SUSTAINABLE SEDIMENT MANAGEMENT AND DREDGING SEMINAR

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SAUSALITO, CA

Water Column Evaluation: Improving and Streamlining Dredged Material Testing and Evaluation

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Conceptual Model

*Water Quality Evaluation (open water disposal)*

- One of 3 exposure pathways:
  - Still consider sediment toxicity
  - Still consider bioaccumulation
- Implications
  - Does not “fail” the material
  - Impacts management options
- Considers historic information
- Chemical, biological, toxicological
Why Dredging Evaluations Are Done

Water Quality Evaluation Requirements

Manage contaminated sediment

Requirements: regulations on sediments

- Ocean disposal: MPRSA (40 CFR 227)
  - Limiting Permissible Concentration (LPC)
    - DM cannot exceed after mixing based on:
      A. WQC, and
      B. Toxicity (or toxicity \times safety factor)

- Inland disposal: CWA (CFR 230, 404b1)
  - Mixing zones determined by the state
  - Compliance with WQS, bioassay testing

“...unreasonably degrade or endanger: human health, welfare, or amenities, marine environment, ecological systems, or economic potentialities...”
Water Column Evaluation

Main Discussion Points

• DM suspended for a short time (short-term exposure, effects)
  ➢ Exclusions, new pollution, previous data?

• Tier 1 Historic info: determination?
  ➢ Exclusions, new pollution, previous data?

• LPC vs. modeled concentration
  ➢ Tier 2: Chemistry vs. WQC / WQS
  ➢ Tier 3: Elutriate toxicity bioassays
  ➢ Tier 4: In depth, site specific investigation
Elutriate Preparation

• Types of elutriates
  - **Standard Elutriate Test (SET)**
  - Effluent (Modified) Elutriate Test (EET, MET)
  - Dredging Elutriate Test (DRET)

<table>
<thead>
<tr>
<th>Application</th>
<th>Test Material</th>
<th>Hold Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elutriate preparation</td>
<td>4 parts site water 2 weeks+</td>
<td>2 weeks+</td>
</tr>
<tr>
<td></td>
<td>1 part sediment 8 weeks</td>
<td>8 weeks</td>
</tr>
<tr>
<td>Elutriate dilution</td>
<td>Disposal site water, lab water</td>
<td></td>
</tr>
<tr>
<td>Statistical comparisons</td>
<td>Dilution water (above)</td>
<td>Not applicable</td>
</tr>
<tr>
<td>(0% treatment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organism Health</td>
<td>Negative Control (lab reconstituted, natural)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reference toxicant test</td>
<td></td>
</tr>
</tbody>
</table>

Elutriate Preparation

- **Application Test Material Hold Time**
- **Elutriate Preparation**
  - 4 parts site water 2 weeks+
  - 1 part sediment 8 weeks
- **Elutriate Dilution**
  - Disposal site water, lab water
- **Statistical Comparisons (0% Treatment)**
  - Dilution water (above)
- **Organism Health**
  - Negative Control (lab reconstituted, natural)
  - Reference Toxicant Test

**Toxicity Evaluation**
- Prepare dilution series
- Conduct bioassays
- Determine NOEC, LOEC, MATC, LC50, and LPC

**Chemistry Evaluation**
- Centrifuge
- Filter supernatant for dissolved analysis
- "Liquid Phase" - Compare concentration to WQC/WQS (after consideration of initial mixing)
Elutriate chemistry

- Establish CoC list
- Compare to WQC/WQS (if available)
- Determine required dilution
- CWA: determination possible?
- MPRSA: conduct bioassays
- There may be triggers

Elutriate testing triggers for metals are derived using the following equation:

$$ET_{\text{metal}} = K_d \times \frac{WQC}{1000}$$

where:
- $ET_{\text{metal}}$ = the elutriate trigger for the particular metal (dissolved) in question in mg/kg sediment
- $K_d$ = the metal partitioning coefficient in L/kg
- $WQC$ = the acute water quality criterion for the metal in μg/L (see below for a discussion on hardness and freshwater metal criteria)
- 1000 = a conversion factor to provide results in milligrams per kilogram sediment
Elutriate Bioassay

- Recommended: species from 3 phyla
  - CWA (if needed)
    - Multiple *recommended*
    - No WQC, unknown toxicity
  - MPRSA (3 species required)
  - Bioassays determine LPC
- Selection of *appropriate* test species

<table>
<thead>
<tr>
<th>Region</th>
<th>Water</th>
<th>Fish</th>
<th>Crustacean</th>
<th>Zooplankton</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWA</td>
<td>Freshwater</td>
<td>Pimephales* Oncorhynchus* Lepomis*</td>
<td>Daphnia* Ceriodaphnia*</td>
<td></td>
</tr>
<tr>
<td>CWA</td>
<td>Estuarine Marine</td>
<td>Menidia* Cyprinodon*</td>
<td>Americamysis*, Palaemonetes* Copepod</td>
<td></td>
</tr>
<tr>
<td>MPRSA</td>
<td>Marine</td>
<td>Menidia* Cyprinodon*</td>
<td>Americamysis* Palaemonetes* Mytilus embryo* Urchin embryo Copepod</td>
<td></td>
</tr>
</tbody>
</table>
Frequently Encountered Issues

- Water hold time impact on field/lab logistics: 2 weeks
- Species selection
  - Ecology, sensitivity
  - Historic use / database
  - Salinity adjustments (stress, control charts)
  - Ammonia toxicity
- Application factor (x 0.01)
- Bin restrictions

<table>
<thead>
<tr>
<th>Salinity (ppt)</th>
<th>Fish</th>
<th>Invertebrate</th>
<th>Zooplankton</th>
</tr>
</thead>
<tbody>
<tr>
<td>30+</td>
<td>Adjust down</td>
<td>▼ Adjust down</td>
<td>▼ Adjust down</td>
</tr>
<tr>
<td>25-30</td>
<td>Cyprinodon</td>
<td>Americamysis</td>
<td>Copepod</td>
</tr>
<tr>
<td></td>
<td>Menidia</td>
<td></td>
<td>Americamysis</td>
</tr>
<tr>
<td>21 – 25</td>
<td>Cyprinodon</td>
<td>Americamysis,</td>
<td>↑ Adjust up</td>
</tr>
<tr>
<td></td>
<td></td>
<td>adjust up</td>
<td></td>
</tr>
<tr>
<td>11 – 20</td>
<td>Cyprinodon</td>
<td>↑ Adjust up</td>
<td>↑ Adjust up</td>
</tr>
<tr>
<td>1 – 15</td>
<td>Cyprinodon</td>
<td>↑ Adjust up</td>
<td>↑ Adjust up</td>
</tr>
<tr>
<td>0–1</td>
<td>Pimephales</td>
<td>Daphnia, Geriophyta</td>
<td></td>
</tr>
</tbody>
</table>
## Data interpretation

### Elutriate Concentration

<table>
<thead>
<tr>
<th>Elutriate Concentration</th>
<th>Percent Survival</th>
<th>Endpoint in Elutriate</th>
<th>Statistical Significance</th>
<th>Lowest LC/EC50</th>
<th>LPC (X 0.01)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>98%</td>
<td>98%</td>
<td>96%</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>10%</td>
<td>94%</td>
<td>98%</td>
<td>97%</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>50%</td>
<td>94%</td>
<td>100%</td>
<td>97%</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>96%</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>64%</td>
<td>0.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Most sensitive species

- 64% LC50 (64%) X 0.01 (LPC) = 0.64

### DMMU 1

- 0%: 98% Fish, 98% Invertebrate, 96% Zooplankton, No >10% reduced & stat. sig.
- 10%: 94% Fish, 98% Invertebrate, 97% Zooplankton, No >10% reduced & stat. sig.
- 50%: 94% Fish, 100% Invertebrate, 97% Zooplankton, No >10% reduced & stat. sig.
- 100%: 100% Fish, 100% Invertebrate, 96% Zooplankton, No >10% reduced & stat. sig.

### DMMU 2

- 0%: 98% Fish, 98% Invertebrate, 96% Zooplankton, No >10% reduced & stat. sig.
- 10%: 98% Fish, 98% Invertebrate, 97% Zooplankton, No >10% reduced & stat. sig.
- 50%: 96% Fish, 96% Invertebrate, 88% Zooplankton, No >10% reduced & stat. sig.
- 100%: 70% Fish, 98% Invertebrate, 0% Zooplankton, Yes >10% reduced & stat. sig.
Data Interpretation

Modeled Concentration

- LPC = 0.64, Requires 156X dilution
- Conclusions
  1. DM discharge toxicity **not predicted** relative to the reference condition
  2. DM discharge toxicity **is predicted** relative to the reference condition
  3. Further information needed for actual determinations (Tier IV)

<table>
<thead>
<tr>
<th>Site</th>
<th>LC$<em>{50}$ or EC$</em>{50}$ (%Elutriate)</th>
<th>Application Factor</th>
<th>Limiting Permissible Concentration (% Elutriate)</th>
<th>Minimum Dilution to Achieve LPC Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Americamysis</td>
<td>Menidia</td>
<td>Mytilus</td>
<td></td>
</tr>
<tr>
<td>DMMU 1</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.01</td>
</tr>
<tr>
<td>DMMU 2</td>
<td>NA</td>
<td>NA</td>
<td>64</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Modernizing Evaluations

Limiting Permissible Concentration (40 CFR 227.27)

**Issue:** Conservative safety factor

- Barge size restrictions
  - LPC = acutely toxic concentration × 0.01
  - Intended for survival, not development
  - Other factors permissible: opportunity?
  - Persistent > 8 weeks: 0.01 (NAS 1972)
  - Non-persistent < 8 weeks: 0.05 (<0.1)

**Solutions & Benefit:**

- Consider dredging method vs. exposure duration
- Is there need for chronic protection?
- Alternative safety factors published
- Most cost effective management option

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Duration</th>
<th>Factor</th>
<th>LC50</th>
<th>LPC</th>
<th>STFATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default, metals, pesticides</td>
<td>Chronic</td>
<td>0.01</td>
<td>3%</td>
<td>0.03%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>Chronic</td>
<td>0.05</td>
<td>3%</td>
<td>0.15%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Ammonia/Sulfides</td>
<td>Chronic</td>
<td>0.1</td>
<td>3%</td>
<td>0.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Other</td>
<td>Acute</td>
<td>0.2</td>
<td>3%</td>
<td>0.6%</td>
<td>0.3%</td>
</tr>
<tr>
<td>USE LOGIC!!!</td>
<td>Acute</td>
<td>EPA BMDL</td>
<td>--</td>
<td>1.09%</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

*Harbor X: Increase from 3600 to 8900 cy allowable disposal*
Modernizing Evaluations

More Appropriate Marine Zooplankton Tests

• Development tests
  ➢ Ammonia, particles

• Marine copepods
  ➢ Full life cycle
  ➢ Lab culture
  ➢ Sensitive to CoCs

![Diagram showing sensitivity levels]

Environmental Toxicology and Chemistry

SENSITIVITY OF THE MARINE CALANOID COPEPOD
Pseudodiaptomus pelagicus TO COPPER, PHENANTHRENE AND AMMONIA

Alan J. Kennedy, Thomas Biber, Lauren Rabalais, Guilherme R. Lutulfo, J. Daniel Farrar, Anthony J. Bednar

First published: 20 February 2019 | https://doi.org/10.1002/etc.4397
Modernizing Evaluations

**Improved Toxicity Reduction / Identification Methods**

- “Toxicity” not always CoC
- Performed as Tier 3 - 4
- Improve SERIM methods
- Select appropriate AF 0.01, 0.05, 0.1, etc.
Sustainable Sediment Management and Dredging Seminar

• Elutriate tests simulate:
  ➢ Potential chemical/biological impacts
  ➢ During short time dredged material is suspended

• Not pass/fail, but may impact management

• Testing methods and interpretation need modernization and site-specific consideration

• Important to understand:
  ➢ Selection of appropriate species
  ➢ Use of application factors

• ERDC has methods for:
  ➢ Appropriate species selection
  ➢ Toxicity cause identification
  ➢ Application factor selection

Water Column Evaluation

What to take home
Toxicity and Bioaccumulation: Benthic Toxicity Evaluation
J. Daniel Farrar
Conceptual Model

**Benthic Toxicity Evaluation**

- One of the pathways considered in open water disposal
  - Still consider elutriate toxicity
  - Still consider bioaccumulation
- Evaluate potential of DM disposal for adverse effects on benthic organisms
- Implications
  - Test failure could require upland placement (e.g., CDF) or other alternative management option
Benthic Toxicity Evaluation

Main Discussion Points

- Assess potential for toxicity of DM following open water disposal
- Concerned with toxicity from direct contact with DM at the disposal site
  - Will DM disposal result in an unacceptable risk at the disposal site?
- All benthic toxicity evaluations occur in Tier 3
Benthic Toxicity Evaluation

- Sediment Quality Guideline values are numerical chemical concentrations intended to be protective of biological resources.
- Include empirical and mechanistically derived values.
- ER-L/ER-M
- TEL/PEL
- AET
- EqP approach for nonionic organics and metals (e.g., AVS-SEM)
- Sediment chemistry is compared to SQG values and the potential for effects is determined.

Benthic Toxicity Evaluation
(Reference Sediment)

- Reference Sediment provides point of comparison for DM toxicity evaluations
- Reference sediment should reflect conditions at disposal site in absence of disposal activity (as practicable as possible)
- Possess physical characteristics similar to DM (e.g., grain size, organic carbon)
- Not be collected in the vicinity of spills, outfalls, or other significant sources of contaminants (i.e., substantially free of contaminants)
- Be subject to the same hydrologic influences, within the limits of what is practicable, as the disposal site
- Selected reference must be compatible with benthic organisms used in testing (e.g., grain size, TOC, etc.)
Benthic Toxicity Evaluation
(Control Sediment)

- Control Sediment used to assess the acceptability of a toxicity test
- Confirms the biological acceptability of test conditions and organism health
- May be sediment in which the organism was collected or cultured
- Carried through testing procedures in an identical manner as test sediments
- Excessive mortality in control sediment suggests a problem with the test and can invalidate results
Benthic Toxicity Testing Summary

- Conduct whole-sediment toxicity tests
- Compare DM to reference sediment
- Survival of organisms as toxicological endpoint
Benthic Toxicity Test Design

- Short-term exposure (typically 10 days)
- Measure survival
- Recommend testing with at least two species
- Feeding is test dependent
- Minimum 5 replicates/treatment
- Test validity based on survival in control sediment
Test Species Selection

- Species representing three life history strategies (burrowing organism, deposit feeder, and filter feeder)
- If only two different species are used, they should together cover the three life history strategies
Test Species Selection

- Other factors to consider:
  - High responsiveness to contaminants
  - Low responsiveness to non-contaminant effects (e.g., grain size)
  - Standardized protocol
  - Ecologically relevant (e.g., infaunal)
  - Availability (e.g., amenable to culturing)
Marine/Estuarine Species
(Amphipods)

- *Leptocheirus plumulosus*
- *Eohaustorius estuarius*
- *Ampelisca abdita*
- *Rhepoxynius estuarius*
Marine/Estuarine Species
(Other Invertebrates)

Neanthes arenaceodentata
Polychaete

Americamysis bahia
Mysid Shrimp

Nephtys caecoides
Freshwater Species

Amphipod

Hyalella azteca

Midge

Chironomus dilutus
Data Evaluation

- Is mortality in dredged sediment 10% greater than reference (20% for marine/estuarine amphipods), and statistically different from reference?
  - If No, material is not predicted to be toxic
  - If Yes, material is predicted to be toxic

- San Francisco Bay region can use a “preponderance of information” approach
Data Evaluation

- Example Calculation #1:
  - Freshwater amphipod survival in Sediment A equals 75% and is statistically different from the reference
  - Reference sediment survival equals 86%
  - Material is predicted to be toxic (i.e., mortality greater than 10% different and statistically different from reference)

- Example Calculation #2:
  - Marine amphipod survival in sediment B equals 74% and is statistically different from the reference
  - Reference sediment survival equals 87%
  - Material is not predicted to be toxic (i.e., statistically different but mortality does not exceed the reference by 20%)
Tier 4 Evaluations

- Case specific studies designed to address uncertainties that must be resolved to reach a decision
  - Implemented when Tier III toxicity tests do not provide adequate information for a risk based decision
  - Includes advanced sediment evaluations (i.e., sediment toxicity identification evaluations, etc.)
- Occurrence is rare
Confounding or Non-contaminant Factors

- Toxicity not always due to CoC
  - Sediment grain size (clay, sand, etc.)
  - Salinity
  - Ammonia
  - Nutrition (TOC as an indicator)
  - Low moisture content
  - 'Should evaluate potential for non-contaminant effects prior to testing when possible (e.g. site historical grain size, TOC, ammonia, etc.)
Identifying Confounding or Non-contaminant Factors

- Evaluate sediment chemistry (e.g., SQGs, etc.) to ensure a contaminant is not cause of toxicity
- Perform factor specific identification procedures:
  - Ammonia: perform ammonia reduction procedures (e.g., water exchanges, TRE with zeolite, alternate organism, etc.).
  - Nutrition: re-test with minimal feeding (i.e., fed and unfed treatments)
  - Grain size: re-test concurrently with alternate approved organism with tolerance for grain size range observed
- TRE/TIE as component of side by side re-tests with the same or alternate approved organism to demonstrate toxicity is likely not due to a contaminant
- MUST consult oversight agency if pursuing methods to identify or eliminate the influence of confounding factors
Conclusions

- Main Goal: Evaluate potential of DM to cause adverse effects on Benthic organisms
- Process: Evaluate toxicity test data with consideration of confounding factors to determine risk associated with DM disposal
- Procedure: Follow tiered process only as far as necessary to make a risk based decision
Bioaccumulation and toxicity: Bioaccumulation evaluation

Gui Lotufo
Per CFR 227.18, Open water disposal is prohibited when “Presence in the material of chemical constituents which may be bioaccumulated or persistent and may have an adverse effect on humans directly or through food chain interactions.”

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

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

**Sources of contamination**:

**Sediment**
- Sediment particles (ingestion)
- Detritus
- Benthic prey

**Sediment porewater**

**Water column**
- Overlying water
- Plankton

---

**Organism**, **Organism**, **Organism**, **Organism**

**Organism not drawn to scale**
Benthos diversity

Predator polychaetes  Filter-feeding clams  Burrowing amphipods  Freshwater oligochaetes
Tier II: Screening evaluation (COC selection and need for testing)

- Predict bioaccumulation (organics only) using theoretical bioaccumulation potential (TPB)
- If applicable, compare with regional sediment threshold values

Table 1. Dredged material testing thresholds effective in 2016-2019
(https://www.sfei.org/projects/dmno-ambient-sediment-conditions)

<table>
<thead>
<tr>
<th></th>
<th>Mercury (mg/kg dw)</th>
<th>Total PCBs (µg/kg dw)</th>
<th>Total PAHs (µg/kg dw)</th>
<th>Total DDTs (µg/kg dw)</th>
<th>Total Chlordane (µg/kg dw)</th>
<th>Dieldrin (µg/kg dw)</th>
<th>Dioxins/Furans (pg/g dw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioaccumulation</td>
<td>N/A</td>
<td>18</td>
<td>4,500</td>
<td>50</td>
<td>37</td>
<td>1.9</td>
<td>10</td>
</tr>
<tr>
<td>Trigger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>TMDL Limit</td>
<td>0.47</td>
<td>29.5</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Basis</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
</tbody>
</table>

1Threshold based on San Francisco Bay ambient sediment concentrations determined via the RMP and are recalculated and updated when new data are available.
2Published bioaccumulation trigger for Puget Sound marine sediments.
3Published marine Screening Level value from the Pacific Northwest Sediment Evaluation Framework.
4Toxic Equivalents (TEQs) based on WHO 1998 Toxic Equivalency Factors (TEFs). Value is consistent with the published Puget Sound limit for unconfined aquatic disposal, and is \( \frac{1}{2} \) the established limit for placement at the Hamilton Wetlands Restoration Project site.
Using historical regional data to select bioaccumulation triggers

Using historical regional data to select bioaccumulation triggers

- Little or no Hg bioavailability from the sediment tested
- No relationship between Hg concentration in sediment in tissues of exposed organisms
- Bioaccumulation tests add no value to decision making process
- As an outcome of the study, bioaccumulation testing for Hg was eliminated from the evaluation
- TMDL limit governs maximum Hg concentration (0.5 mg/kg) for in-Bay disposal
Tier III: Bioaccumulation test

Under ITM and OTM, if DM not exempted from testing, sediment bioaccumulation testing is required for decision making (regional guidance may include a screening step)

**Approach**
- Conduct whole-sediment bioaccumulation tests
- Compare DM to reference
- Whole-body burden chemicals of interest in benthic organisms as endpoint

**Test Design**
- Time zero tissue analysis
- 28-day exposure
- No feeding
- Typically 5 replicates/treatment
- Measure tissue concentration at conclusion of exposure
Test species

Desirable characteristics

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

**OTM:** Use burrowing polychaete and a deposit-feeding bivalve mollusk

**ITM:** One benchmark species (use of others is desirable)

- Alitta virens (formerly Nereis)
- Macoma nasuta
- Neanthes arenceodentata
- Lumbriculus variegatus
- Nephtys caecoides
Tier III: Bioaccumulation test termination and initial analysis

- Collect all remaining/surviving organisms from exposure chambers
- Allow organisms to purge gut content or excise gut
- Obtain whole-organism chemistry data
- Correct for steady-state
- Statistically compare DM and reference site body residues
- If DM ≤ reference, no further evaluation is necessary
- If DM > reference, evaluate bioaccumulation data

Bioaccumulative Contaminants of Concern for Routine Tissue Evaluation*

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total lipids</td>
<td>PAHs</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Pesticides</td>
</tr>
<tr>
<td>Copper</td>
<td>PCBs</td>
</tr>
<tr>
<td>Selenium</td>
<td>Butyltins</td>
</tr>
<tr>
<td>Mercury</td>
<td></td>
</tr>
</tbody>
</table>

Tier III: Bioaccumulation test termination

Removing large polychates from test sediment

ERDC method for Lumbriculus:
Worms self-extract out of detritus into a gravel column
Beyond the benthos: Bioaccumulation in fish, wildlife and humans

Bioaccumulation data interpretation and conclusions

Bioaccumulation test: DM vs. reference site
Interpreting Bioaccumulation Data

Toxicological relevance

Bioaccumulation above threshold levels may cause biological impairments

Should bioaccumulation data be used as additional line of evidence for adverse impact to the benthos?

- No. The benthic toxicity evaluation uses sensitive species and integrates the effects of all contaminants present in the sediment

The focus of the bioaccumulation evaluation should be potential for exposure and toxicological impacts to higher trophic level organisms

- Food webs are complex
- Predation on benthic organisms is only one of the many sources of exposure for fish
- The disposal site represents only a portion of the entire forage area for most fish species
Tier III: Interpreting Bioaccumulation Data

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

**Assessment Factors**

- 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)
Interpreting Bioaccumulation Data

Magnitude of difference

Sources of variability
- Bioassay variability within lab (replicates): typically low
- Interlab bioassay variability: unknown
- Interlab analytical variability: unknown
- Consequently, statistical differences are detected when the magnitude of difference (MOD) is low [e.g., between 1 and 2]

Does statistical difference equates to biological/ecological significance?

ASTM (2010): “Although there is no consensus concerning what constitutes an acceptable minimum difference, it is suggested that the bioaccumulation experiment be designed to detect a two-fold difference between tissue residues in the test and control sediments or the test and reference sediments. A two-fold difference should provide a sufficient signal for ecological and human health concerns in most cases.”
Interpreting Bioaccumulation Data

Toxicological relevance regarding biomagnification and food web 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 biomagnify
  - 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 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.
- Option to use spatially-explicit exposure concentrations
- For SF Bay: compare with ambient fish tissue concentration (shiner surfperch and white croaker)
- 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 evaluation for Douglas Harbor, Alaska

- The concentrations of mercury in Douglas Harbor Marina sediment are elevated in comparison to reference.
- No acute, chronic, or sublethal toxicity was observed.
- Project sediment bioaccumulation 4x > reference.
- Site specific evaluation (Tier IV) of the risks associated with the consumption of contaminated fish and shellfish was conducted.

<table>
<thead>
<tr>
<th>Area</th>
<th>Hg concentration (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ref</td>
<td>0.00</td>
</tr>
<tr>
<td>Area 1</td>
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</tr>
<tr>
<td>Area 2</td>
<td>0.10</td>
</tr>
<tr>
<td>Area 4A</td>
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</tr>
<tr>
<td>Area 4B</td>
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</tr>
<tr>
<td>Lower</td>
<td>0.25</td>
</tr>
<tr>
<td>Weighed Avg</td>
<td>*</td>
</tr>
</tbody>
</table>

* * *
• Despite the small volume of dredged material (40,000 cy) and the size of the disposal site (4.5 acres), the risk assessment used very conservative assumptions.

• Tier III benthic *Macoma* bioaccumulation was used for Level 2 trophic level organisms and ecosystem-wide biomagnification factors were used to estimate Level 3 and 4 trophic level values.

• Tier IV evaluation demonstrated that the uptake of mercury into the tissues of higher trophic levels species does not pose an unacceptable risk to fishermen.
- Tier IV evaluation concluded no risk and section 404(b)(1) evaluation determined open-water disposal to be the least damaging to the environment.

- However, the community was highly concerned with creation of a mercury hot spot in the channel and disagreed with unrestricted open-water disposal, pressuring federal and state regulators for a more conservative outcome.

- To alleviate concerns regarding mercury contamination, the final decision included capping of the Gastineau Channel disposal site and post-dredging capping of Douglas Harbor.
Conclusions

• Complexity and lack of detailed interpretative guidance leads to high conservatism when interpreting bioaccumulation data

• Biological and ecological significance should be explicitly considered

• Using historic data for selecting COCs and test species makes sense and can be highly cost-saving
Discussion Questions

Water Column:
1. Are test species appropriate and relevant to the site?
2. Do you see bin size restrictions? Is ammonia a real CoC?
3. Purpose of using application factors (AFs)? Acute/Chronic? Species protection? Would chronic data eliminate need?

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Discussion Questions

Bedded Sediment:
1. Should passive sampling be used during testing to determine contaminant bioavailability to support evaluation of confounding factors and predict bioaccumulation?
2. Should toxicity and bioaccumulation be used as lines of evidence in a weight of evidence approach?
3. Should biological and ecological significance derived from a conceptual site model (e.g., spatial scale) be used?
4. Are “bioaccumulation trigger” values, as used in the Pacific Northwest, useful or overly conservative?

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