Practical Tools for Dealing with Bioavailability in Soil Standard Setting

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Risk Assessment Fundamentals

- **The Risk Characterisation Ratio (RCR) is the ratio of the predicted (or measured) environmental concentration (PEC) divided by the predicted no effect concentration (PNEC)**

$$RCR = \frac{PEC}{PNEC}$$

Risk Assessment Fundamentals

- The Predicted Environmental Concentration (PEC) can be a predicted concentration in soil given assumptions on addition rate (for new contamination), or a measured concentration (at historically contaminated sites)
- The Predicted No Effect Concentration (PNEC) is derived from ecotoxicity data, usually from the literature
- An acceptable Risk Characterisation Ratio is dependent on policy of the country in question – generally a value of 1.0 is regarded as the threshold

Issues for risk assessment of metals/metalloids in soil

- Background concentrations in soil
- Soil bioavailability effects
- Soil organism sensitivity
- Differences between toxicity in the laboratory and in the field

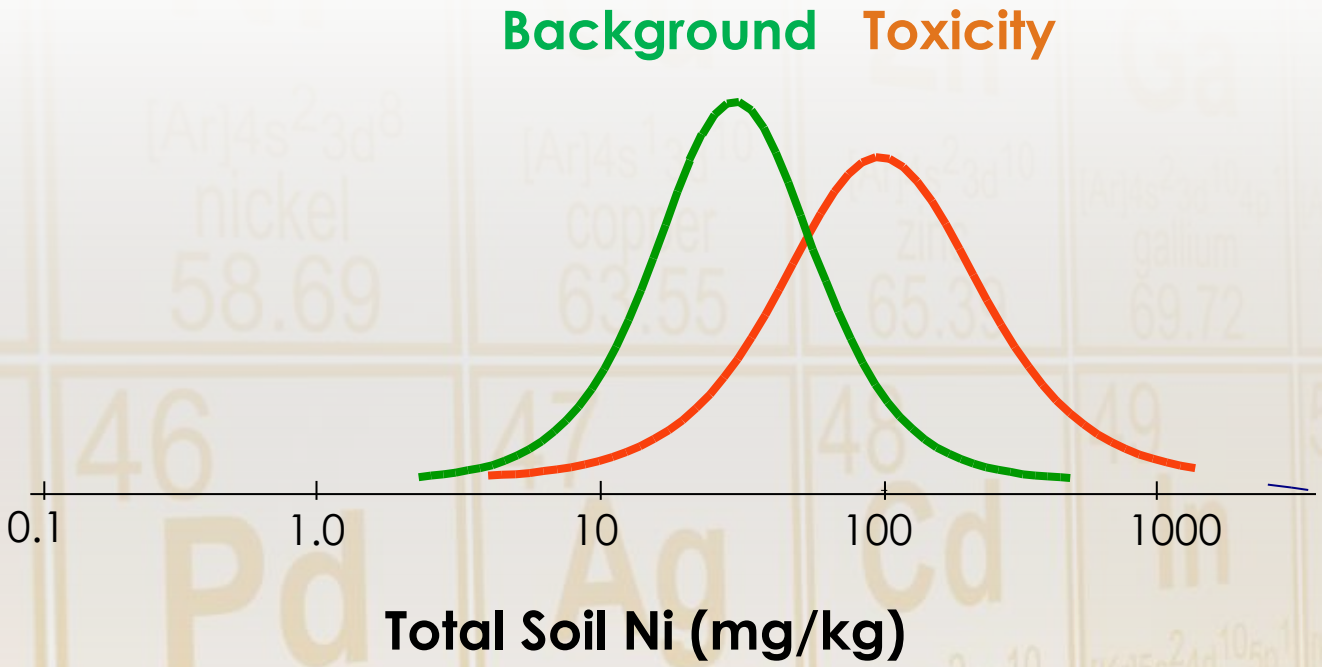
How should background concentrations be accounted for?

- **Metals occur naturally in soils**
- **For example: Red soils - Ferrosols or Oxisols - naturally contain 100–400 mg/kg Cr and 100–300 mg/kg Ni**
- **Ecosystems on these soils are adapted to these naturally occurring concentrations**

Source: http://soer.justice.tas.gov.au

Dealing with Ambient Background

- **Dealing with ambient background concentrations is difficult**



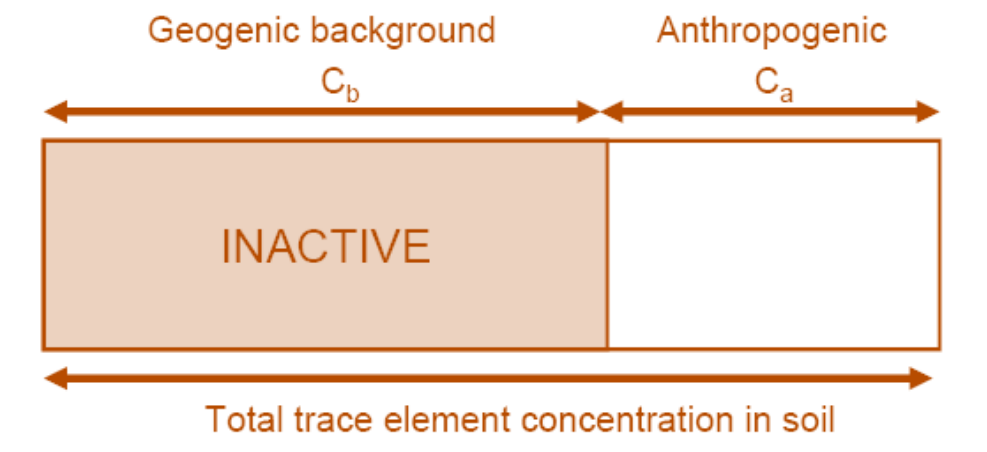
Where is the PEC and PNEC?

Dealing with Ambient Background

- **We can separate the total concentration of metal/ metalloid in soil into 2 portions**

    1. **Ambient background (geogenic)**
    2. **Added by man (anthropogenic)**

- **We assume geogenic metals are not harmful to ecosystems as the organisms have adapted to these concentrations**
- **There are various methods to estimate 'background" levels**



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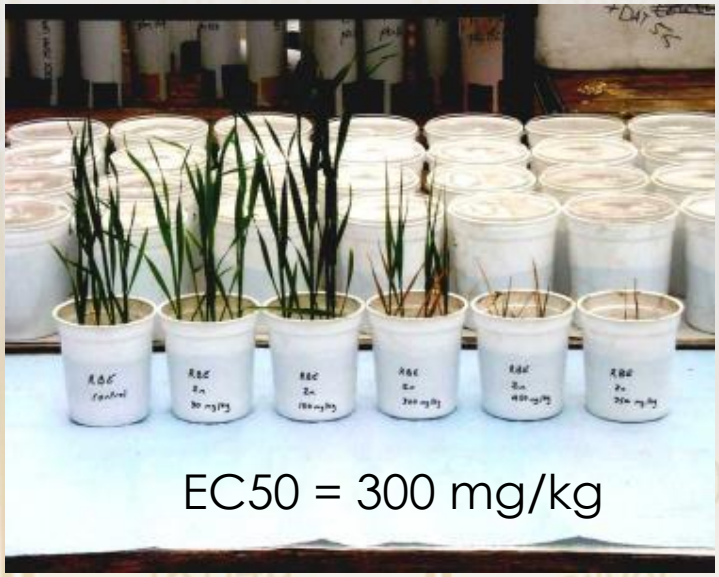
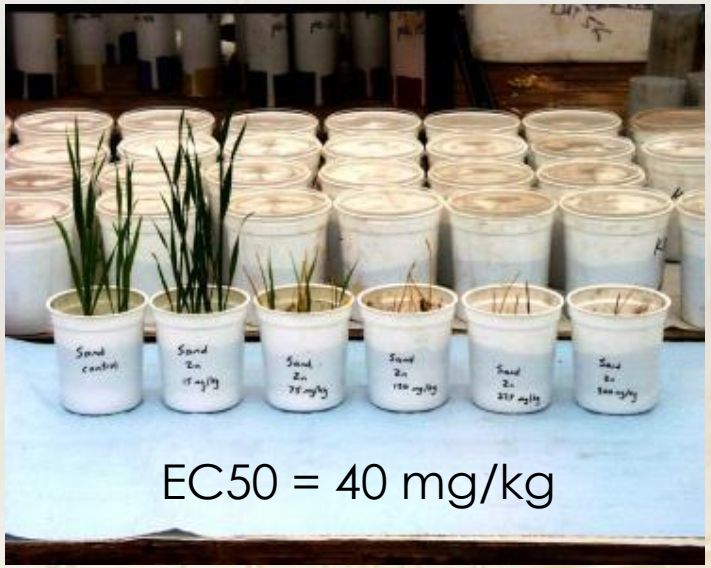
Soil bioavailability effects for added metals/metalloids

- **Metals/metalloids added to soil will interact with clay minerals and organic matter in the soil (remember all soils have charged surfaces, mostly negative charge)**
- **Some added metals may also form precipitates in soil with common soil elements e.g. lead (Pb) precipitates with soil phosphate (PO_4)**
- **These reactions generally reduce metal/metalloid solubility and hence toxicity**

Soil bioavailability effects for added metals/metalloids

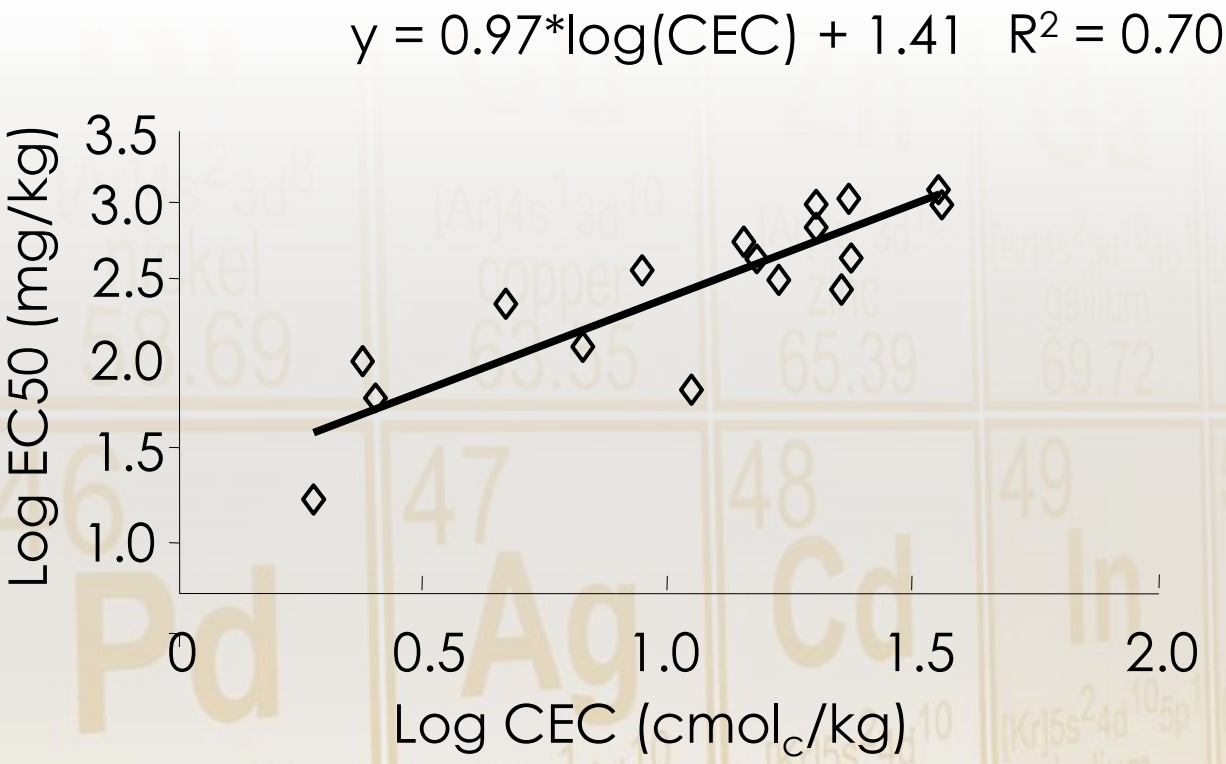
- **Toxicity therefore depends on this interaction with the soil surfaces**
- **Contamination levels protective in a alkaline clay soil would be toxic in an acidic sand**





Accounting for soil bioavailability effects

Normalisation relationships are relationships between toxicity and soil physico-chemical properties (e.g. organic carbon, pH, cation exchange capacity (CEC))



Rooney et al. (2006) *Environmental Toxicology and Chemistry* **25,** 726-732.

CEC = a measure of the magnitude of the negative charge in a soil

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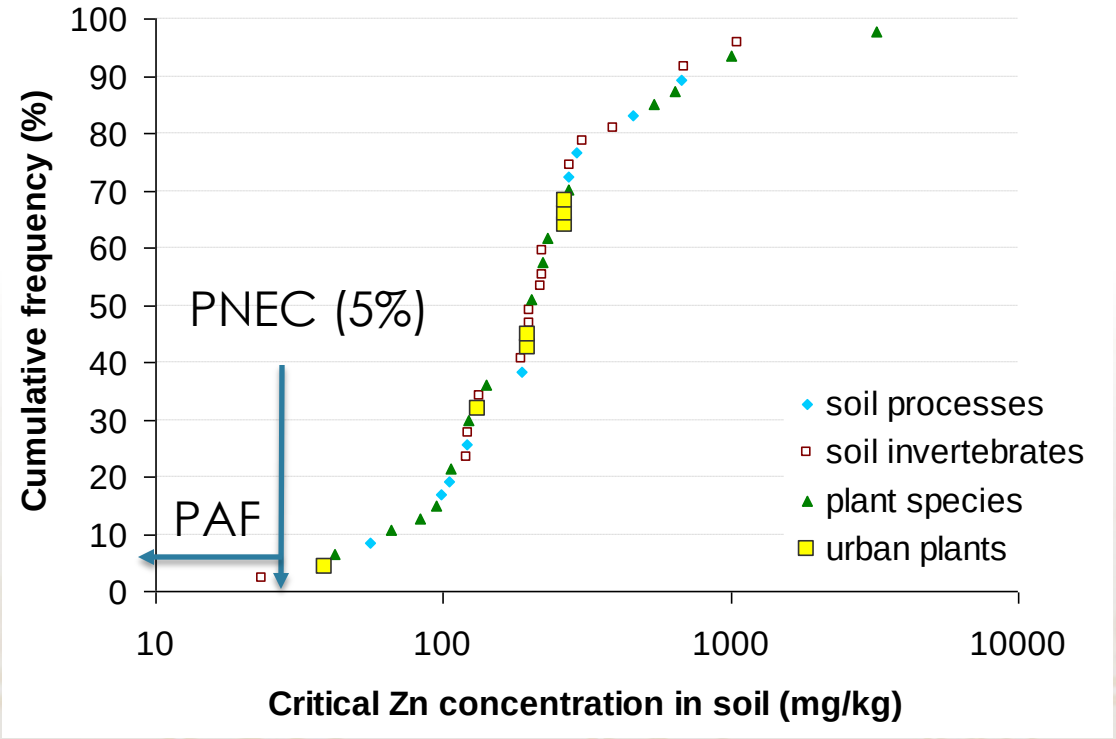
Organism sensitivity to metals/metalloids

- Some organisms are sensitive to small increases in concentration of metals/metalloids in soil, others are tolerant
- We need to ensure we protect sensitive species, especially if these are involved in keystone soil processes e.g. soil nitrogen cycling
- Species sensitivity distributions (SSDs) are used to describe this variation in toxicity for each metal/metalloid and a sensitive trigger value chosen
- Soil concentrations used in the SSD are generally corrected for bioavailability so that only species sensitivity is assessed

Accounting for organism sensitivity



Each species is given equal weight – so one data point per species in SSDs

PNEC=Predicted No Effect Concentration
PAF = Potentially Affected Fraction (assume = 5%, i.e. 95% protection)

- Data need to be screened for quality and relevance before constructing the SSD
- If insufficient toxicity data in the literature to develop a SSD, assessment factors are used

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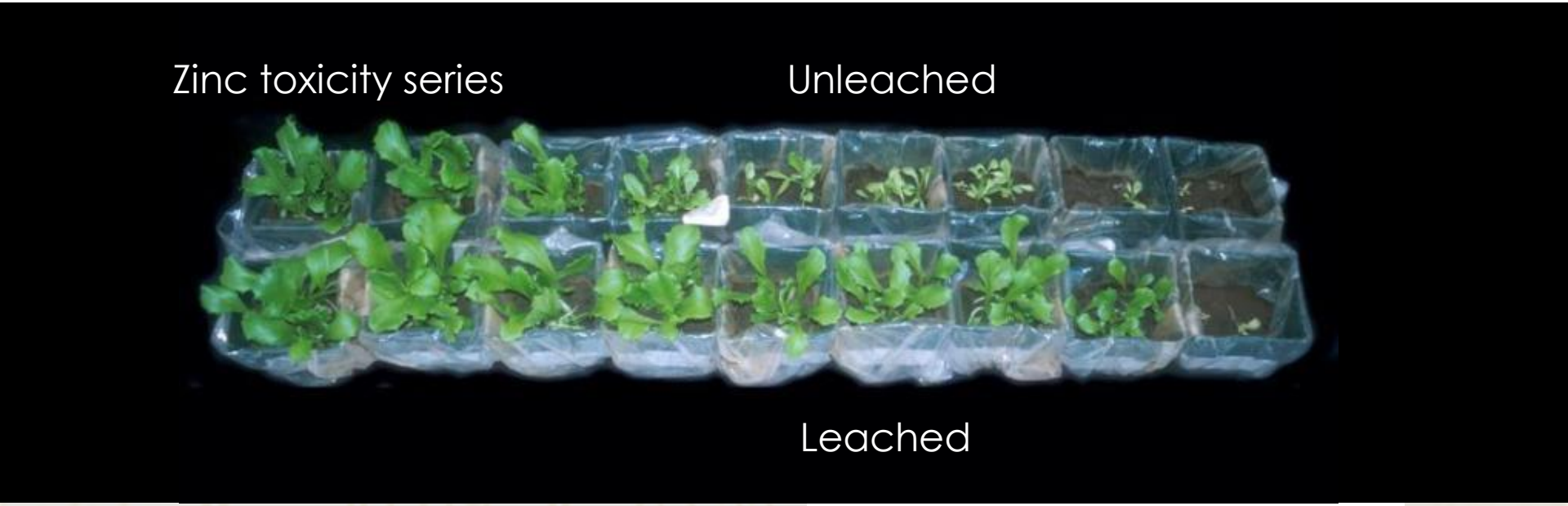
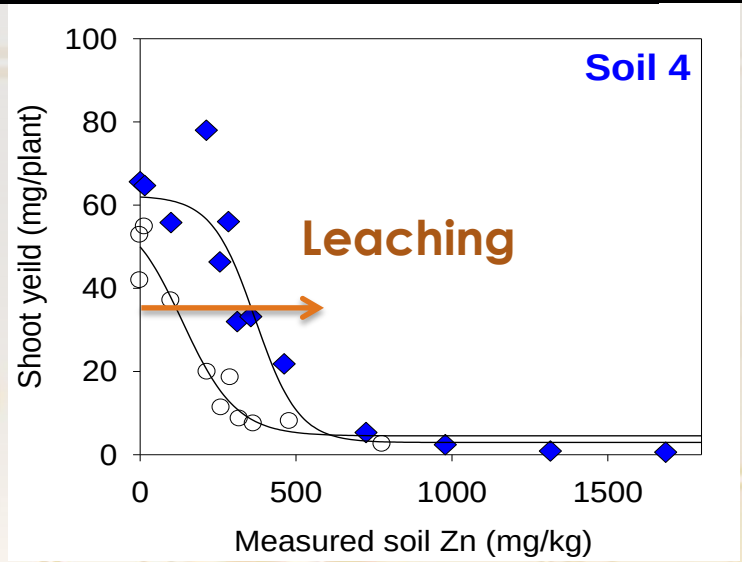
Laboratory Artifacts: Salt Effects (Leaching)





Source: Stevens DP et al. (2003).

Laboratory Artifacts: Ageing

Source: Smolders et al. (2004).

Leaching/Aging Factors

- Both salt (leaching) and time (aging) effects must be considered when using short-term toxicity data derived from spiking soil with soluble metal salts
- Leaching/Aging Factors have been developed for several metals from EU REACH research programs
- These Leaching/Aging Factors are used to convert laboratory toxicity thresholds to more field-relevant thresholds

Seems Complex?

- Simple Excel-based calculators have been developed to include all the above factors for data-rich metals
  EU - http://www.arche-consulting.be/en/our-tools/soil-pnec-calculator/

  Australia - http://www.scew.gov.au/node/941
- These have quality screened ecotoxicity data, incorporate SSDs and soil normalisation relationships to develop Soil Quality Standards
- 2 case studies will be examined using one of these Excel tools

Case Study 1

- A waste material is proposed to be used in your country as a soil amendment and it contains 500 mg/kg zinc (Zn)
- At recommended rates of application the product is expected to increase Zn concentrations in agricultural soils by +80.0 mg Zn/kg in the next 200 years
- Background Zn concentrations in your soils are ~40 mg Zn/kg
- Will this pose an ecological risk to soil organisms or plants, and which soils are most susceptible?

Case Study 1

- **Need to think about soils in your jurisdiction in terms of**

  a) background Zn concentrations
  b) soil pH and organic matter content (or CEC)

- **Assume a background Zn concentration of 40 mg Zn/kg in your jurisdiction**

- **Assume the 5th percentile of soil pH in your country is 5.0, clay content of 5% and organic matter is 1.0% C (i.e. a sensitive soil scenario with high bioavailability, therefore protective of most soils)**

Use PNEC calculator

Case Study 2

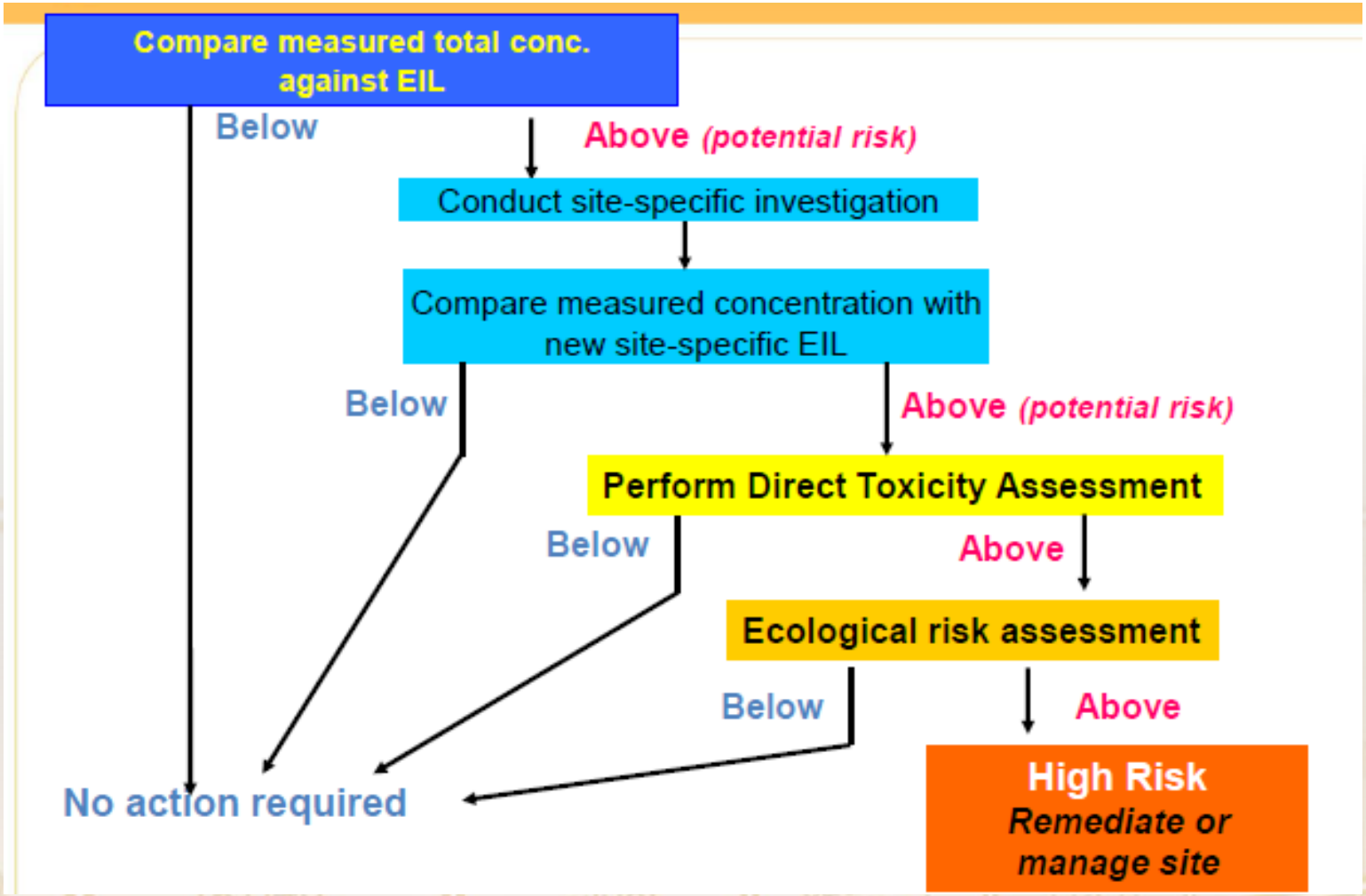
- A large copper smelter has closed and the area downwind of the smelter has elevated soil Cu concentrations (above background), with total concentrations in soil varying from 110 to 230 mg/kg
- Background concentrations of Cu in the soils however are also high, varying from 100 to 180 mg/kg
- The soils have a high clay content (30-45%) and are neutral in pH (6.5-7.5) with an organic matter content of 4%

Case Study 2

- Total Cu concentrations up to 230 mg/kg
- Background concentrations of Cu in the soils are 100 (lower limit)
- The soils have a high clay content (~45%) and are neutral in pH (7.0)
- Assume an organic matter content of 4.0%

→ Use PNEC calculator

Remember Soil Quality Standards are screening values!



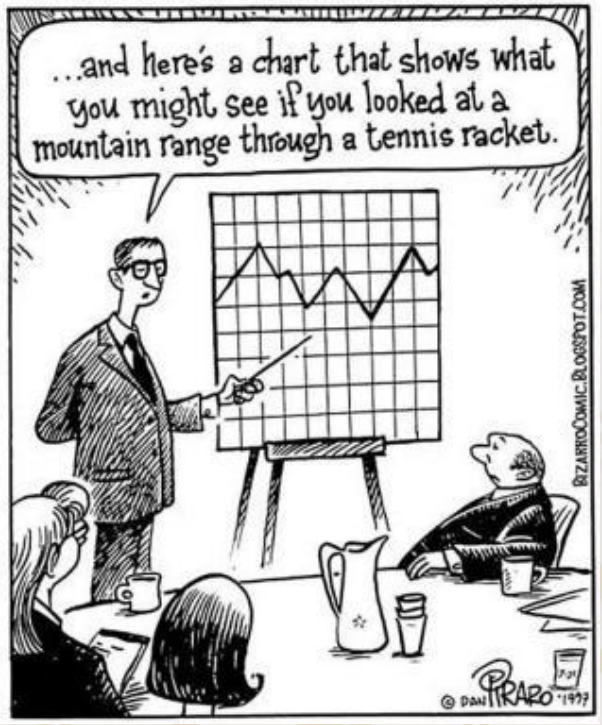
Adopting an overseas soil quality standard

There is no formal guidance on this

Do not shop around for the value that best suits a pre-determined outcome

Adopting an overseas standard

Do not use the lowest, median, average or largest value – its still shopping around but hiding behind statistics



British Prime Minister Benjamin Disraeli (1804–1881); Benjamin Disraeli

"There are three types of lies -- lies, damn lies, and statistics."

Adopting an overseas standard

Issues to consider:

- **the aim of the overseas standard;**
- **the purpose of the legislation;**
- **the level of protection provided - % of species and what types of effect;**
- **the organisms to be protected; and**
- **the method of calculation**

Discussion/Questions?

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