Water Column Evaluation

Jeffery A Steevens

Email: steevej@wes.army.mil

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

Water Column Evaluation

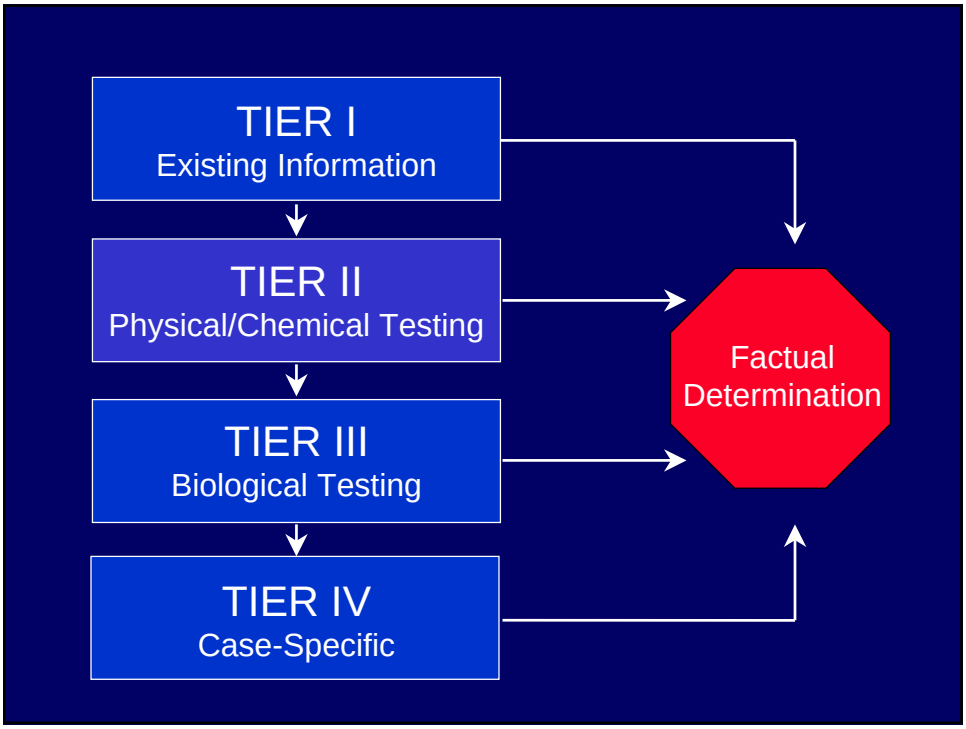
Issues

- 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

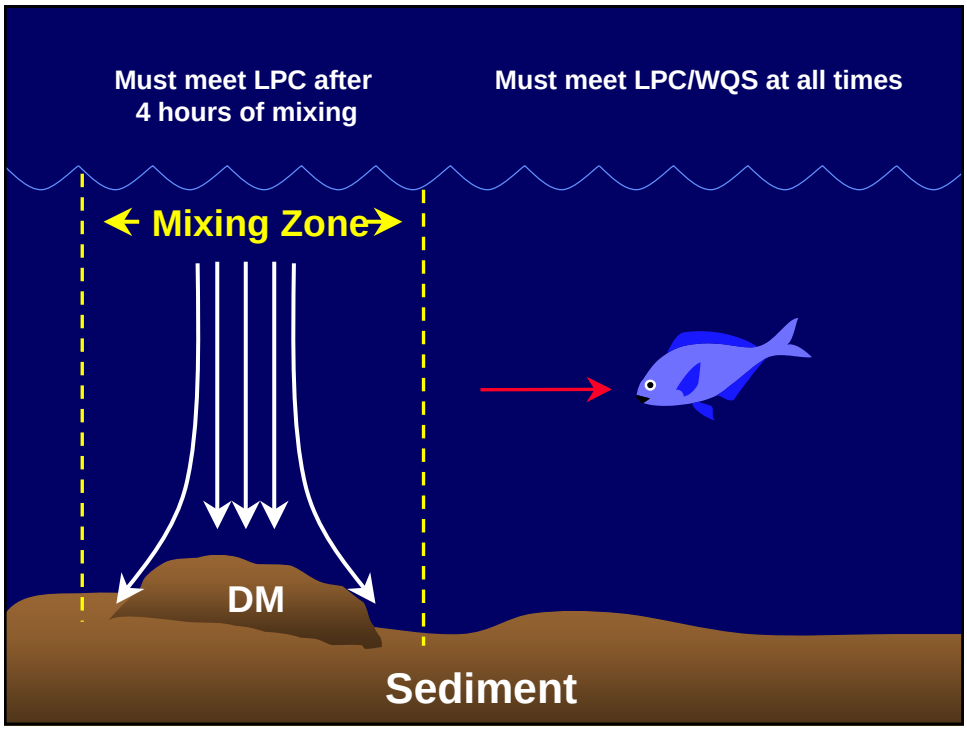
Approach

- 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



TIER II: Physical/Chemical Testing

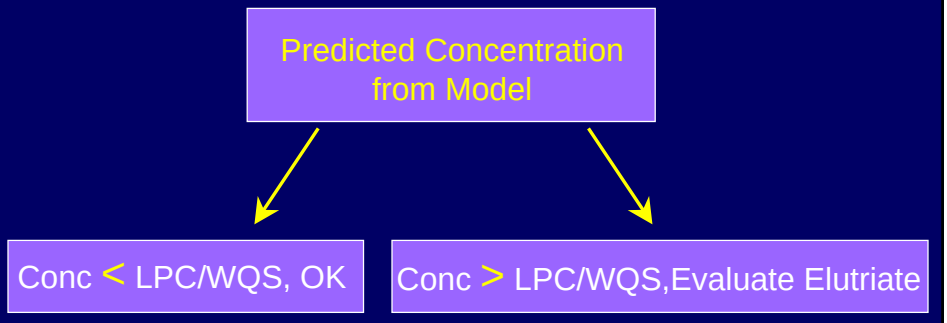
Two-Step Process

- 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



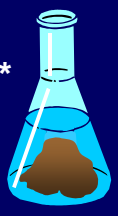
TIER II: Physical/Chemical Testing

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)**

↓

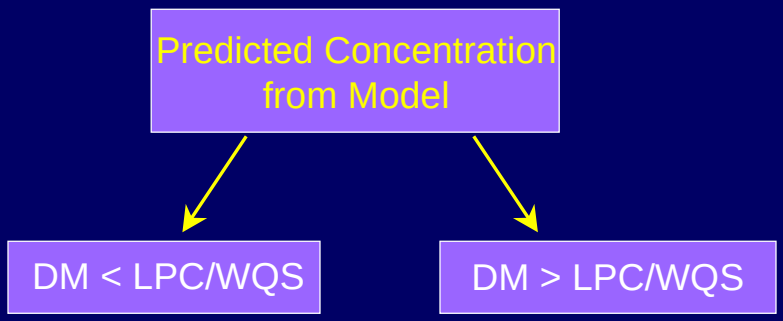
Chemical Analysis of Dissolved Components of Elutriate

*** 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



TIER II: Physical/Chemical Testing

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)

TIER III: Biological Testing

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

TIER III: Biological Testing

Selection of Toxicity Test Species

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)

Daphnia pulex

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

Candidate Toxicity Test Species

(Continued)

Fish

- Silversides, *Menidia* sp. (N,E) *
- Sheepshead minnow, *Cyprinodon variegatus* (N) *
- Speckled sanddab, *Citharicthys 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, *Coryhaena hippurus* (N)

Fathead minnow

Channel catfish

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) *

Mussel

Copepod

Sea Urchin Larvae

Commonly Used Test Species

Marine/Estuarine

Species	Group	Users
Mysid Shrimp	Crustacean	Many
Atlantic silverside	Fish	Many
Inland silverside	Fish	Many
Sea urchin *(arbacia)*	Echinoderms	Few
Sand dollar	Echinoderms	Few
Commercial Shrimp *(Penaeus)*	Crustacean	Few
Grass shrimp	Crustacean	Few
Coot clam (*Mulinia)*	Bivalve	Few
Hardshell clam *(Mercenaria)*	Bivalve	Few

Commonly Used Test Species

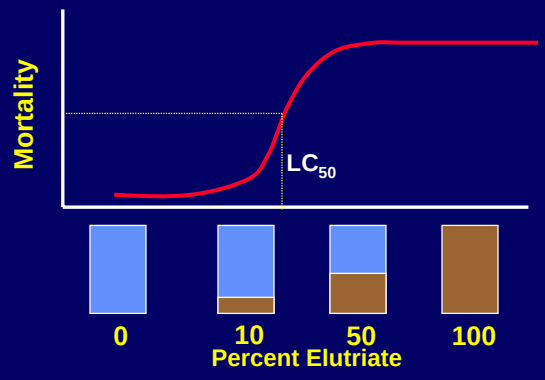
Freshwater

Species	Group	Users
Fathead minnow	Fish	Many
Daphnia	Cladoceran	Many
Channel catfish	Fish	Few
Rainbow trout	Fish	Few

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:

= 60% Survival

100% Elutriate

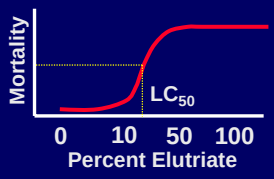
= 95% Survival

Dilution water

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

Data Analysis: Step 2

1. Determine LC_{50}



LC50 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)