Application of Ecological Risk Assessment in Natural Resources Protection – Assessing the Effects of Selenium on Aquatic Life

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National Criteria Program MISSION

Develop sound scientific water quality criteria that provide the basis for protecting and restoring the condition of the nation’s waters to meet the mandates of the Clean Water Act

Clean Water Act – Section 304(a)(1)

- Requires EPA to develop and publish criteria for water quality accurately reflecting the latest scientific knowledge

- Criteria provide guidance to States and authorized Tribes to establish water quality **standards** to protect designated uses

- Criteria are recommendations, NOT regulations

Clean Water Act – Section 304(a)(1)

- Criteria development does NOT include consideration of economic and technical feasibility of meeting the criteria

- Criteria concentrations are intended to be neither over- or under-protective (necessary and sufficient to protect)

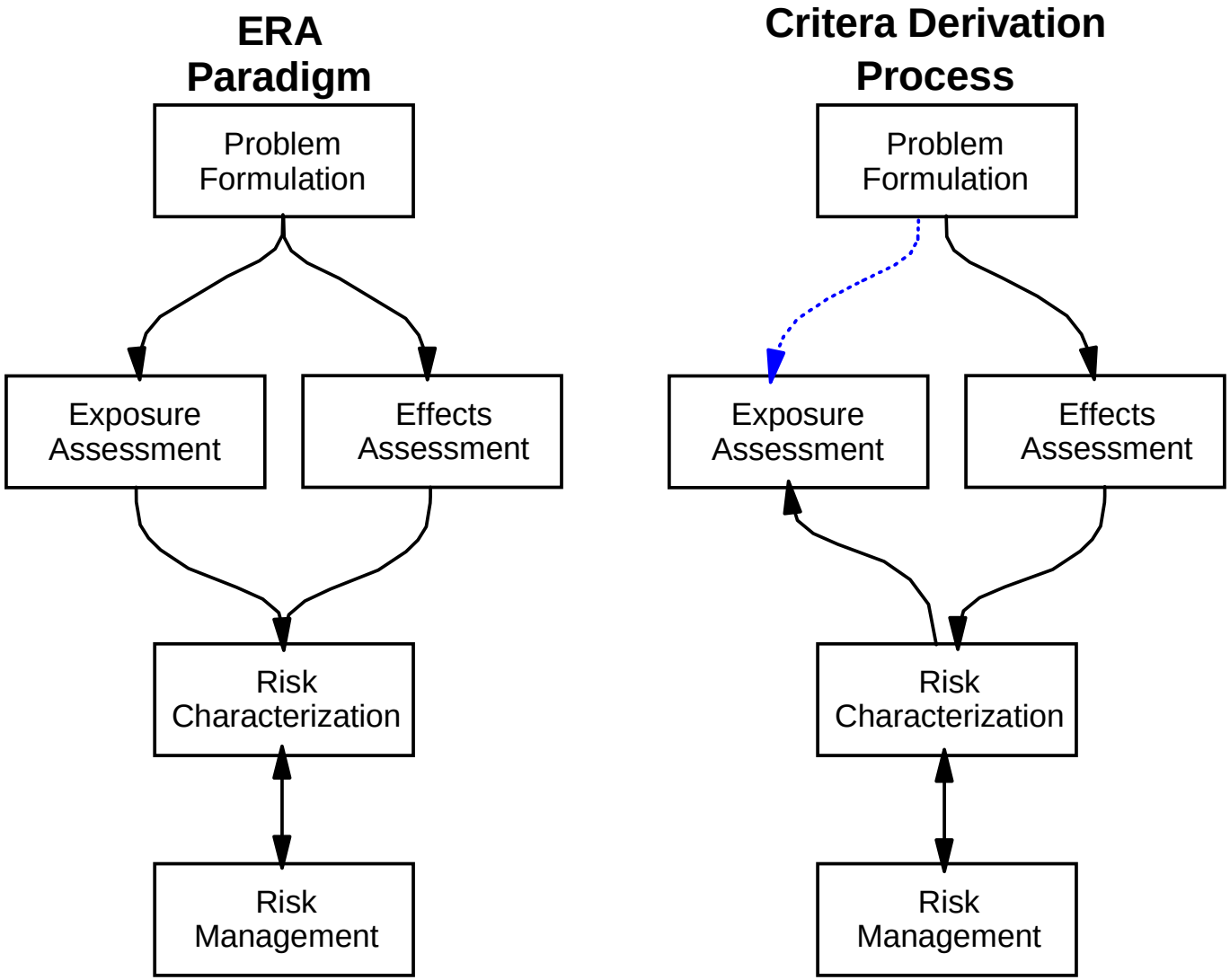
Clean Water Act – Section 303(c)

- Criteria are not legally enforceable until adopted into a State/Tribal Water Quality Standards
- Standards are a basis for developing regulatory controls on the discharge or release of pollutants
- States/Tribes may consider economic and technical feasibility when adopting criteria into standards
- States/Tribes may use scientifically-defensible criteria or approaches different from EPAs

National Water Quality Criteria Program

- Ecological Criteria: Chemicals, Nutrients, Biological, Suspended & Bedded Sediments
- Risk assessed to aquatic and aquatic-dependent organisms and habitat
- Compliance with the Endangered Species Act achieved via Consultation

Ecological Risk Assessment and Criteria Development



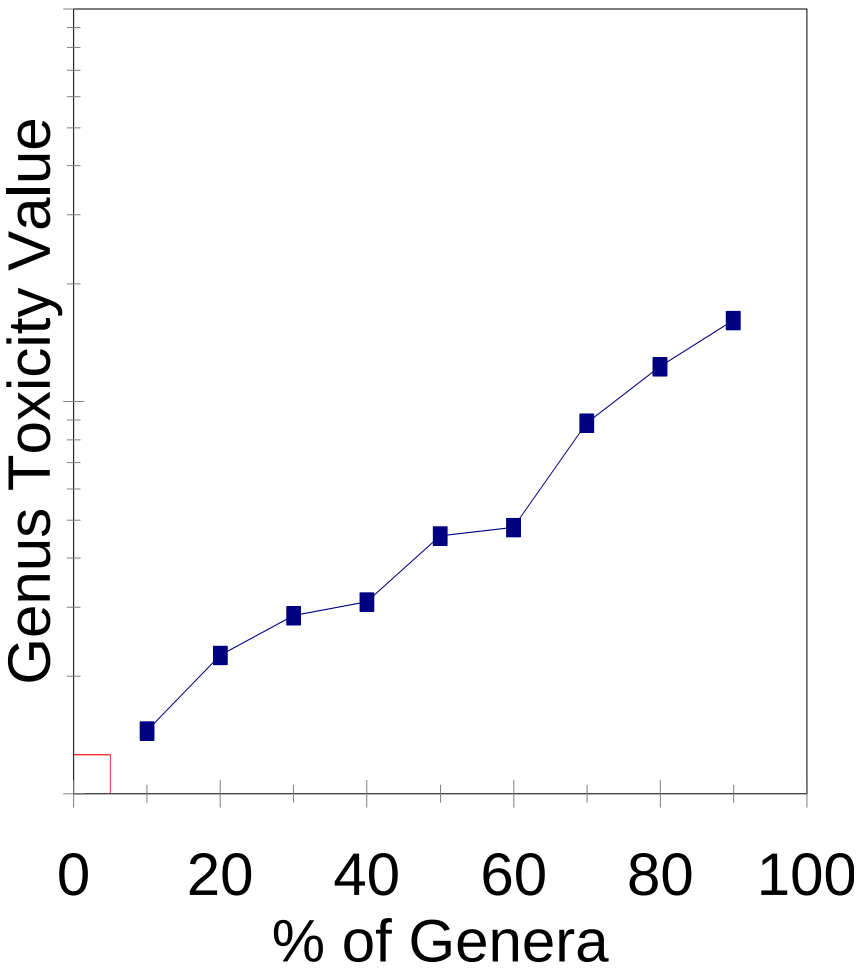
Aquatic Life AWQC Methodology

- **"1985 Guidelines"**
  - Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses (1985)
  - Toxicity data from laboratory tests (water-only exposures)
  - Criteria expressed as water concentrations

www.epa.gov/waterscience/criteria/85guidelines.pdf

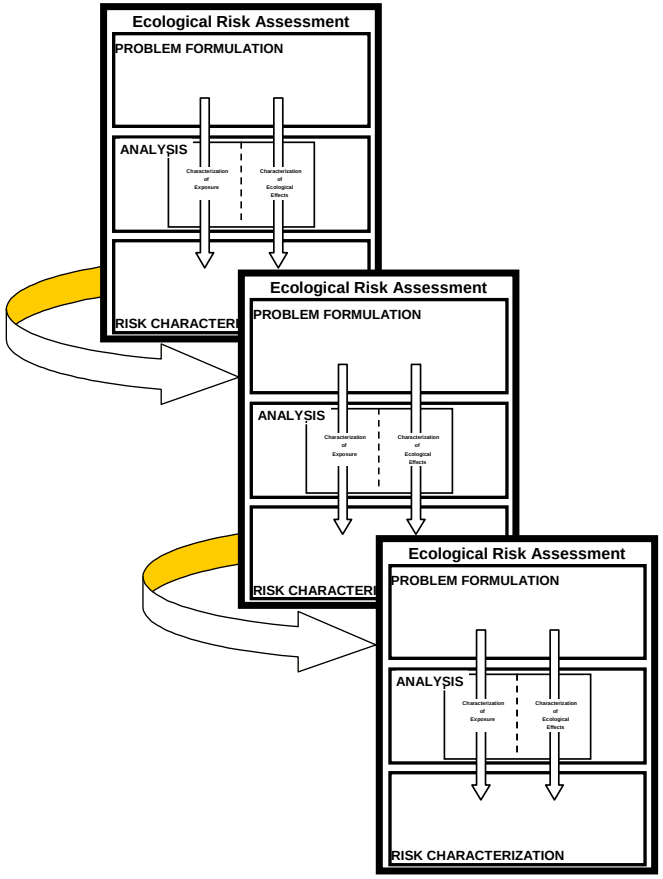
1985 Guidelines Methodology

- Compile data on toxic concentration for diverse set of taxa
- Construct Species Sensitivity Distribution
- Project water concentration needed to protect 95% of taxa



Tiered Assessment Procedures:
Assessment Uncertainties and Risk Management Decisions

- Low spatial/temporal resolution (National applicability)
- Species assemblage



- Site-specific water chemistry
- Species-specific criteria or recalculations

Tiered Assessment Procedures

- Ancillary Methods and Guidance Developed
  - Total-to-Dissolved Metals in National Toxics Rule (1993)
  - Water Effects Ratio Guidance (1994)
  - Recalculation Procedure (1994)
  - Tier II Values in Great Lakes Water Quality Initiative (1995)

State-of-the-Practice has Evolved

- New Science Incorporated in Specific Criteria
  - Field Concentration-Effects Data: Selenium Criteria (1987)
  - Population Modeling: Dissolved Oxygen Criteria (2000)
  - Biotic Ligand Model: Copper Criteria (draft 2003)
  - Aquatic Community Modeling: Atrazine Criteria (draft 2003)

Comprehensive Revision of the 1985 Guidelines

- Inter-Agency (FWS & NOAA) and Inter-Office (OW, ORD, OPP, Regions) Committee

- Incorporate Latest Science:
  - Ecological Risk Assessment Guidelines
  - Kinetic Toxicity Modeling
  - Population Modeling
  - Bioaccumulation

Bioaccumulative Chemical Criteria Problem Formulation

Selenium

1985 Methodology is Problematic for Selenium

- Real world aquatic animals are exposed to selenium primarily through diet
- Selenium is bioaccumulative, although not significantly biomagnified.
- 1985 methodology is not well suited for dietary exposure and bioaccumulation:
  - In standard toxicity tests, dietary exposure is not assessed
  - Dosimetric for most aquatic toxicity tests is water concentration
  - Water concentration is not a good predictor of toxicity for bioaccumulative chemicals

How did EPA address this problem two decades ago?

- In 1987, when EPA published its current water-based criterion, 5 µg/L, it opted **not** to use laboratory toxicity data or its usual criteria derivation procedure.

- Rather, it used field data collected at Belews Lake, North Carolina, comparing sunfish health with water concentration in different portions of the lake.

Limitations of the 1987 Approach

- The water-based criteria value is based on bioaccumulation occurring at a particular site, Belews Lake.

- As a water-based fixed-value criterion, it does not account for site-to-site variations in bioaccumulation.

- The 1987 criterion is criticized variously as too lax or too stringent.

Selenium Criterion Problem Formulation

- Data Availability:
  - Water Criterion: Limits data base to a few field studies
  - Tissue Criterion: Allows use of laboratory studies where tissue concentrations were measured

- Bioaccumulation:
  - Water Criterion: Tailored to a particular BAF
  - Tissue Criterion:
    - Removes BAF site-to-site variability from the criterion
    - Translation to media concentrations can be derived based on site-, region- or national bioaccumulation data; decision contingent on level of uncertainty that risk management decision can tolerate

Selenium Criterion
Problem Formulation

Should a Tissue-based Approach be Considered?

- Tissue concentration integrates multiple exposure routes.
- Tissue-based effect concentrations address bioavailability differences.

How much data were available?

Aquatic species with chronic tissue-based effect data:

Rotifer
Chinook salmon
Rainbow trout
Cutthroat trout
Brook trout
Fathead minnow
Flannelmouth sucker
Razorback sucker
Bluegill sunfish
Sunfish mixture
Striped bass

Selenium Criterion
Problem Formulation

- Assessment Endpoints:
  - Assemblage most sensitive to selenium
    - Selenium Aquatic Life = **Fish**
  - Identified vulnerable species
    - Selenium Aquatic Life = **Bluegill sunfish**

Selenium Criterion Effects Assessment

- Laboratory, field and mesocosm studies where tissue concentrations were measured

- Tissue Concentration-Response
  - individual species concentration-response curves
  - Species Sensitivity Distribution (data permitting)

- Data Extrapolations:
  - tissue (ovary) to whole body concentrations
  - temperature-dependent toxicity

Bluegill Chronic Toxicity Tissue Thresholds, parts per million

Type	Value		Type	Value
Field	20 – 44		Lab	> 6.0
Field	> 5.4		Lab	> 13
Field	21 – 28		Mesocosm	12
Lab	8.95		Mesocosm	> 17
Lab	<5.85 – 7.9			

Criteria Implementation – Translating Tissue Criteria into Media Concentrations

- Define bioaccumulation for each species in the assemblage or a representative food web

- Model(s) used will depend on available data, as determined in problem formulation
  - Field-derived estimates of bioaccumulation (BAF)
  - Food web model(s)

- National values vs. Site-specific values

Risk Characterization: Selenium Criterion
2004 Proposed Draft

- Interpretation of concentrations that protect from adverse effects on assessment endpoints

- Tissue concentrations related to effects on:
  - Sensitive target fish species (Bluegill sunfish)
  - Not as a concentration in a medium shared by an assemblage of species

- Implementation Guidance:
  - Bioaccumulation modeling and/or
  - Fish tissue sampling