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Bioaccumulation Testing
Walter J Berry
US EPA, ORD/NHEERL/AED, Narragansett, RI
Gui Lotufo
USACOE, ERDC, Vicksburg, MS
What I want to talk about today

• Some definitions
• Conceptual model of bioaccumulation
• Test design
• Test species
• Exposure duration/adjustment
• Test interpretation
  • “8 factors”
  • Modelling
• Take home messages
Bioavailability and Bioaccumulation: Definitions

- **Bioavailable**: Portion of the total quantity or concentration of a chemical in the environment that is potentially available for uptake by organisms.

- **Uptake**: Movement of a contaminant into an organism.

- **Biotransformation**: Chemical alterations of a compound occurring within the organism.

- **Elimination**: Movement of a contaminant out of an organism.

- **Bioaccumulation**: Net uptake of a chemical from all sources following exposure over a set exposure period.

Chemical structure from Wikipedia
Early take home message

- The details matter
- So you need to check with all of the involved parties ahead of time before you change anything

Details

- How many samples do I take?
- How many lab reps do I need?
- What test species do I use?
- What are the contaminants of concern (COCs)?
- How do we screen out COCs?
- How will the results be evaluated?
- Etc, etc, etc….
Conceptual models: Bioaccumulation

- Biomagnification
- Bioaccumulation
- Bioavailability
Tier II: Predicting Bioaccumulation

Thermodynamically-based Theoretical Bioaccumulation Potential (TBP)

- An estimate of the steady-state concentration of non-polar organic chemicals in organisms exposed to contaminated sediment
- Used as a coarse screening tool to determine if bioaccumulation testing is warranted
- Compare TBP for Reference and DM
- Only works for non-polar (hydrophobic) organics
  - PAHs, PCBs, Chlorinated pesticides
Tier II: Predicting Bioaccumulation

\[ TBP = \frac{C_s}{\%TOC} \times \%L \]

BSAF = biota/sediment accumulation factor

\( C_s \) = conc. in sediment (any units)

\%TOC = total organic carbon content of sediment

\%L = lipid content of organism

BSAF = \( \frac{C_{\text{org}} \text{ (lipid normalized)}}{C_s \text{ (organic carbon normalized)}} \)
BSAF Database  -  https://bsaf.el.erdc.dren.mil/
Tier III: Bioaccumulation Test

- Conduct whole-sediment bioaccumulation tests
- Compare DM to reference
- Accumulation of chemicals of interest in organisms as endpoint
Tier III: Bioaccumulation Test

Test Design

- Time zero tissue analysis
- 28-day exposure
- No feeding
- Minimum 3 replicates/treatment
- Measure tissue concentration at conclusion of exposure
Selection of Test Species

Desirable characteristics

• Sediment ingester
• Infaunal
• Tolerant of contamination and sediment characteristics
• Easily collected or cultured
• Inefficient metabolizer (PAHs)
• Adequate biomass

• 2 species should / must be used (CWA / MPRSA)
Bioaccumulation Test Species

Freshwater

Oligochaete

Lumbriculus variegatus

Asian Clam

Corbicula fluminea
Bioaccumulation Test Species
Marine / Estuarine

- Alitta virens
- Macoma nasuta
- Arenicola marina
- Neanthes arenaceodentata
- Mercenaria mercenaria
- Yoldia limatula
Exposure duration

• Steady State – final stable concentration of a contaminant in tissue under constant exposure conditions

• SS will not always be reached in 28-d depending on:
  
  ➢ contaminant hydrophobicity
  
  ➢ species ability to biotransform and eliminate contaminants

Example: 2,3,7,8TCDF

Macoma nasuta

\[ \text{SS} = 108 \, \text{d} \]

Nereis virens

\[ \text{SS} = 21 \, \text{d} \]
Exposure duration

Exposures up to 56 d to New York harbor sediments and kinetic method to determine fraction of SS at 28-d

- 28-d exposure adequate for *Alitta virens* but longer exposure required for *Macoma nasuta*

- Site-specific determinations of SS can be made in Tier IV or correction factors may be applied (See Appendix H in the SERIM, for examples)

- Correction factor of 2 or less appears appropriate for most compounds and species
Conclusion of Exposure

- Collect all remaining/surviving organisms from exposure chambers
- Allow organisms to purge gut content or excise gut
- Conduct chemical analysis of tissues
Interpreting Bioaccumulation Data

- Statistical comparison to FDA action levels or state fish advisories
- Statistical comparison of bioaccumulation in DM vs. Reference Material

**Dredge site > Reference site**

- Comparison to background (i.e., regional) values from in situ surveys
- Magnitude of exceedance (e.g., 4 x more relevant than 1.5x)
- Toxicological relevance (e.g., high for PCBs, low for zinc)
- Propensity to biomagnify (high for PCBs and some pesticides, low or negligible for most metals and PAHs)
- Number of contaminants with exceedances
- Number of species with exceedances

**Assessment Factors**

- Evaluate potential to impact higher trophic levels (compare residue to effect values)

**Environmental Residue Effects Database** [https://ered.el.erdc.dren.mil/](https://ered.el.erdc.dren.mil/)
Food-web Transfer and Impacts

Contaminants with high relevance
- Legacy persistent organic pollutants (POPs)
  ▶ High propensity to biomagnify
  ▶ Wide range of effects to fish and wildlife reported for some POPs (e.g., coplanar, dioxin-like PCBs)
- Mercury
  ▶ High propensity to biomagnify and wide range of effects to fish and wildlife reported

Contaminants with moderate relevance
- Metals forming organic species: selenium and butyltins (e.g., TBT)
  ▶ Uncertainty concerning potential to biogagnify
  ▶ Only certain taxa highly susceptible to deleterious effects (e.g., gastropods for TBT and birds for selenium)

Contaminants with low relevance
- Other metals and metalloids
- PAHs
  ▶ Low or no propensity to biomagnify
  ▶ For metals, sediment bioaccumulation tests may have little value in predicting bioaccumulation in the field
  ▶ For metals, weak relation between bioaccumulation and onset of toxicity
Food Web / Trophic Transfer

- Some regions use models when test tissue concentrations exceed reference tissue concentrations
- When biomagnification suspected, higher-trophic level receptors included in the evaluation

Trophic Transfer Models
- Use bioaccumulation test data to estimate residue in higher trophic levels

- Use site-specific information
Food Web Models: FishRand-Migration (FR-M)

- Provide estimates of human health and ecological risk at contaminated sites and to support fish consumption warnings.
- Uses GIS-based databases and site characterization tools.
- Simulates fish foraging behavior together with spatially-explicit exposure concentrations.

https://dots.el.erdc.dren.mil/models5.html
Food Web Models: BRAMS

- Two separate tools, *Trophic Trace (TT)* and the *Bioaccumulation Evaluation Screening Tool (BEST)*.
- The TT model estimates expected concentrations in fish using a sediment-based food-web model.
- The BEST tool estimates expected risks to human receptors by
  - (1) calculating the edible tissue concentration
  - (2) calculating an average daily dose to humans and
  - (3) using standard EPA risk equations to determine potential carcinogenic and non-carcinogenic risks.

https://dots.el.erdc.dren.mil/models5.html
Bioaccumulation Take Home Messages

• Evaluation of bioaccumulation provides information for assessing long-term effects to higher trophic-level receptors

• Bioaccumulation should be used along with other lines of evidence (e.g., direct toxicity) to determine risk or evaluate for compliance

• Evaluation complexity ranges widely from simple modeling to full risk assessment.

• Experimental and evaluation details matter, so make sure that all consulting parties are on board before you make a plan, or make any changes to agreed upon procedures (e.g. in the RIA), or do any retesting
References

• USEPA/USACE. 2003. Regional implementation agreement for testing and reporting requirements for ocean disposal of dredged material off the Louisiana and Texas coasts under section 103 of the marine protection, research and sanctuaries act. (RIA) July, 2003.
Thank You!