**Water Column Evaluation**

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**KEY WORDS:** Limiting Permissible Concentration (LPC), Water Quality Criteria (WQC), Mixing Zone, Elutriate

**Issues**

• Evaluation of potential environmental impact from dredged material disposal
  – Assess presence of contaminants
  – Determine the concentration of contaminants and relate to applicable State Water Quality Standards or Federal Water Quality Criteria
  – Evaluate potential for contaminants to cause adverse effects on organisms inhabiting water column
Water Column Evaluation

**Approach**

- Tiered process (I - IV) as far as necessary to make a factual determination
- Factual determination
  - A determination of the potential short-term and long-term effects of a proposed discharge of dredged or fill material on the physical, chemical, and biological components of the aquatic environment.
  - Water column evaluations are only short-term
TIER II: Physical/Chemical Testing

- Concentration of contaminant in water column after dumping dredged material must meet **Limiting Permissable Concentration** (Ocean) or **Water Quality Standards** (Inland Waters)
  - LPC is concentration of contaminant after mixing that will not exceed applicable WQC/WQS (at all times for area outside mixing zone) (4 hours after mixing within zone)
  - In case of synergy/no applicable WQC/WQS, LPC is 0.01 (1%) of acutely toxic concentration of DM

[Diagram showing mixing zone and sediment]
TIER II: Physical/Chemical Testing

Two-Step Process

• Step One
  – Screening step, assumes 100% of all contaminants measured in DM are released to water column

• Step Two
  – Utilize results from chemical analysis of elutriate prepared from DM and compare to LPC/WQS

• Both steps utilize a predictive numerical model

TIER II: Physical/Chemical Testing

Step One

• Chemical analysis of dredged material for COC
• Assume 100% of contaminants released into water column and apply mixing model

Predicted Concentration from Model

Conc < LPC/WQS, OK
Conc > LPC/WQS, Evaluate Elutriate
TIER II: Physical/Chemical Testing

Step Two
- Obtain elutriate from DM, elutriate is the resulting material from “washing” the DM
- Analyze elutriate for COC
- Apply elutriate chemical analysis data into mixing model

Collecting DM elutriate
- 4 parts water * 1 part DM (volume)
  - Mix Thoroughly 30 Min
  - Settle for 1 hour
  - Centrifuge Supernatant ** (2,000 x g for 30 min)
  - Chemical Analysis of Dissolved Components of Elutriate

* Water is obtained from the dredging site
** Filtration can be used in place of centrifugation
TIER II: Physical/Chemical Testing

• Apply elutriate chemical analysis data into mixing model

Three possible conclusions

• DM meets LPC (WQC) at all times beyond boundaries of mixing zone, and 4 hours after dumping within mixing zone
• DM exceeds LPC, no further testing
• LPC is met; however, more than one contaminant is present (possible synergy) or no WQC are available for contaminants present in DM… …Move to Tier III
TIER III: Biological Testing

• Evaluate toxicity of DM elutriate
• Conduct these tests if:
  – Tier I evaluation suggests the DM may contain contaminants that might result in adverse effects
  – Potential for synergistic interactions between chemicals identified in DM elutriate
  – No WQS for contaminants of concern
  – No factual determination has been made

TIER III: Biological Testing

• Prepare elutriate as previously described
• Compare survival of organisms in dilution water and diluted elutriate water
  – Determine concentration that results in 50 percent mortality ($ LC_{50}$)
  – Apply toxicity data into mixing model (STFATE, CORMIX)
Selection of Toxicity Test Species

- Three species of different phyla should be utilized (two are a minimum)
- One should be a routinely utilized benchmark species
- Species should be representative of organisms that inhabit the disposal site

Factors to consider:

- Sensitivity to contaminants (age)
- Sensitivity to non-contaminant factors (dissolved oxygen, handling)
- Standardized protocol
- Ecologically relevant
- Availability of organisms
Candidate Toxicity Test Species

**Crustaceans**

- Shrimp
  - *Mysidopsis* sp. (N)
  - *Neomysis americana* (N)
  - *Holmesimysis costata* (N)
  - *Palaemonetes* sp. (N)
  - *Pandalus* sp. (N)
  - *Penaeus* sp. (N)

- Cladocerans
  - *Daphnia magna* (F)
  - *Daphnia pulex* (F)
  - *Ceriodaphnia dubia* (F)

- Crabs
  - *Callinectes sapidus* (N)
  - *Cancer* sp. (N)

* = Benchmark species, F = Freshwater <1o/oo, E = Estuarine 1-25o/oo, N = Near coastal >25o/oo

**Fish**

(Continued)

- Silversides, *Menidia* sp. (N,E)
- Sheepshead minnow, *Cyprinodon variegatus* (N)
- Speckled sanddab, *Citharichthys stigmaeus* (N)
- Grunion, *Leuresthes tenuis* (N)
- Fathead minnow, *Pimephales promelas* (F)
- Bluegill Sunfish, *Lepomis macrochirus* (F)
- Channel catfish, *Ictalurus punctatus* (F)
- Rainbow trout, *Oncorhynchus mykiss* (F)
- Shiner perch, *Menidia* sp. (N)
- Pinfish, *Lagodon rhomboides* (N)
- Dolphinfish, *Coryphaena hippurus* (N)
Candidate Toxicity Test Species

(Continued)

Bivalves
- Larvae/Adult Oyster *
  *Crassostrea sp. (N,E)
- Larvae/Adult Mussel *
  *Mytilus edulis (N,E)

Echinoderms
- Sea Urchins Larvae
  *Lytechinus pictus (N) *
  *Strongylocentrotus sp. (N) *
- Sand Dollar
  *Dendraster sp. (N) *

Copepods
*Acartia sp. (N) *

Commonly Used Test Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Group</th>
<th>Users</th>
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<tbody>
<tr>
<td>Mysid Shrimp</td>
<td>Crustacean</td>
<td>Many</td>
</tr>
<tr>
<td>Atlantic silverside</td>
<td>Fish</td>
<td>Many</td>
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<tr>
<td>Inland silverside</td>
<td>Fish</td>
<td>Many</td>
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<tr>
<td>Sea urchin (arbacia)</td>
<td>Echinoderms</td>
<td>Few</td>
</tr>
<tr>
<td>Sand dollar</td>
<td>Echinoderms</td>
<td>Few</td>
</tr>
<tr>
<td>Commercial Shrimp (Penaeus)</td>
<td>Crustacean</td>
<td>Few</td>
</tr>
<tr>
<td>Grass shrimp</td>
<td>Crustacean</td>
<td>Few</td>
</tr>
<tr>
<td>Coot clam (Mulinia)</td>
<td>Bivalve</td>
<td>Few</td>
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<tr>
<td>Hardshell clam (Mercenaria)</td>
<td>Bivalve</td>
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</table>
Commonly Used Test Species
Freshwater

<table>
<thead>
<tr>
<th>Species</th>
<th>Group</th>
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<tbody>
<tr>
<td><em>Fathead minnow</em></td>
<td>Fish</td>
<td>Many</td>
</tr>
<tr>
<td><em>Daphnia</em></td>
<td>Cladoceran</td>
<td>Many</td>
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<td><em>Rainbow trout</em></td>
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</table>

TIER III: Biological Testing

**Test Design**
- At least 3 concentrations
- control survival > 90%
- 5 replicates
- 10 organisms/replicate
- 48- to 96-hour duration
Data Analysis

Compare dilution water to 100% elutriate (t-test if greater than 10%) → If not significantly different, elutriate meets LPC

Transform data (arcsine) and calculate 50% lethal concentration (LC_{50}). Utilizing model, determine if concentration outside mixing zone exceeds 0.01 of the LC_{50}.

Elutriate exceeds LPC → Elutriate meets LPC

Data Analysis: Step 1

Step 1. Is 100% elutriate different from dilution water

Example:

- 100% Elutriate = 60% Survival
- Dilution water = 95% Survival

Difference is greater than 10%
Statistical test (t-test) result is significantly different
Next step: determine LC_{50} value and model dilution
1. Determine LC$_{50}$

LC$_{50}$ is 40%  
Multiply 40% by 0.01 to determine maximum allowable concentration (40% x 0.01) = 0.4%

2. Model dilution of effluent from CDF or DM in mixing zone

Model demonstrates DM outside of mixing zone will be less than 0.1% and will be less than 0.1% within the mixing zone after 4 hours

DM will be diluted to lower concentration (0.1%) than maximum allowable concentration (0.4%) Dredged material elutriate does not exceed WQC or LPC

TIER IV: Case-Specific Studies

- Implemented when lower tiers do not provide enough information to make a factual determination
  - Inconclusive test results
  - Conflicting evidence
  - Ammonia suspected
- Specific studies may include:
  - Different species
  - Different endpoints (reproduction, growth, etc.)
  - In situ exposures
Water Column Evaluations

Conclusions

• Main Goal: Evaluate for potential to cause adverse effects on organisms inhabiting water column
• Follow tiered process only as far as necessary to make a factual determination

Pictures were obtained from Engineer Research Development Center, Carolina Biological Supply online catalog (http://www3.carolina.com), Woods Hole Marine Biological Laboratory (http://www.mbl.edu/) Splash (www.splash.org)