Benthic Toxicity Evaluations

J. Daniel Farrar

US Army ERDC, Vicksburg, MS

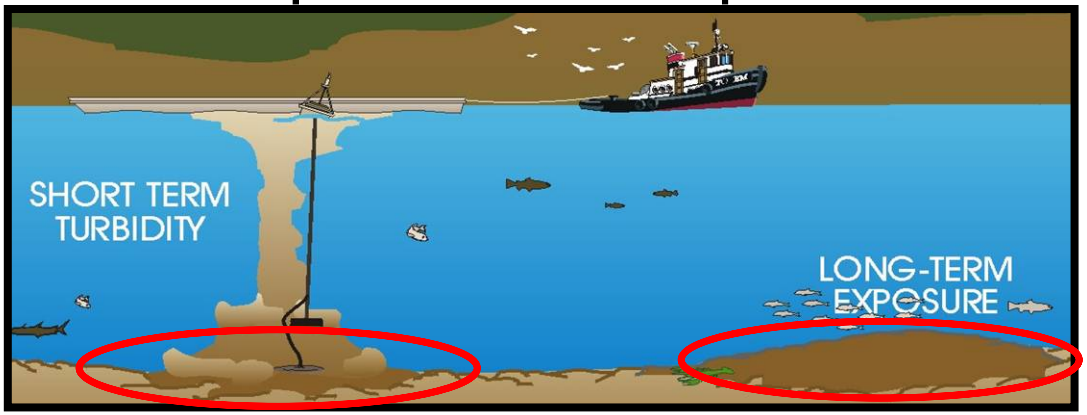
E-Mail: Daniel.Farrar@usace.army.mil

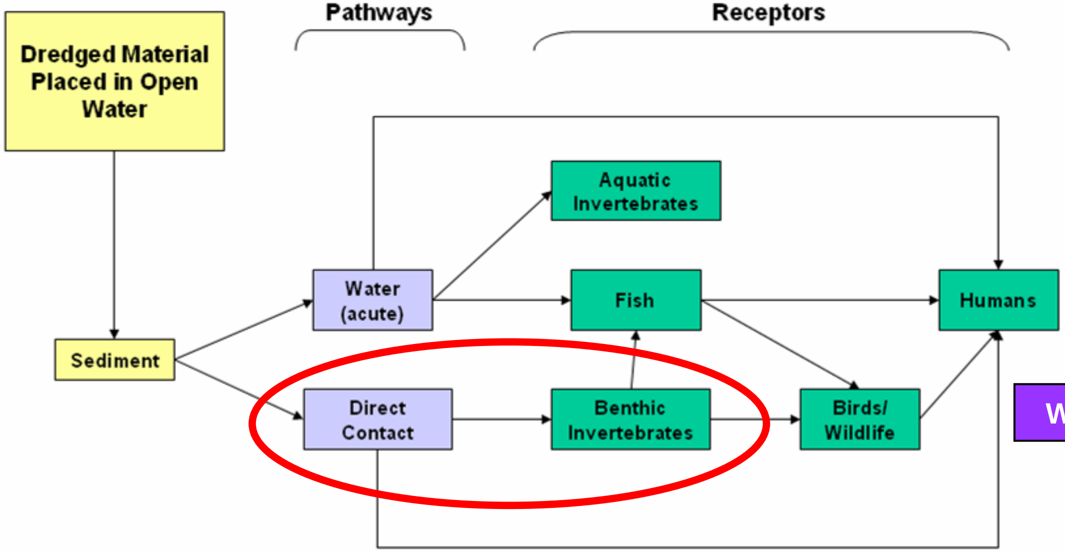
Benthic Toxicity Evaluation (Approach)

- **Main points**
  - **Assess potential for toxicity of DM following open water disposal**
  - **Concerned with toxicity from direct contact with DM at disposal site**
    - **Will DM placement result in an unacceptable risk at the disposal site?**
  - **Benthic Toxicity Evaluations provide additional lines of evidence in the decision making process.**

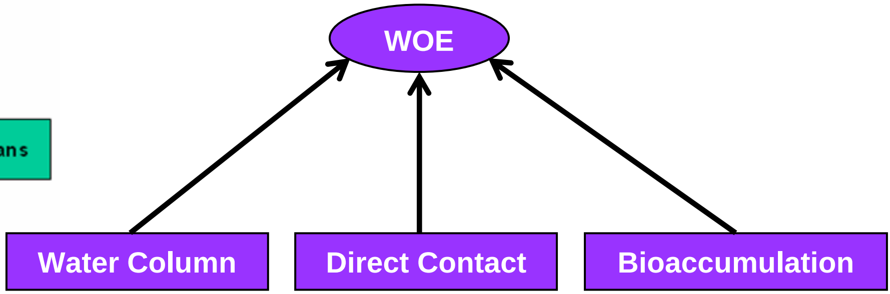
Benthic Toxicity Evaluation Conceptual Model

Evaluate potential of DM disposal for adverse effects on benthic organisms





Process

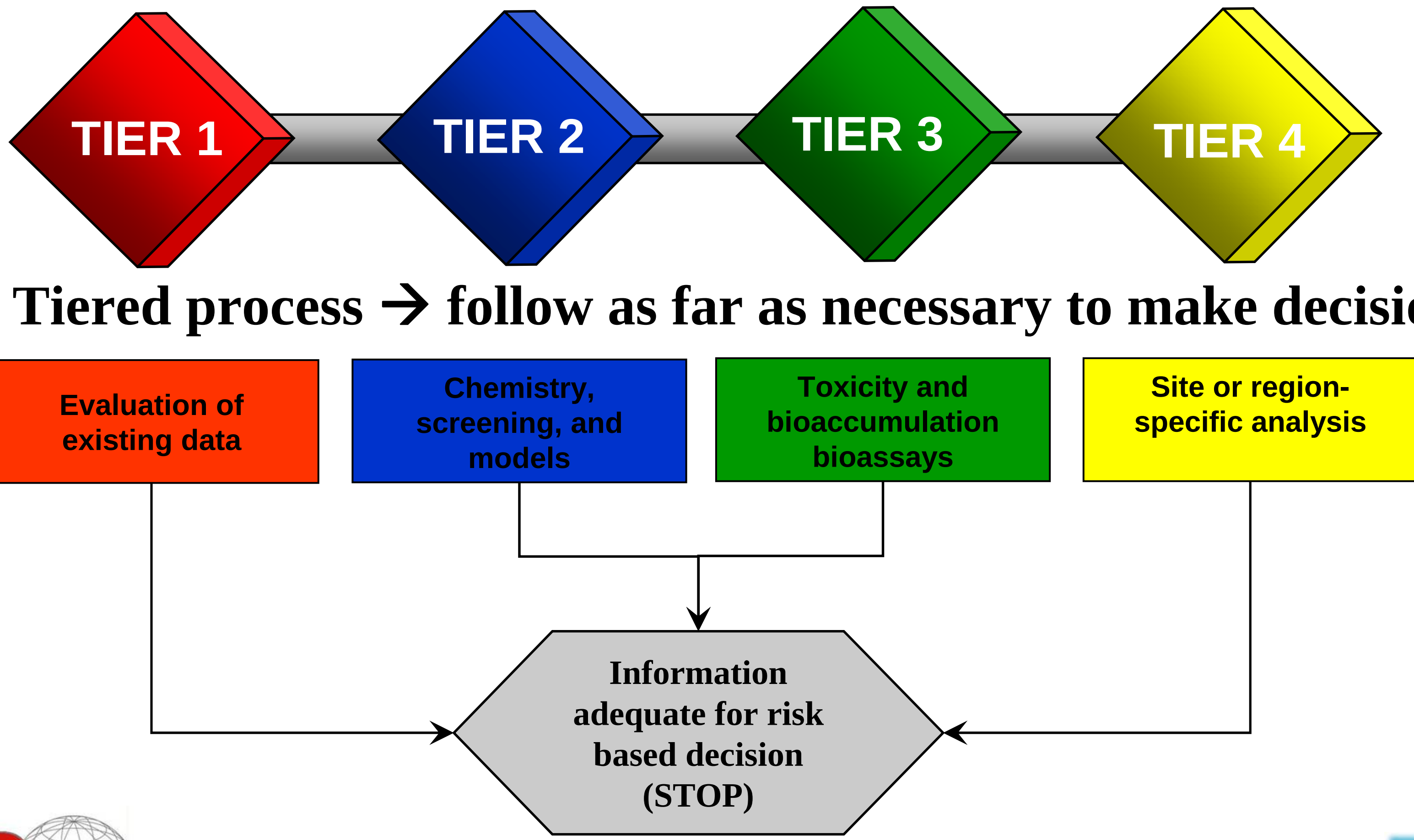


Lines of Evidence

Benthic Toxicity Evaluation

Increasing information and cost

Procedure



Benthic Toxicity Evaluation (Sediment Quality Guideline Values)

- **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**
- **Provides an additional LOE for determining risk to the benthos associated with DM disposal**

http://www.setac.org/htdocs/files/SQGSummary.pdf

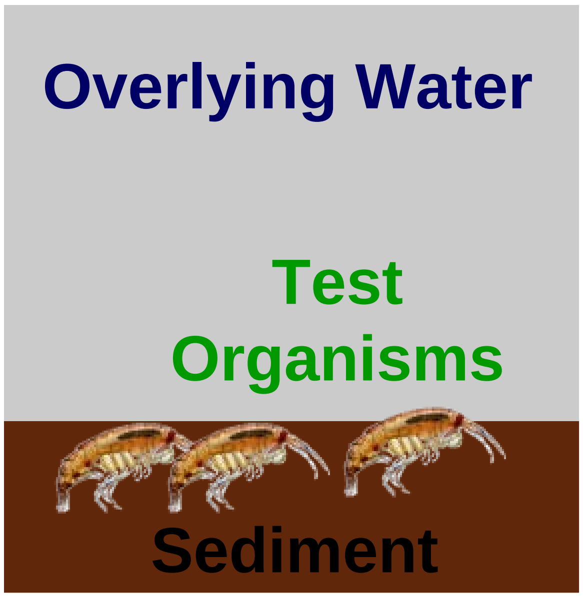
Benthic Toxicity Evaluation (Reference Sediment)

- 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

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**

Tier III: Biological Testing Summary



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

Tier III: 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

Tier III: 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

Tier III: 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)

- Required to utilize at least one “benchmark” or recommended species

Tier III: Marine/Estuarine Test Species (Amphipods)

*Leptocheirus plumulosus**

*Ampelisca abdita**

*Eohaustorius estuarius**

*Rhepoxynius estuarius**

*** = Recommended species**

Tier III: Marine/Estuarine Test Species (Polychaetes)

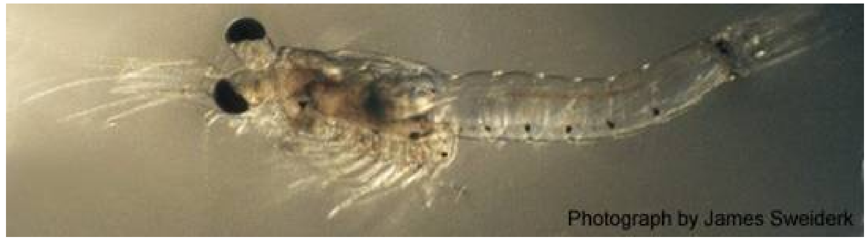
*Neanthes arenaceodentata**

Nereis virens

* = Recommended species

Tier III: Marine/Estuarine Test Species (Other Invertebrates)

Mysid shrimp



***Americamysis* sp.**

Clams

Panaope generosa

Copepods

Amphiascus tenuiremis

Grass shrimp

***Palaemonetes* sp.**

Tier III: Freshwater Test Species

Amphipods

*Hyalella azteca**

Midges

*Chironomus tentans**
*Chironomus riparius**

Oligochaetes

Tubifex tubifex

Mayfly

Hexagenia limbata

* = Recommended species

Tier III: Commonly Used Test Species (Marine/Estuarine)

Species	Group	Users
Ampelisca abdita	Amphipod	Many
Leptocheirus plumulosus	Amphipod	Many
Euhastorius estuarius	Amphipod	Many
Rhepoxinius abronius	Amphipod	Many
Neanthes arenaceodentata	Polychaete	Few
Panope generosa	Clam	Few
Nereis virens	Polychaete	Few
Palaemonetes sp.	Grass shrimp	Few
Grandidierela japonia	Amphipod	Few

Tier III: Commonly Used Test Species (Freshwater)

Species	Group	Users
Hyalella azteca	Amphipod	Many
Chironomus tentans or C. *riparius*	Midge	Many
Hexagenia limbata	Mayfly	Few
Lumbriculus variegatus	Oligochaete worm	Few
Tubifex tubifex	Oligochaete worm	Few

Tier III: Non-contaminant Factors

- Sediment grain size
- Salinity
- Ammonia / Sulfide toxicity

Tier III: Data Evaluation

- **Mortality in dredged material is 10% greater than reference (20% for amphipods), <u>and</u> Statistically different from reference?**
  - **If No, material is not predicted to be toxic**
  - **If Yes, material is predicted to be toxic**

TIER IV: Case Specific Studies

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

TIER IV: Case Specific Studies

- **When to conduct a Tier IV evaluation?**

  -Examples:

  - **Positive toxicity results not supported by chemistry (i.e, no anthropogenic contaminants). Conduct a TIE?**
  - **Concerns that exposure duration may not be adequate in a acute test for the COC. Conduct a chronic sublethal test?**
  - **Chemistry suggests that sediment should be toxic but test results are marginal. Concerned that contaminant may not have reached steady state. Conduct a chronic sublethal test?**

Chronic Sublethal Toxicity Tests

- Definitive method for evaluating marginally contaminated dredged material
- Direct means of assessing long-term exposures
  - Especially relevant to highly hydrophobic contaminants
- Exposures can be more representative of field conditions (i.e., longer than 10 days)
- Sublethal endpoints are ecologically relevant
- Can provide greater discriminatory ability

Acute Versus Chronic Toxicity Tests

- **Acute toxicity**
  - Short-term exposure (hrs-days)
  - Older organisms
  - Lethality endpoint
  - Higher levels of contamination

- **Chronic toxicity**
  - Longer-term exposure (days-weeks)
  - Early life stages
  - Sublethal endpoints (growth, reproduction)
  - Lower levels of contamination

Acute versus Chronic Toxicity Tests

L. plumulosus Comparison of Acute and Chronic Tests

	10-d		28-d	
Compound	LC_{50}	LOEC	LC_{50}	LOEC
DANT	55.9	81	67.2	81
DDT	2.0	1.9	2.1	1.9
PCB-29	177.2	240	145.6	120
Lead	4.72	8	5.43	2
Fluoranthene	75.0	55.0	70.3	15.9

Chronic Marine/Estuarine Toxicity Tests

- ***Neanthes arenaceodentata*** **(28-day, survival, growth, >25‰)**
- ***Polydora cornuta*** **(14-day, survival, growth)**
- ***Leptocheirus plumulosus*** **(28-day, survival, growth, reproduction, 5-20 ‰)**

Neanthes arenaceodentata

Leptocheirus plumulosus

Chronic/Sublethal Freshwater Toxicity Tests

- ***Chironomus tentans*** **(10-day, survival, growth, <1‰)**
- ***Chironomus tentans*** **(>40-day, survival, growth, & reproduction, <1 ‰)**
- ***Hyalella azteca*** **(10 and 28-day, survival, growth, <1 ‰)**
- ***Hyalella azteca*** **(42-day, survival, growth, and reproduction, <1 ‰)**

Hyalella azteca

Chironomus tentans

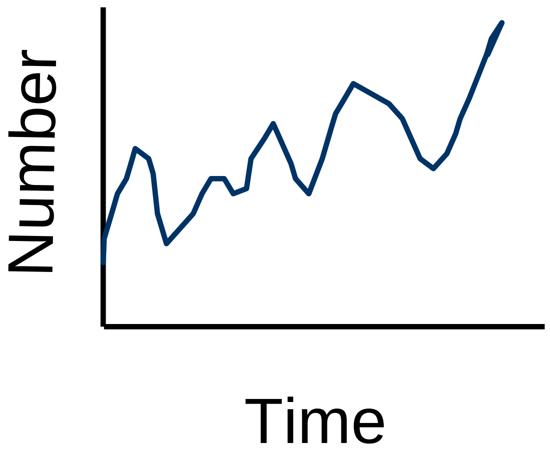
Ecological Meaning of Chronic and/or Sublethal Toxicity?

- **The meaning of acute toxicity test results is prescriptively defined**
  - **e.g., 20% plus statistical significance**
- **The meaning of chronic toxicity test results is currently undefined**
  - **e.g., what does a 10% reduction in growth mean in terms of population viability?**

Population Modeling

Individual >>>>>>>>>>> Population

-Survivorship
-Growth
-Reproduction



Chronic/sublethal Testing (Issues and Concerns)

- They cost more
  - Which is better, using a chronic test or getting twice the spatial coverage with an acute test?
- They are more likely to fail to meet performance standards
  - Necessitating retesting
- They are not always more discriminating than acute tests
  - e.g., sublethal endpoint variability and role of feeding
- Uncertainty on the ecological consequence of sublethal effects

Conclusions

- **<u>Main Goal</u>: Evaluate potential of DM to cause adverse effects on Benthic organisms**
- **<u>Process</u>: Evaluate SQG and toxicity test data to develop LOEs of the risk associated with DM disposal**
- **<u>Procedure</u>: Follow tiered process only as far as necessary to make a risk based decision**