# Convergence Towards Development of Consensus-Based Ecological Screening Values for Metals in Sediment Pore Water

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## BACKGROUND / OBJECTIVES

Ecological screening benchmarks are typically applied in the ecological risk assessment (ERA) process to screen out contaminants detected at nominal concentrations and to focus the ERA on contaminants most likely to elicit adverse effects (*i.e.*, contaminants of potential ecological concern [COPECs]). For sediment risk assessments, screening evaluations may be conducted via comparisons of bulk sediment or sediment pore water concentrations to solid- and aqueous-phase effects-based screening values, respectively, to identify sediment COPECs.

The concentration of freely dissolved contaminant in sediment pore water has been shown to be a better predictor of toxicity to epibenthic and infaunal species than bulk sediment concentration, particularly when other sediment attributes that can influence contaminant bioavailability are taken into consideration. Although a significant amount of literature has been devoted to approaches for establishing sediment remediation goals for the protection of benthic organisms, consensus is lacking on a standardized set of screening values to identify sediment COPECs based on inorganic contaminant concentrations in pore water.

## PORE WATER SCREENING METHODS

### GENERAL PORE WATER SCREENING APPROACH

- Literature search conducted of sediment ERAs and regulatory guidance throughout the United States and overseas
  - ✓ 37 ERAs reviewed – 89% compared pore water levels to aquatic life surface water criteria
  - ✓ Federal/state guidance – screen against water-column criteria, or no recommendation for screening provided
- Journal publications – studies compare pore water to aquatic life criteria or "reference area" pore water

## FACTORS INFLUENCING PORE WATER TOXICITY

### PORE WATER CORRELATION WITH UPTAKE/TOXICITY

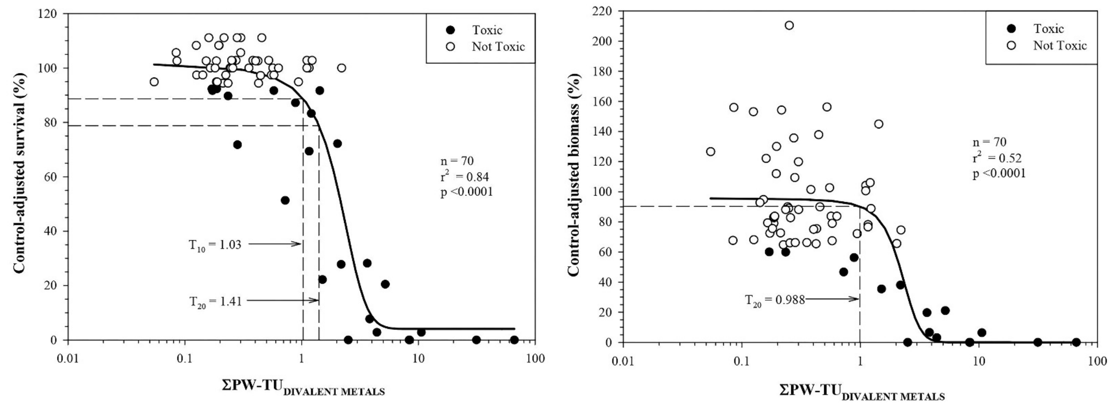
- *Question: Do pore water concentrations of metals correlate with ecological effects/toxicity?*
- Pore water data provide a stronger measure of the chemical conditions and effects experienced by benthic invertebrates than sediment data (USEPA 2005, Equilibrium Partitioning for Metal Mixtures)
- Benthic Fishes

| Variable | Riffle Fish Density | Species Richness | Sculpin Density | Fish Tissue Co | Fish Tissue Ni | Fish Tissue Cd | Fish Tissue Zn | Fish Tissue Pb | Pore Water Co | Pore Water Ni | Pore Water Cd | Pore Water Zn | Pore Water Pb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Distance from Mine | 0.31 | 0.15 | **0.71** | **-0.69** | -0.62 | -0.14 | **-0.71** | **-0.93** | -0.35 | **-0.55** | **-0.56** | **-0.76** | **-0.78** |
| PW Pb | -0.45 | -0.48 | **-0.59** | **0.74** | **0.74** | 0.37 | **0.77** | **0.90** | **0.68** | **0.81** | **0.73** | **0.94** | |
| PW Zn | -0.45 | **-0.50** | **-0.67** | **0.82** | **0.88** | 0.32 | **0.81** | **0.88** | **0.71** | **0.83** | **0.65** | | |
| PW Cd | -0.39 | -0.30 | **-0.74** | 0.53 | **0.62** | 0.35 | **0.60** | **0.64** | **0.66** | **0.71** | | | |
| PW Ni | **-0.75** | **-0.70** | **-0.66** | **0.74** | **0.82** | 0.18 | **0.83** | **0.73** | **0.90** | | | | |
| PW Co | **-0.67** | **-0.67** | **-0.65** | **0.55** | **0.53** | 0.12 | **0.68** | **0.63** | | | | | |
| Fish Tissue Pb | **-0.52** | **-0.57** | **-0.58** | **0.88** | **0.79** | **0.51** | **0.87** | | | | | | |
| Fish Tissue Zn | **-0.70** | **-0.73** | **-0.70** | **0.95** | **0.88** | 0.43 | | | | | | | |
| Fish Tissue Cd | -0.24 | -0.45 | -0.40 | 0.41 | 0.38 | | | | | | | | |
| Fish Tissue Ni | **-0.62** | **-0.61** | **-0.65** | **0.90** | | | | | | | | | |
| Fish Tissue Co | **-0.60** | **-0.66** | **-0.59** | | | | | | | | | | |
| Sculpin Density | **-0.60** | **0.60** | | | | | | | | | | | |
| Species Richness | **0.77** | | | | | | | | | | | | |
| Riffle Fish Density | | | | | | | | | | | | | |

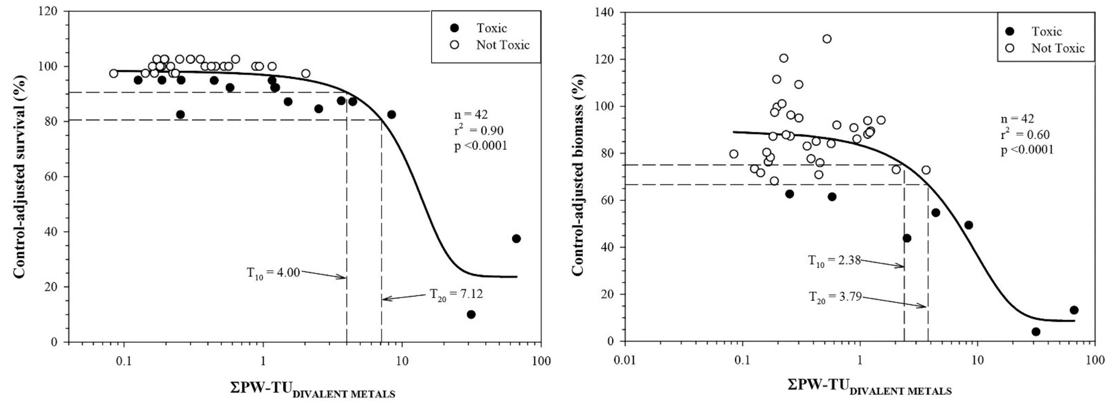
Spearman rank correlation coefficients for pore water, fish tissue concentrations, and riffle-dwelling benthic fish health indices for various metals (reproduced from Allert *et al.* 2009). Coefficients in **bold** type are statistically significant ($p$<0.05).

- ✓ Allert *et al.* (2009) studied toxicity of riffle-dwelling benthic fishes exposed to lead-zinc tailings at 16 sites in MO mining district
- ✓ Pore water levels of metals positively correlated with fish tissue levels and negatively correlated with fish health indices
- ✓ Consistent with findings of fish communities in VT mining district

- Benthic Macroinvertebrates



Divalent metal pore water concentration vs. control-adjusted survival and biomass of amphipods (*Hyalella azteca*)

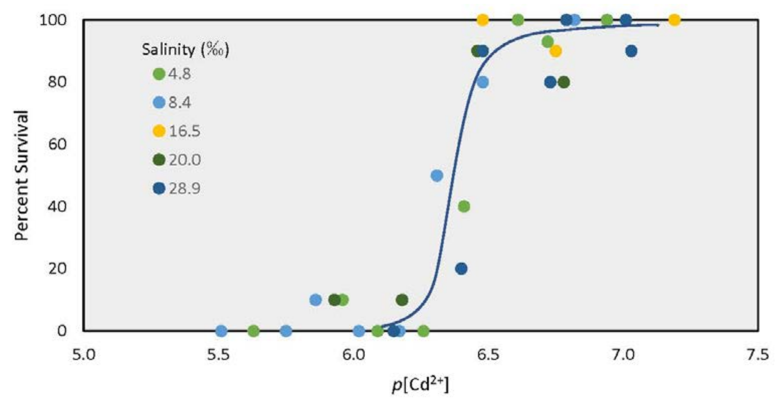


Divalent metal pore water concentration vs. control-adjusted survival and biomass of mussels (*Lampsilis siliquoidea*)

- ✓ McDonald *et al.* (2009) evaluated sediment and pore water toxicity thresholds for benthic invertebrates inhabiting numerous watercourses in the Tri-State Mining District (KS, MO, and OK)
- ✓ Low ($T_{10}$) and high risk ($T_{20}$) toxicity thresholds established from concentration-response relationships for divalent metals; pore water thresholds more reliable predictor of sediment toxicity in invertebrates

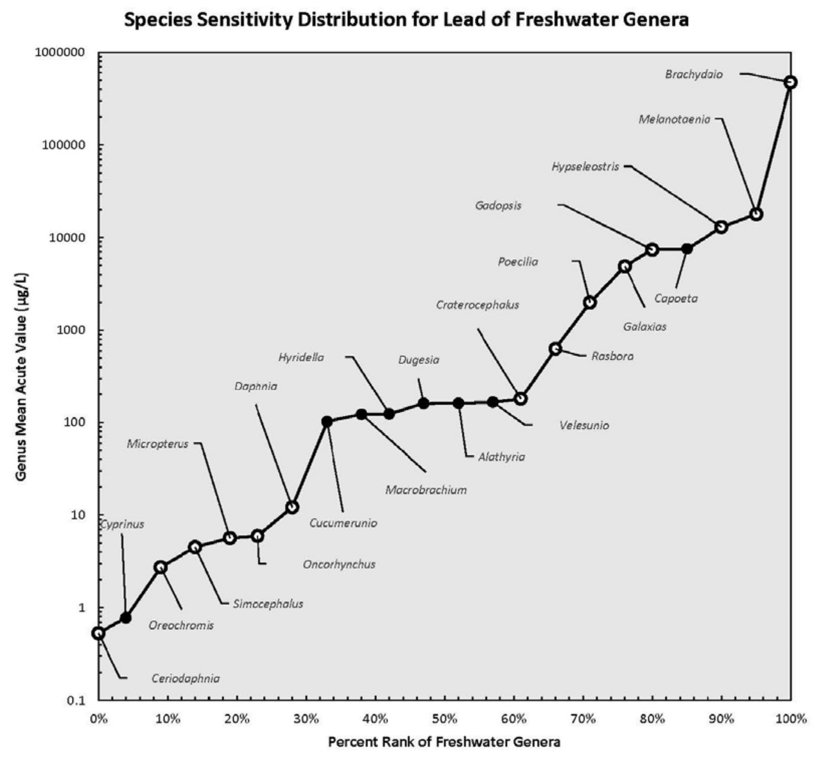
## PHYSICOCHEMICAL FACTORS

| | |
|---|---|
| Dissolved/colloidal organic carbon concentration | Organic ligand complexes, chelators, acid-volatile sulfides (anoxic conditions) |
| Presence of aluminum, iron, and manganese oxides or hydroxides | Hardness, pH, dissolved oxygen, <u>*salinity*</u> |

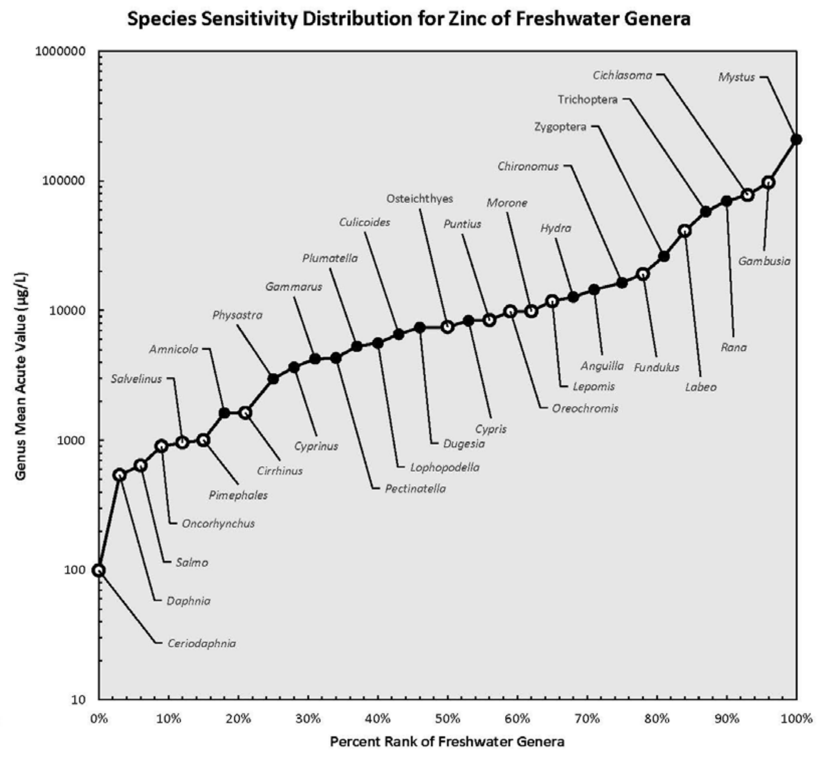



Acute toxicity to grass shrimp (*Palaemonetes pugio*) of free cadmium with varying salinity (reproduced from Sunda *et al.* 1978).

## SPECIES SENSITIVITY DISTRIBUTIONS (SSDs) FOR BENTHIC AND PELAGIC GENERA




Symbols representing benthic species are solid; those representing water column species are open.




Symbols representing benthic species are solid; those representing water column species are open.

- Genus mean acute values (GMAVs) are based on:
  - Mortality endpoints ($LC_{50}$)
  - Laboratory tests of freshwater fish and invertebrates
- Toxicity data sources:
  - USEPA ECOTOXicology Knowledgebase System – Version 5.0
  - Markich *et al.* 2002
  - Omidi *et al.* 2009
  - Shuhaimi-Othman *et al.* 2012
  - Markich 2017

## APPLICATION OF AMBIENT WATER QUALITY CRITERIA TO PORE WATER DATA

- Federal ambient water quality criteria (AWQC) for aquatic life assigned as highest concentration yielding "no significant risk to the majority of species" (including benthic species) in an aquatic system
- USEPA (1985) acknowledges AWQC purposefully conservative given that they were derived by tests conducted: 1) on sensitive species, and 2) in water very low in particulate and organic matter
- AWQC for most metals quantified partly using benthic organism toxicity data (*e.g.*, arsenic: polychaete worm, amphipod, channel catfish, Dungeness crab, mysid shrimp, crayfish, pteronarcid stonefly)

## IMPLICATIONS FOR SCREENING LEVEL ECOLOGICAL RISK ASSESSMENTS

- Benthic toxicity to metals generally correlated with aqueous-phase concentration, therefore COPEC screening for sediments should consider dissolved concentration in interstitial water
- Existing AWQC for metals generally incorporate ecotoxicity to benthic organisms
- SSDs developed for copper and lead indicate similar sensitivities between benthic and water-column species
- *This evaluation suggests that aquatic life AWQC for metals are appropriate for identifying sediment COPECs*