Dredging Operations and Environmental Research

Improved Bioaccumulation Modeling

Preliminary Observations

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Contaminated Sediments in the United States

USACE Dredging and Contaminated Sediments

Impact on Navigational Dredging:

– Federal, state, and regional requirements that dredging won’t significantly degrade aquatic resources and must minimize adverse impacts.

– USACE and USEPA Guidelines for Dredged Material Disposal require an assessment of the potential for aquatic organisms to bioaccumulate sediment-associated contaminants.

– USACE has developed foodweb bioaccumulation models (e.g., trophic trace, fishrand-migration) to address requirements.

Potential risks from contaminated sediments have a large impact on ability to dredge and create the need to evaluate bioaccumulation:

– Dioxin-contaminated dredged material from New York/New Jersey Harbor and Puget Sound;
– PCB-contaminated material from Portland Harbor (OR);
– PAH-contaminated material in Boston Harbor and Portland Harbor (ME).
Project Objectives

• Review the application of foodweb bioaccumulation models to inform, expedite, and improve USACE approaches.

• Mine the millions of dollars used to apply these models at sites to
  – Understand model output and its value
  – Determine detrimental/beneficial practices
  – Avoid mistakes
  – Avoid unnecessary expenditures.

➔ Product: Improved USACE models and approaches.
Bioaccumulation Modeling Overview

- Toxicant in water: fate processes either internal or external to model
- Partitioning
- Toxicant in food sources
  - Organic sediments
  - Algae
- Uptake through gill:
  - respiration rate
  - assimilation efficiency
- Uptake from diet:
  - consumption rates
  - assimilation efficiency
  - growth rates
  - toxicity
  - lipid content
  - food web structure
- Losses of toxicant:
  - biotransformation
  - predation
  - mortality
  - depuration
  - spawning
  - promotion
  - emergence

Source: Imhoff et al. (2004)
Bioaccumulation Modeling Overview

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\[
C_0 = \frac{(k_1 \times m_0 \times C_{WD}) + (k_1 \times m_P \times C_{WD,P}) + (k_0 \times \sum P \times C_{D,I})}{(k_2 + k_E + k_C + k_u)}
\]

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Toxicant in food sources:
- Organic sediments
- Algae

Partitioning
Bioaccumulation Modeling
Equations for Predicting PCB Concentrations in Fish

\[
C_{\text{WD}} = \frac{C_{\text{WT}}}{[1 + (\chi_{\text{POC}} \times D_{\text{POC}} \times \alpha_{\text{POC}} \times K_{\text{OW}} + \chi_{\text{DOC}} \times D_{\text{DOC}} \times \alpha_{\text{DOC}} \times K_{\text{OW}})] \times 1000}
\]

\[
G_{\text{D}} = 0.022 \times W_{0}^{0.05} \times e^{(0.06 \times T)}
\]

\[
V_{\text{VCD}} = P_{P} \times V_{\text{OCP}} + P_{\text{SED}} \times O_{\text{SED}}
\]

\[
V_{\text{ND}} = \sum P_{i} \times V_{\text{WB},i}
\]

\[
G_{F} = [(1-\varepsilon_{L}) \times V_{\text{LD}} + (1-\varepsilon_{N}) \times V_{\text{OCD}} + (1-\varepsilon_{N}) \times V_{\text{ND}} + (1-\varepsilon_{W}) \times V_{\text{WD}}] \times G_{D}
\]

\[
E_{D} = (3.0 \times 10^{-7} \times K_{\text{OW}} + 2.0)^{-1}
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Improved Bioaccumulation Modeling Project

I: State of the Science: Application Survey

Evaluate the application of food web bioaccumulation models at 4 sediment megasites: Fox River, WI; Housatonic River, MA; Hudson River, NY; and Lower Duwamish River, WA.

At these sites, review: purpose of modeling; model used; organisms evaluated; areas predicted; calibration and validation procedures; uncertainty analysis; consideration of spatial variability; linkage to environmental fate and transport models.

II. Bioaccumulation Model Improvement
Bioaccumulation Modeling

Common Uses at Contaminated Sediment Sites

• Estimate fish tissue contaminant concentrations based on contaminant concentrations in sediment and water.

• Forecast the effect that contaminated sediment will have on fish tissue concentrations.

• Develop risk-based sediment cleanup levels.
“Where numerical models are used, verification, calibration, and validation typically should be performed to yield a scientifically defensible modeling study”

- **Verification**: Establishing that the model’s code does what it purports and that it’s consistent with the theory behind the model.
- **Calibration**: The process of using site-specific information from a historical period to adjust model parameters and obtain optimal agreement between measured and modeled data.
- **Validation** refers to running the calibrated model on an independent data set to establish that the calibrated model is predictive of independent conditions.

Source: EPA (2005)
Bioaccumulation Models
Housatonic River; Mature Largemouth Bass

(Mature Fish Aged 6+ Or Greater Only)
# Bioaccumulation Models

Housatonic River; Mature Largemouth Bass

## Calibration/Validation

<table>
<thead>
<tr>
<th>Period</th>
<th>Data sets</th>
<th># Fish</th>
<th>Validation Acceptability Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998 to 1999</td>
<td>1998, 1999</td>
<td>38 fish, 3 areas</td>
<td>Modeled fish mean should be within a factor of 2 in either direction of the measured fish mean</td>
</tr>
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<th>Period</th>
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<th>Site Report Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979-2004</td>
<td>1990, 1994, 2002</td>
<td>33 fish; 2 areas; Independent Data</td>
<td>Modeled performance was good</td>
</tr>
</tbody>
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Bioaccumulation Models
Fox River, WI, Little Lake Butte des Morts; Carp and Walleye
## Bioaccumulation Models
**Fox River, WI; Carp and Walleye**

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Discussion

• Value of model output.

• What level of confidence do the models afford that it’s predictions will be accurate?

• Can similar information/confidence be provided via other less complex techniques?
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