

> Transport of metal-rich silt in major surface water systems over long distances.
>
> Deposits of metal-rich silt in bays.
>
> Dredging of waterways to facilitate ship traffic, with dredge spoils deposited on the island wetlands.
>
> Transformation of the island into a peninsula, almost doubling the land area.

METALS CONCENTRATIONS: Examples of elevated metal concentrations and the potential human health concerns are shown in the following tables.



BACKGROUND CONCENTRATIONS AT SITE A IN MG/KG

METAL	SAMPLE NUMBER	DETECTED NUMBER	MINIMUM CONC.[2]	MAXIMUM CONC.[2]	MEAN CONC.[2]	PRG[3]
As – native soil[1]	30	28	2.1	21.1	8.2	0.062 (ca); 22 (nc)
As – fill soil[1]	363	322	0.7	48.8	13.4	0.062 (ca); 22 (nc)
Mn – native soil[1]	69	69	156	628.31	300.5	1,800 (nc)
Mn – fill soil[1]	3,123	3,123	27.1	13,559	707	1,800 (nc)

1. Native soil is soil found in original parts of the island. Artificial fill soil is soil found in parts of the island that were formed from hydraulic material dredged from the bay.
2. Outliers were removed from the upper and lower ends of distributions.
3. The PRG is the 2004 U.S. EPA Region 9 Preliminary Remediation Goal based on residential exposure to soil. The PRG units are mg/kg. The "ca" and "nc" designations are for cancer and noncancer endpoints, respectively.

CANCER RISK AND NONCANCER HAZARD FOR METALS IN FILL SOIL AT SITE A

		RISK[1]		HAZARD INDEX[1]	
METAL	CONCENTRATION	RESIDENTIAL	INDUSTRIAL	RESIDENTIAL	INDUSTRIAL
As	95TH PERCENTILE (36 MG/KG)	6E-04	1E-04	1.6	0.1
As	MAXIMUM (49 MG/KG)	8E-04	2E-04	2.2	0.2
Mn	95TH PERCENTILE (1,600 MG/KG)	N/A	N/A	0.9	0.1
Mn	MAXIMUM (13,559 MG/KG)	N/A	N/A	7.5	0.7

1. Screening-level risk and noncancer HIs were calculated using 2004 U.S. EPA Region 9 PRGs for residential and industrial soil. The residential soil PRGs are shown in the preceding table. The industrial soil PRGs for As are 0.25 and 260 mg/kg for cancer and noncancer, respectively. The industrial soil PRG for Mn is 1.9E4 mg/kg.

OBSERVATIONS ABOUT THE DATA FROM SITE A

1. Arsenic and manganese illustrate the striking potential for increased concentrations of metals in land that has been created from dredged hydraulic fill.

2. Arsenic is of particular concern for human health.

3. Although the mean concentrations of manganese in both native soil and fill soil are well below the safe level for human health, hot spots may greatly exceed safe levels.

4. High concentrations of arsenic, manganese and other metals can be of concern for ecological receptors as well.

5. Samples from fill soil also exhibit a much greater range of concentrations, compared to those from native soil. That is, minimum concentrations are less than minimums from native soil and maximums are greater than native soil maximums. This was a consistent feature for all metals.

IMPORTANT CONCLUSIONS ABOUT SITE A

1. These metal concentrations would be thought of as representing background, in that they are not impacted by ongoing industrial activities on the island.

2. However, the high concentrations result from two historical human activities.

   A. Mining for gold and other metals in the Sierra Nevada Mountains released mineral-rich material to the surface. This material was transported hundreds of miles by river systems and ultimately deposited in river deltas.

   B. Dredged material from the deltas and bays was used to enlarge the size of the island, thus bringing the high concentrations of metals to areas of contact for humans and for terrestrial plants and animals.

3. Risk assessment should evaluate and present potential risks and hazards from all sources, including “background” for situations such as Site A.

SITE B

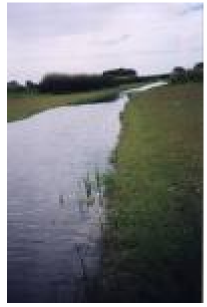


Photo credit: U.S. Fish and Wildlife Service, Sacramento, CA

SITE: Kesterson Reservoir in the San Luis National Wildlife Refuge, Central California.

SOURCE OF METALS: Beginning in 1979, agricultural drainage from the San Luis Drain brought selenium leached from soil to the Reservoir where it was concentrated by evaporation.

TOXICITY: Plants and animals were harmed by high levels of selenium. Most fish species disappeared; malformations and deaths resulted in birds; plant die-offs occurred. Algal blooms were common.

CONCLUSIONS: Although the extreme conditions at Kesterson Reservoir clearly resulted from human activities, selenium occurs naturally at elevated concentrations in many areas of the Western U.S. The distinction between “background” conditions and “site-related” conditions can be difficult to discern. Protection of the environment may require evaluating the potential for ecological harm, regardless of that distinction.

SELENIUM CONCENTRATION					
	Surface water[1]	Sediment, dry weight[1]	Aquatic insect tissue, dry wt.[1]	Mosquito fish tissue, dry wt.[1]	Marsh wren liver, dry wt.[2]
Reference Area[3]	4E-4 – 1E-3 mg/liter	ND - 0.5 mg/kg	1.1 – 3.0 mg/kg	1.1 -1.4 mg/kg	2.9 - 17 mg/kg
Kesterson Reservoir	0.08 - 0.32 mg/liter	1.8 - 23 mg/kg	24 -220 mg/kg	110 -280 mg/kg	67 - 100 mg/kg

1. Source: M Saki and Lowe T. 1987.
2. Source: H Ohlendorf et. al. 1990.
3. The reference area is near Kesterson Reservoir, but not impacted by agricultural drainage. It serves as a control.

SITE C

Photo credit: J. Michael Eichelberger

SITE: Power Plant located in urban, coastal California

SOURCE OF METALS: Natural deposits of nickel and chromium in soils and sediments from ultramafic serpentine rock.

HISTORY: Soil and rock used as fill for buildings and breakwater have resulted in high concentrations of metals, particularly nickel and chromium in soils and sediments.

ECOLOGICAL RISK ASSESSMENT: The existing terrestrial community has adapted to the high concentrations of metals in the soils. In contrast, the aquatic community was not exposed to such high levels before human activity introduced the naturally occurring soil and rock into the water. Nickel and chromium site sediment concentrations exceed their respective ERLs (Effects Range Lows) (20.9 mg/kg; 81 mg/kg) by 21 times and 3 times, suggesting a potential hazard to benthic organisms.

HUMAN HEALTH RISK ASSESSMENT: These high concentrations of metals may be of concern for human health from direct and indirect soil exposure pathways and from indirect sediment exposure pathways (consumption of seafood).

CONCLUSIONS: Risk assessment for this site views metals in soil differently for human receptors than for ecological receptors because the latter have adapted to the soil conditions. High sediment concentrations of metals may pose hazards to both receptor types. Although the source of metals is natural rocks and soil, they have been transported to another location where they could be harmful to a different habitat.

CONCENTRATIONS OF NICKEL AND CHROMIUM (mg/kg)							
BACKGROUND SOILS				**SITE SOILS**			
Ni UCL[1]	Ni C_{max}[2]	Cr UCL[1]	Cr C_{max}[2]	Ni UCL[1]	Ni C_{max}[2]	Cr UCL[1]	Cr C_{max}[2]
1,929	2,107	566	666	1,668	2,098	622	1,017
BACKGROUND SEDIMENTS				**SITE SEDIMENTS**			
Ni UCL[1]	Ni C_{max}[2]	Cr UCL[1]	Cr C_{max}[2]	Ni UCL[1]	Ni C_{max}[2]	Cr UCL[1]	Cr C_{max}[2]
138	197	121	145	439	717	251	424

1. "UCL" – the 95% upper confidence limit on the arithmetic mean.
2. "C_{max}" – the maximum concentration in the sample population.

SITE D

Photo credit: J. Michael Eichelberger

SITE: Housing development in the Sierra Nevada foothills in California.

SOURCE: High concentrations of arsenic in soils containing gold

HISTORY: Refining and extraction of gold at the site from 1890 – 1958. Residential development occurred on land containing mine tailings with high arsenic levels.

Development allowed because of assumption that arsenic was complexed with iron as arsenopyrite (FeAsS) and thus not bioavailable.

After houses were built and occupied (43 lots on 13 acres), it was found that arsenic in the soil is bioavailable (14% in one study).

ARSENIC CONCENTRATIONS:

Soil levels of arsenic were as high as 1,320 mg/kg.

Dust samples from 14 homes were collected and arsenic concentrations ranged from 5 to 278 mg/kg, with a mean of 55 mg/kg.

TOXICITY:

Arsenic is classified as a known human carcinogen. A risk assessment performed by the CA Dept. of Toxic Substances Control showed a high potential cancer risk (3E-3) and hazard index (19) from arsenic at this site.

Two construction workers at the site exhibited skin anomalies that were consistent with dermal exposure to arsenic.

CONCLUSIONS: High concentrations of arsenic in soil at this residential area are clearly related to human activities. The distinction between “background” conditions and “site-related” conditions is ambiguous. Protection of residents and workers obviously necessitates risk assessment and appropriate risk management. A cap of clean soil was used to prevent exposure to arsenic in the existing soil.

GENERAL CONCLUSIONS

Background metals can be major contributors for potential risks to human and ecological receptors. Example sites illustrate mineralized soils, dredged material used to create land, drainage from mine tailings, and agricultural drainage.

Human activities can obscure the distinction between "background" conditions and "site-related" conditions.

Elimination of background metals during selection of Chemicals of Potential Concern results in the loss of information about such potential risks in the risk assessment. This may be inadequate for decision-making by risk managers and the public.

Ecological risk assessment may evaluate high concentrations of metals differently than human health risk assessment. As illustrated by Site C, ecological communities are adapted to local conditions including any elevated levels of metals. However, when such elevated levels are transported to other locations (Site B and Site C), they may become a concern.

High concentrations of metals cannot be remediated in traditional ways over large areas. Risk management steps to address risk from background metals can include excavation of soil, use of clean soil to cover the contamination, or land use restrictions.

REFERENCES

Department of Toxic Substances Control. 1997. Selecting Inorganics as Chemicals of Potential Concern at Risk Assessments at Hazardous Waste Sites and Permitted Facilities. http://www.dtsc.ca.gov/AssessingRisk/upload/backgrnd.pdf

H Ohlendorf et. al., 1990. Bioaccumulation of Selenium in Birds at Kesterson Reservoir, Archives of Environmental Contamination and Toxicology 19, 495- 507.

M Saki and Lowe T. 1987. Selenium in Aquatic Organisms From Subsurface Agricultural Drainage Water San Joaquin Valley, California, Archives of Environmental Contamination and Toxicology 16, 657-670.

US Environmental Protection Agency. 1989. Risk Assessment Guidance for Superfund. http://www.epa.gov/oswer/riskassessment/ragsa/index.htm

US Environmental Protection Agency. 2002. Role of Background in CERCLA Cleanup Program. http://www.epa.gov/oswer/riskassessment/pdf/role.pdf

DISCLAIMER

Professional affiliations are listed for contact purposes only. Analysis and conclusions contained herein are solely those of the authors and do not represent guidance or official policy of the California Department of Toxic Substances Control or California Environmental Protection Agency.