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## **Unique Aspects of Metals and Inorganic Metal Compounds in Environmental and Human Health Risk Assessments**

Submitted by: Australia



**APEC**  
PHILIPPINES  
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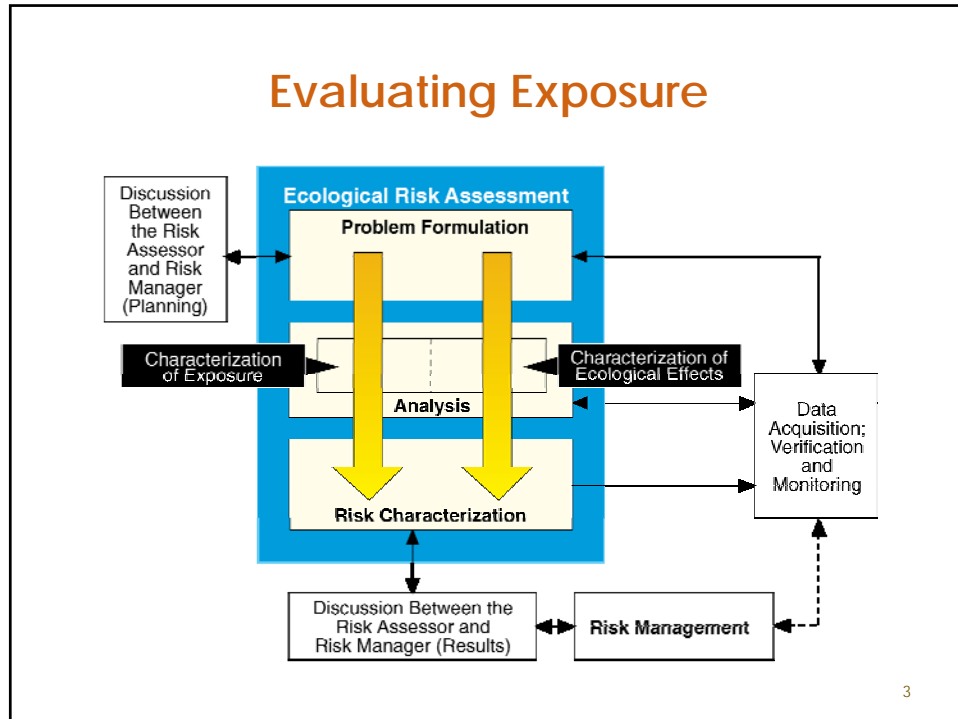
# Unique Aspects of Metals and Inorganic Metal Compounds in Environmental and Human Health Risk Assessments

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## Topics Discussed

- Overview of risk assessment process
- Key principles to consider in the assessment metals
- Environmental chemistry
- Use of bioaccumulation factors (BCF/BAF)
- Human health issues
- Ecological issues





## Risk Assessment Phases

- **Planning and scoping:** Purpose and range of the assessment; Public, stakeholder and community involvement
- **Problem formulation (PF):** An important outcome of PF is a conceptual model that describes the linkages between stressors and adverse human or ecological effects, including the stressor(s), exposure pathway(s), exposed lifestage(s) and population(s), and endpoint(s) that will be addressed in the risk assessment. Based on the conceptual model, an analysis plan is developed, which describes the approach for conducting the risk assessment.

## Risk Assessment Phases *(continued)*

- **Exposure and effects assessment:**  
Exposure assessment measures or estimates pathways and life stages, identified in PF. Effects assessment includes hazard identification and dose-response assessment. Susceptible or more highly exposed populations are identified.
- **Risk characterization:**  
Exposure and effects assessments are integrated to provides risk estimates and conclusions about the risk

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## Risk Assessment Phases *(continued)*

- **Public, stakeholder and community involvement:**  
Input from the public is sought and considered at various stages throughout the process
- **Informing decisions:**  
The description of the decision should clarify how the risk assessment and other factors informed the decision

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## Principles for Risk Assessment of Metals (US EPA, 2007)

- Metals are naturally occurring constituents in the environment and vary in concentrations across geographic regions
- All environmental media have naturally occurring mixtures of metals, and metals often are introduced into the environment as mixtures
- Some metals are essential for maintaining proper health of humans, animals, plants, and microorganisms



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## Principles for Risk Assessment of Metals *(continued)*

- Unlike organic chemicals, metals are neither created nor destroyed by biological or chemical processes
  - They can transform from one chemical species to another (valence states) and can convert between inorganic and organic forms
- The absorption, distribution, transformation, and excretion of a metal (toxicokinetics) within an organism depends on:
  - The metal
  - The form of the metal or metal compound
  - The organism's ability to regulate and/or store the metal

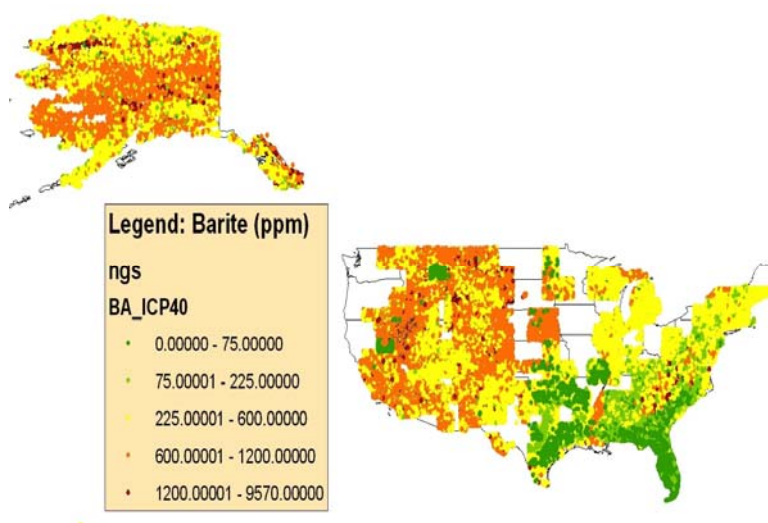
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## Ambient Background

- **Background levels** refers to those concentrations of metals that derive from natural as well as anthropogenic sources that are not the focus of the risk assessment
  - Metal concentrations vary widely over space and time owing to differences in geology, hydrology, anthropogenic and natural loads from “nontarget” sources, and other factors
- It is recommended that, when appropriate, regional- or national- level ecological risk assessments be subdivided into metal-related ecoregions, referred to as metalloregions (McLaughlin and Smolders, 2001)

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## Natural Occurrence of Barite (USGS)



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## Mixtures of Metals

- **Metals can interact in ways that can affect toxicity**
  - Independent  $1 = 1$
  - Additive  $2+2 = 4$
  - Antagonistic  $2+2 = 2$
  - Synergistic  $2+2 = 20$
- **Interactions among metals within organisms may occur when they compete for binding locations on specific enzymes or receptors during the processes of absorption, excretion, or sequestration, or at the target site**

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## Essential Metals

- **Essential metals include for:**
  - Human health: Fe, Zn, Cu, Mn, Cr, Mo, Se
  - Ecological: Fe, Zn, Cu, Mg, Ni, Mo (partial list)
- **Essentiality should be viewed as part of the overall dose-response relationship for those metals shown to be essential**
- **Reference Doses (RfDs) or toxicity thresholds should not be below the Required Daily Amount (RDAs)**

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## EPA Integrated Risk Information System: Example for Zinc

- In establishing an RfD for zinc, the data on essentiality were combined with the data on toxicity to define a level that would meet physiological requirements without causing toxic responses when consumed daily for a lifetime
- The exposure values that were considered in determining the RfD suggest that there is only one order of magnitude between the minimum amount of zinc that will maintain physiological function (5.5 mg/day) and the amount associated with appearance of potentially adverse effects (60 mg/day)

Source: <http://www.epa.gov/iris/subst/0426.htm#docoral>

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## Additional Issues

- Environmental chemistry
- Limited use of bioaccumulation factors (BAF/BCF)
- Incorporation of bioavailability
- Human health
- Ecological
- Secondary poisoning





## Environmental Chemistry

- Metal speciation affects metal behavior in environmental media
- pH and redox potential affect speciation
- $K_d$  values—a coefficient for mobility in soils
  - Limited use of single values
- Metal sorption behavior affects bioavailability
- Aging of metals in media reduces bioavailability



## Qualitative Bioavailability of Metal Cations in Natural Soils to Plants and Soil Invertebrates

Soil pH	Soil Organic Matter		
	Low organic matter (<2%)	Medium organic matter (2 to 6%)	High organic matter (6 to 10%)
4 < Soil pH < 5.5	Very high	High	Medium
5.5 < Soil pH < 7	High	Medium	Low
7 < Soil pH < 8.5	Medium	Low	Very low

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## Bioaccumulation Factor and Bioconcentration Factor (BAF/BCF) Issues

- Certain metal compounds are known to bioaccumulate in tissues and this bioaccumulation can be related to their toxicity
- BCFs for metals vary with species, environmental conditions, generally show an inverse relationship with media concentration, and are not a predictor of toxicity



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## BAF/BCF Issues *(continued)*

- For soil invertebrates and most plants, metal BAFs are typically less than 1 and usually are based on the total metal in soil and tissue that do not account for bioavailability differences
- The latest scientific data on bioaccumulation do not currently support the use of single bioconcentration factor (BCF) or bioaccumulation factor (BAF) values when applied as generic threshold criteria for the hazard potential of inorganic metals



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## Bioavailability Issues

- Bioavailability of metals and the associated risk vary widely according to the physical, chemical, and biological conditions under which an organism is exposed
- Bioavailability should be explicitly incorporated into all risk assessments
- Where data or models are insufficient, assumptions should be clearly articulated

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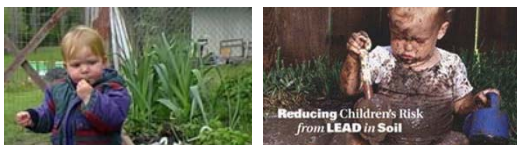
## Human Health Issues

- The organ or tissue in which metal toxicity occurs may differ from the organ or tissue(s) in which the metal bioaccumulates and may be affected by the metal's kinetics
  - Target organs may differ by species, mainly owing to differences in absorption, distribution, and excretion
- Both the exposure route and the form of a metal can affect the metal's carcinogenic potential and its noncancer effects
- Sensitivity to metals varies with age, sex, pregnancy status, nutritional status, and genetics

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## Human Health Issues *(continued)*

- **Bioavailability**—critical factor in determining the uptake of contaminants;
- Risk assessments used to determine whether a contaminated site poses a current or future threat to human health that warrants remedial action
- **At contaminated sites, oral ingestion of soil and dust can be a “risk driver” for human exposure to metal contaminants**



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## Human Health Issues *(continued)*

- **Metals attached to small airborne particles are of primary importance for inhalation exposures**
- **Adverse nutritional effects can occur if essential metals are not available in sufficient amounts**
  - Increases the vulnerability of humans to other stressors, including those associated with other metals
- **Because the diets of people are diverse, there may be wide variability in the dietary intake of some metals (e.g., in seafood)**
  - Results in temporal, geographic or cultural variability of responses

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## Ecological Issues

- Ambient background levels refers to those concentrations of metals that derive from natural as well as diffuse anthropogenic sources that are not the focus of the risk assessment
- For aquatic organisms, routes of exposure include absorption across (or in some cases adsorption to) respiratory organs, dermal absorption, sediment ingestion, and food ingestion
- For terrestrial organisms, routes of exposure include binding to roots, foliar uptake, food, water, and soil ingestion, or inhalation



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## Ecological Toxicity

- For most cationic metals, the free ionic form is most responsible for toxicity
- Free-ion activity models are useful for establishing relative toxicity among metals in different media
  - BLM: EPA Water Quality Criteria
- Sediment toxicity is reduced by acid volatile sulfides, organic carbon and other factors that bind free ions and decrease bioavailability
- Soil toxicity is affected primarily by pH and cation exchange capacity (CEC)
- Al and Fe: Metal complexes in soil versus toxicity tests as soluble metal salts

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## Secondary Poisoning

- **Inorganic metal compounds rarely biomagnify across three or more trophic levels**
- **Soil: Plant barrier issues (Chaney, 1980; Chaney et al., 2000)**
  - Can assume that most plant species do not bioconcentrate metals (i.e., BCF < 1)
  - Some metals, such as, Pb, Cr, and Co are not taken up by plants in measurable quantities
- **Wildlife**
  - Incidental soil ingestion is a proportionally more important pathway for herbivores than for carnivores or invertivores

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## Workshop Approach

- **Ecological topics**
  - Aquatic
  - Terrestrial
- **Human health topics**
  - Risk assessment
  - Exposure pathways
  - Bioavailability—two talks
- **Regulatory topics**
- **Criteria and standards discussions**
- **Survey on additional topics for training**

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