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# Bioaccumulation Evaluations

**Jacob K. Stanley, Ph.D.**

U.S. Army ERDC, Vicksburg, MS

Environmental Laboratory

E-mail: [jacob.k.stanley@us.army.mil](mailto:jacob.k.stanley@us.army.mil)



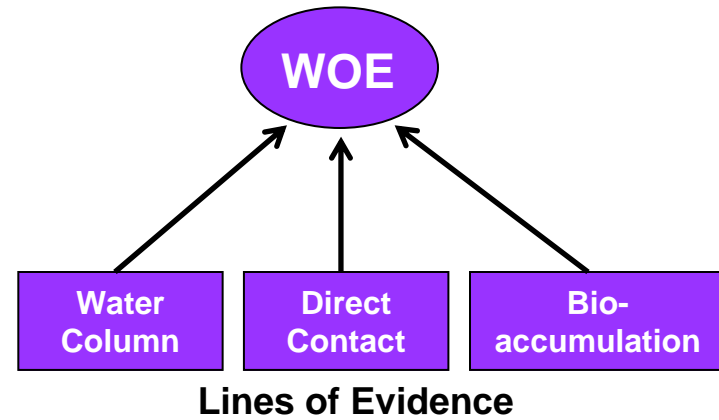
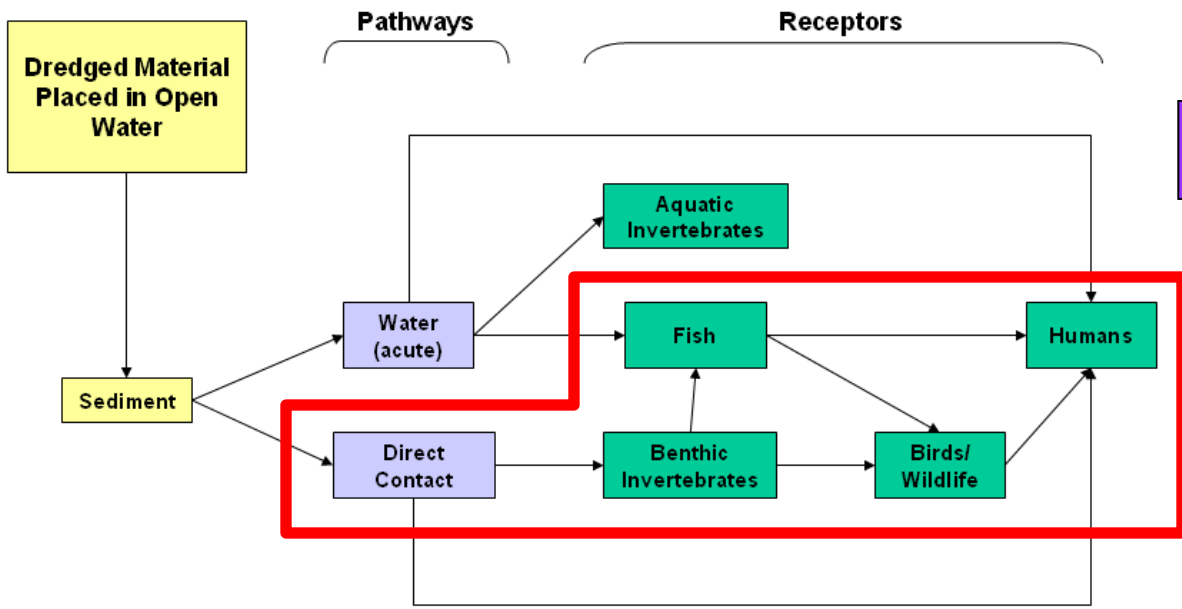
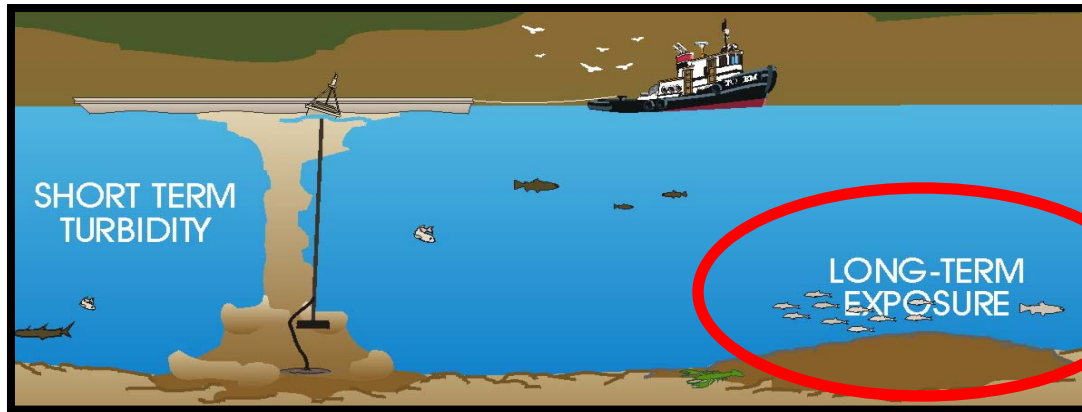
# Bioaccumulation Evaluations

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- One line of evidence to support assessment of risk of dredged material
- Used to estimate risk through trophic transfer of contaminants

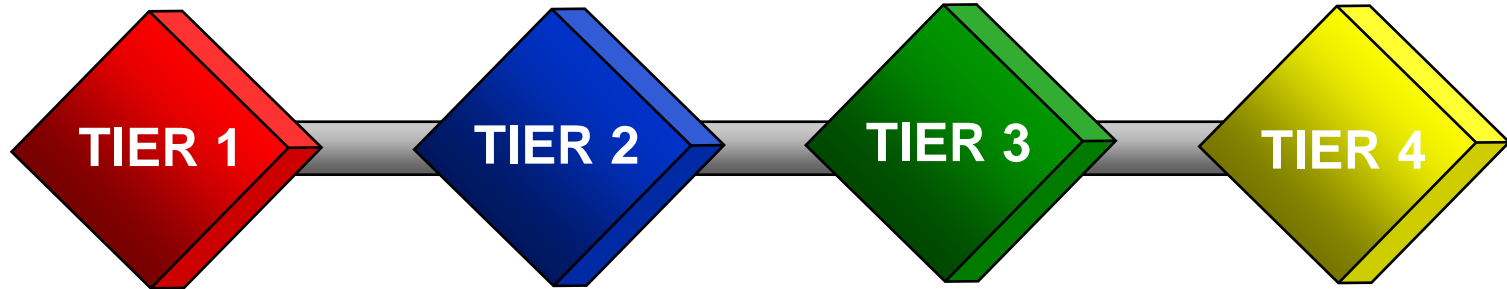


# Conceptual Model

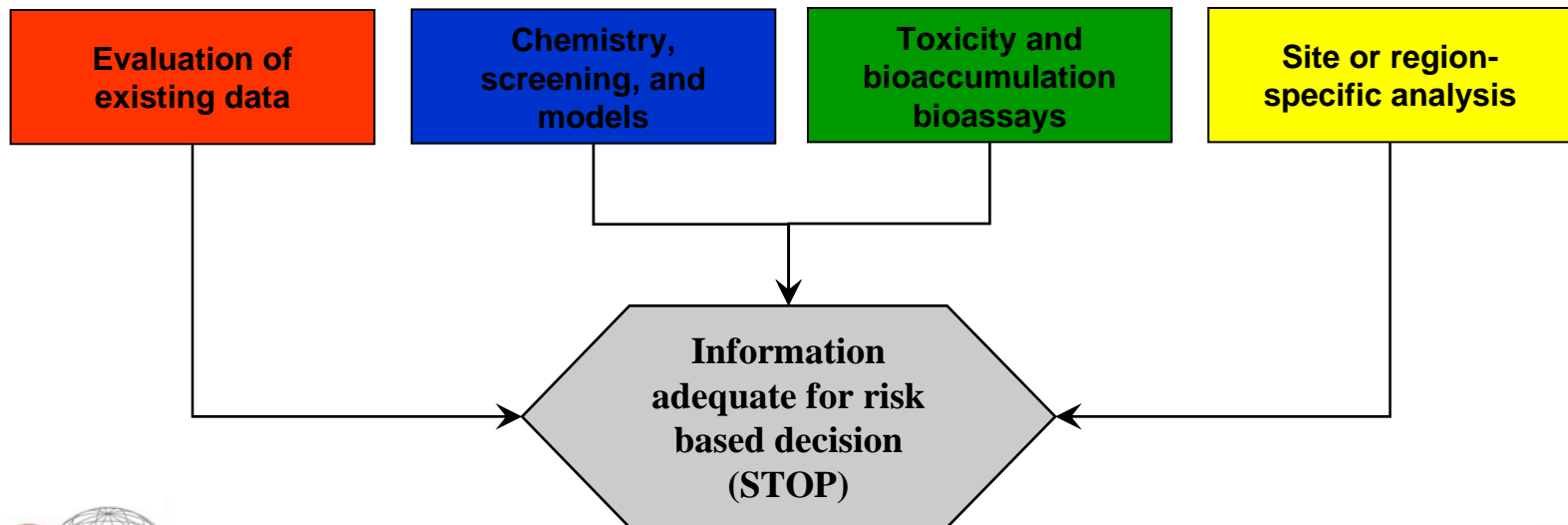


# Bioaccumulation Evaluation

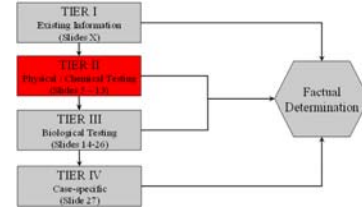
→  
Increasing information and cost



Tiered process → follow as far as necessary to make decision



# Tier II: Predicting Bioaccumulation

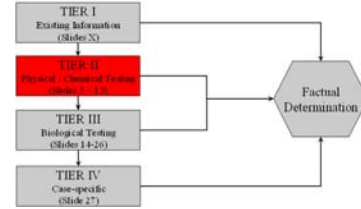


## Thermodynamically-based Theoretical Bioaccumulation Potential (TBP)

- An estimate of the steady-state concentration of non-polar organic chemicals in organisms exposed to contaminated sediment
- Used as a coarse screening tool to determine if bioaccumulation testing is warranted
- Compare TBP for Reference and DM
- Only works for non-polar (hydrophobic) organics
  - PAHs, PCBs, Dioxins, Chlorinated pesticides



# Tier II: Predicting Bioaccumulation



$$\text{TBP} = \text{BSAF} \frac{C_s}{\% \text{TOC}} \times \% \text{L}$$

**BSAF** = biota/sediment accumulation factor

**C<sub>s</sub>** = conc. in sediment (any units)

**%TOC** = total organic carbon content of sediment

**%L** = lipid content of organism





# BSAF Database - <http://el.erdc.usace.army.mil/bsaf>

BSAF Database - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites Media

Address <http://el.erdc.usace.army.mil/bsaf/> Go Google .fda.gov/~rd/fdaact.html Search Web Open Links

# BSAF Database

(Your Source For Biota-Sediment Accumulation Factor and Lipid Data)

Technical Point of Contact: [Mr. Charlie Lutz Email](#)

[U.S. Army Corps of Engineers](#) | [Engineer Research and Development Center](#) | [Environmental Laboratory](#) | [Search EL](#)

Search For:

BSAF Data	Lipid Data	Reference
<ul style="list-style-type: none"><li><a href="#">By Organism</a></li><li><a href="#">By Chemical</a></li><li><a href="#">Benthic BSAFs with Statistics</a></li></ul>	<ul style="list-style-type: none"><li><a href="#">By Organism</a></li></ul>	<ul style="list-style-type: none"><li><a href="#">Search For A Reference</a></li><li><a href="#">Display All References</a></li></ul>

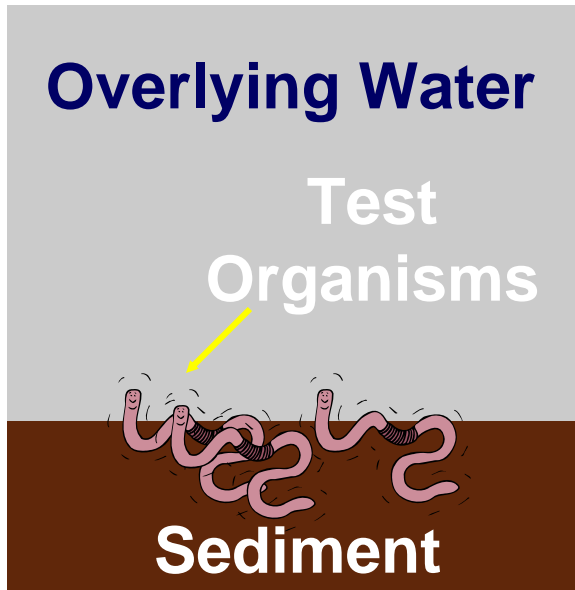
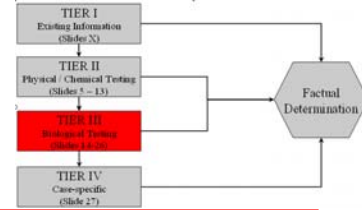
BSAF Background Information

[Dredging Operations Technical Support \(DOTS\) Program](#)

[Technology Transfer](#) | [What's New!](#)



# Tier III: Bioaccumulation Test

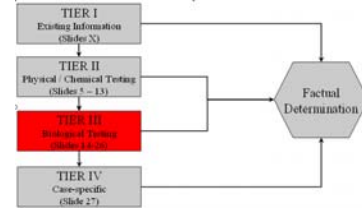


- Conduct whole-sediment bioaccumulation tests
- Compare DM to reference
- Accumulation of chemicals of interest in organisms as endpoint

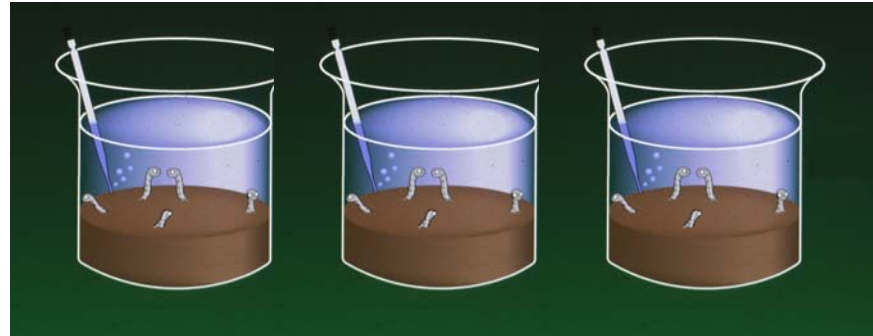




# Tier III: Bioaccumulation Test



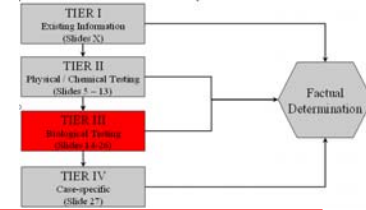
## Test Design



- Time Zero tissue analysis
- 28-day exposure
- No feeding
- Minimum 3 replicates/treatment
- Measure tissue concentration at conclusion of exposure

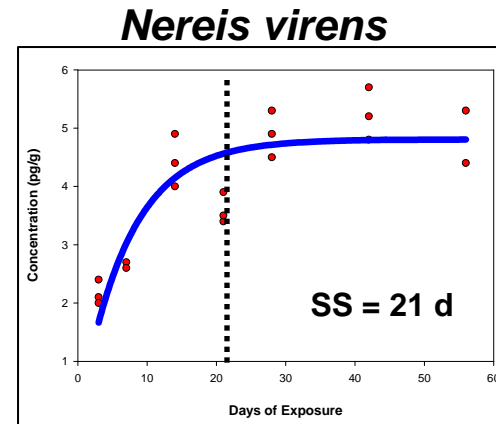
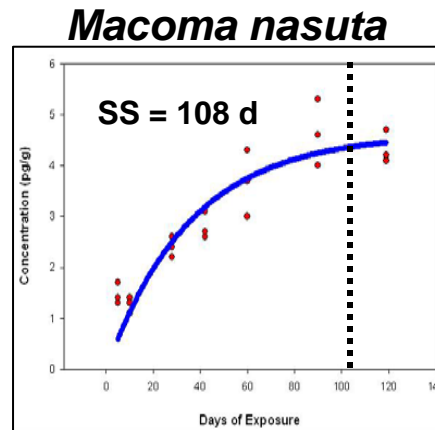


# Exposure duration



- **Steady State** – the concentration of contaminant that would occur in tissue after constant exposure conditions
- **SS will not always be reached in 28-d** depending on:
  - contaminant  $K_{ow}$
  - species

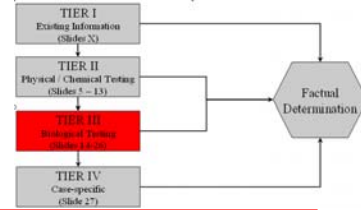
Example: 2,3,7,8 TCDF



- Most compounds will be detectable in tissue after 28-d, even if SS not reached.
- If needed, determinations of SS can be made in Tier IV



# Selection of Test Species



## Desirable characteristics

- Sediment ingester
- Infaunal
- Tolerant of contamination
- Easily collected or cultured
- Inefficient metabolizer (PAHs)
- Adequate biomass
- **2 species should / must be used**  
(CWA / MPRSA)



# Bioaccumulation Test Species

## Freshwater

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### Oligochaete



*Lumbricus variegatus*

### Amphipod



*Diporeia sp.*

### Clam



*Corbicula sp.*





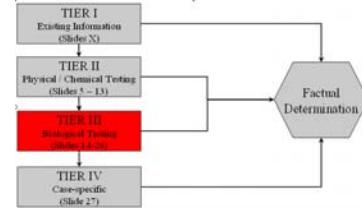
# Bioaccumulation Test Species

## Marine / Estuarine

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# Tier III: Bioaccumulation Test



## Conclusion of Exposure

- Collect all remaining/surviving organisms from exposure chambers
- Allow organisms to purge gut content or excise gut
- Conduct chemical analysis of tissues



# Interpreting Bioaccumulation Data

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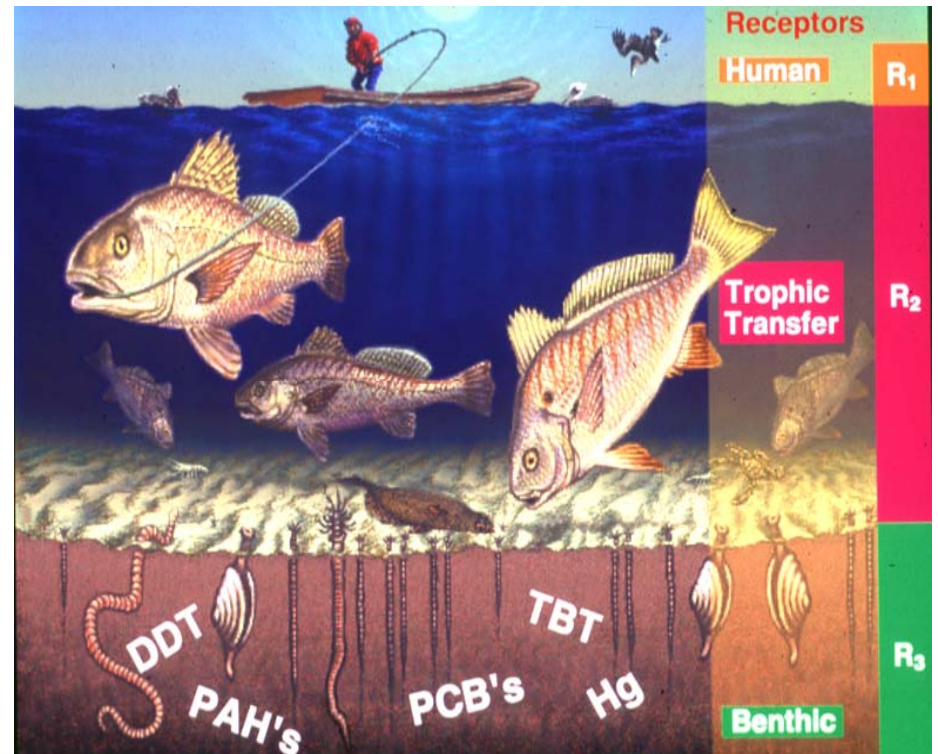
- Guidance recommends comparison to FDA action levels (limited utility)
- Compare bioaccumulation in DM vs. Reference Material
- Use residues to estimate food web transfer
- Compare residue in organism to effect values





# Food Web / Trophic Transfer

- Evaluate uptake of contaminants in food web and exposure for animals in food chain
- Trophic Transfer Models
  - Kinetics
  - Thermodynamics
  - Bioenergetics
- Used for predicting movement of contaminants in a “system”

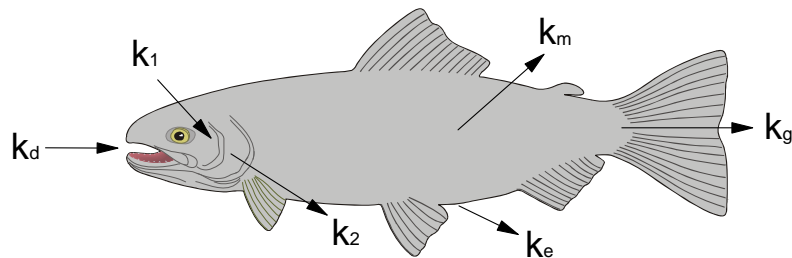


*“all models are wrong and some are useful”*



# Food Web Model: TrophicTrace

- Steady-state bioaccumulation model based on Gobas (1993 and 1995) for organics
- Uptake and trophic transfer of inorganics are modeled using empirical BCFs or Trophic Transfer Factors (TTF)



$$C_f = \frac{k_1 * C_{wd} + k_d * C_{diet}}{k_2 + k_e + k_m + k_g}$$

**TrophicTrace**  
Version 3.01 (January 2003)

The screenshot shows the TrophicTrace software interface. On the left, a food web diagram illustrates the flow of contaminants from Invertebrates and Sediment to Forage Fish, then to Piscivorous Fish, and finally to Piscivorous Birds and Humans. A label 'Direct uptake from dissolved water across gill' points to the Forage Fish. On the right, a 'Database' menu lists categories: Chemicals, Environment, Invertebrates, Fish, Human Exposure, Mammals, and Avian. Below the menu are 'Help' and 'Create Output' buttons.

*TrophicTrace was developed by Menzie-Cura & Associates, Inc., Chelmsford MA under contract to the U.S. Army Engineer Research and Development Center*

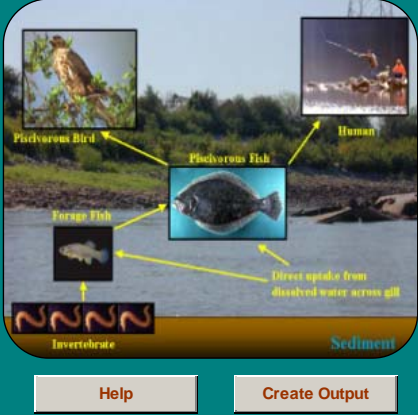
*The TrophicTrace program calculates human health and ecological risks associated with potential exposure to contaminants via fish consumption based on user provided inputs. No warranties are assumed or implied.*



# Food Web Model: TrophicTrace

- Calculates cancer risk and hazard indices for humans via fish ingestion
- Can also calculate risks to ecological receptors (e.g., fish, osprey, bald eagle, mink, and otter)

**TrophicTrace**  
Version 3.01 (January 2003)



Database

- Chemicals
- Environment
- Invertebrates
- Fish
- Human Exposure
- Mammals
- Avian

Help Create Output

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<http://el.erdcd.usace.army.mil/trophictrace/index.html>



# Interpretation of Tissue Residue

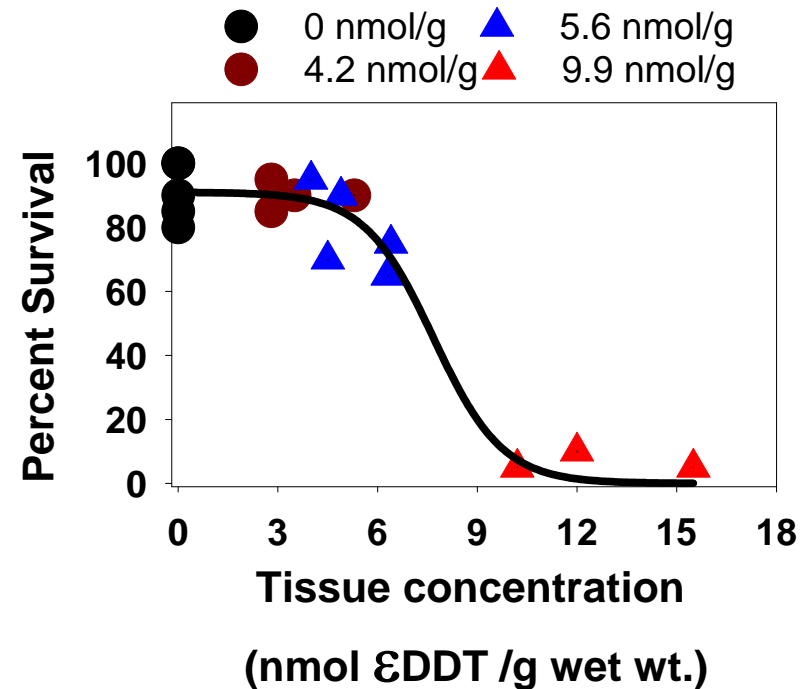
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- Humans
  - FDA fish advisory levels
  - cancer and non-cancer protection levels (IRIS database)
- Fish and Wildlife
  - Tissue residue benchmarks (i.e., CBR values, probabilistic approaches, and TRVs)



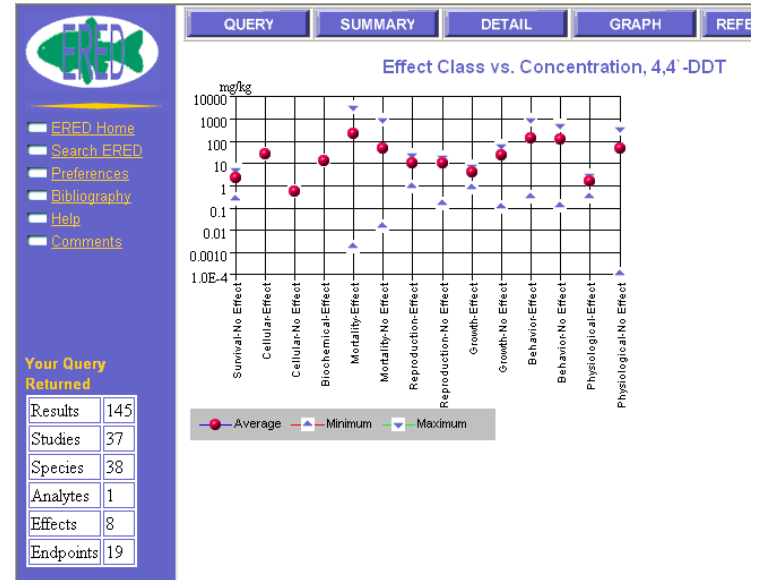
# Interpretation of Tissue Residue


- **Critical body residue**
  - Statistic that describes an adverse biological response (e.g., LR50, ER10, LOER) that is associated with a tissue concentration expressed in mass or molar units.
- Provides more information on likelihood for adverse ecological effects and helps identify likely causative agents



# Interpretation of Tissue Residue

- **Environmental Residue Effects Database**
- Summary of CBR values
- 7,192 records for 323 chemicals
- Includes data from peer-reviewed journal articles
- Updated annually



  
500 µg/kg  
PCB



Literature: (lowest effect value)  
NOER: 300 µg/kg clam  
LOER: 1,530 µg/kg worm

ERED found at: <http://el.erdc.usace.army.mil/ered/>

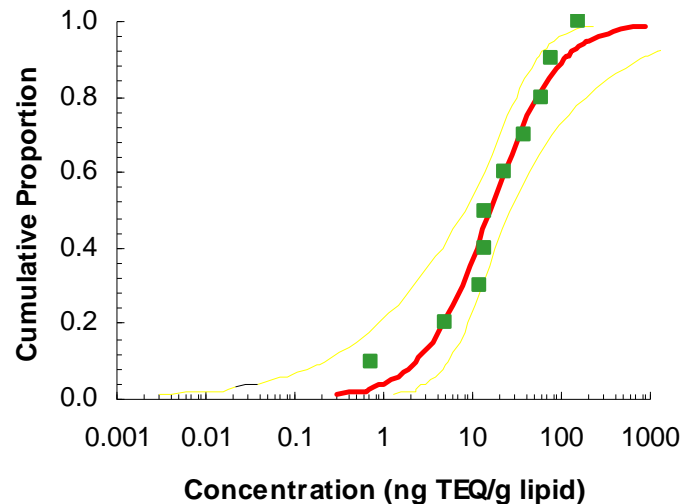




# Interpretation of Tissue Residue

## Species Sensitivity Distribution (SSD)

- Distribution of literature data reporting effect associated with tissue concentration
- Use the SSD to select the level of species protection and degree of conservatism



Species Protection Level	Benchmark Value (ng TCDD/g lipid)		
	LCL	Mean	UCL
LR50			
1%	0.0003	0.058	0.382
2.5%	0.0025	0.169	0.802
5%	0.0117	0.386	1.43
10%	0.0583	0.909	2.64

From Steevens et al., 2005





# Interpretation of Metals

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- **Potential for trophic transfer**
  - Only metal in certain compartments is biologically available
  - High metal distribution in the prey and potential for detoxification (metallothioneins, granules)
- **Critical body residues**
  - Essential (Fe, Cu, Zn) vs. non-essential metals (Hg, Pb, Cd, U)
  - Concentration at site of toxic action not necessarily related to whole-body accumulation due to sequestration mechanism
  - Therefore, difficult to predict effects from whole-body concentration



# Human Health

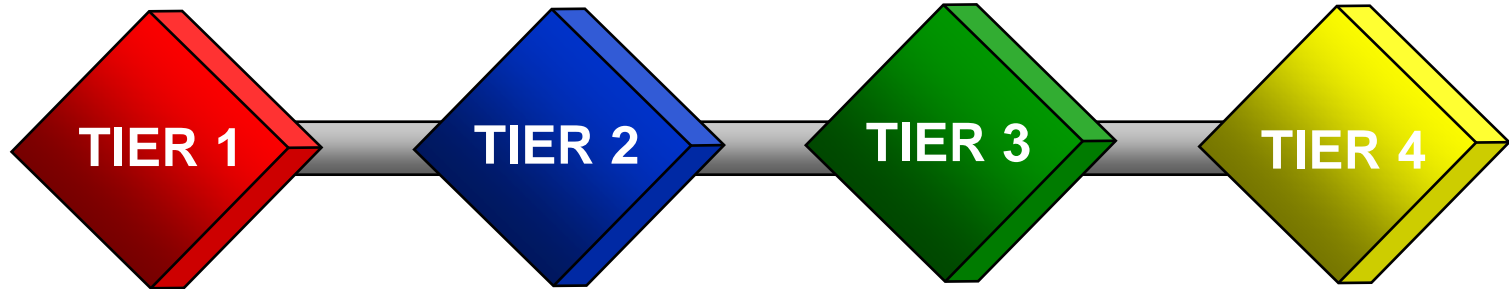
$$TotalCR = \sum_{COC=1}^y = \frac{(\sum_{sp=1}^x [EPC_{sp} \times AF_{sp} \times F_{sp}]) \times MS \times EF \times ED \times CSF \times CF}{AT \times BW}$$

- Total CR = cancer risk for member of target population that accounts for exposures to all carcinogenic COCs as a child and adult
- $EPC_{sp}$  = species-specific exposure point concentration of chemical in edible, uncooked fish tissue (mg/kg)
- $AF_{sp}$  = species-specific adjustment factor that accounts for the difference between chemical concentration in edible, uncooked fish tissue and as-consumed fish tissue
- $F_{sp}$  = fraction of diet represented by species;  $\sum F_{sp} = 1$
- MS = size of meal in terms of uncooked, edible fish tissue (gram/meal)
- EF = meal frequency (meal/day x day/yr OR meal/yr)
- ED = number of years consuming fish (yr)
- AT = averaging time (day); equal to ED for noncancer evaluations and lifetime for cancer evaluations
- BW = body weight (kg)
- CSF = cancer slope factor (kg-day/mg)
- CF = kg/1000 g

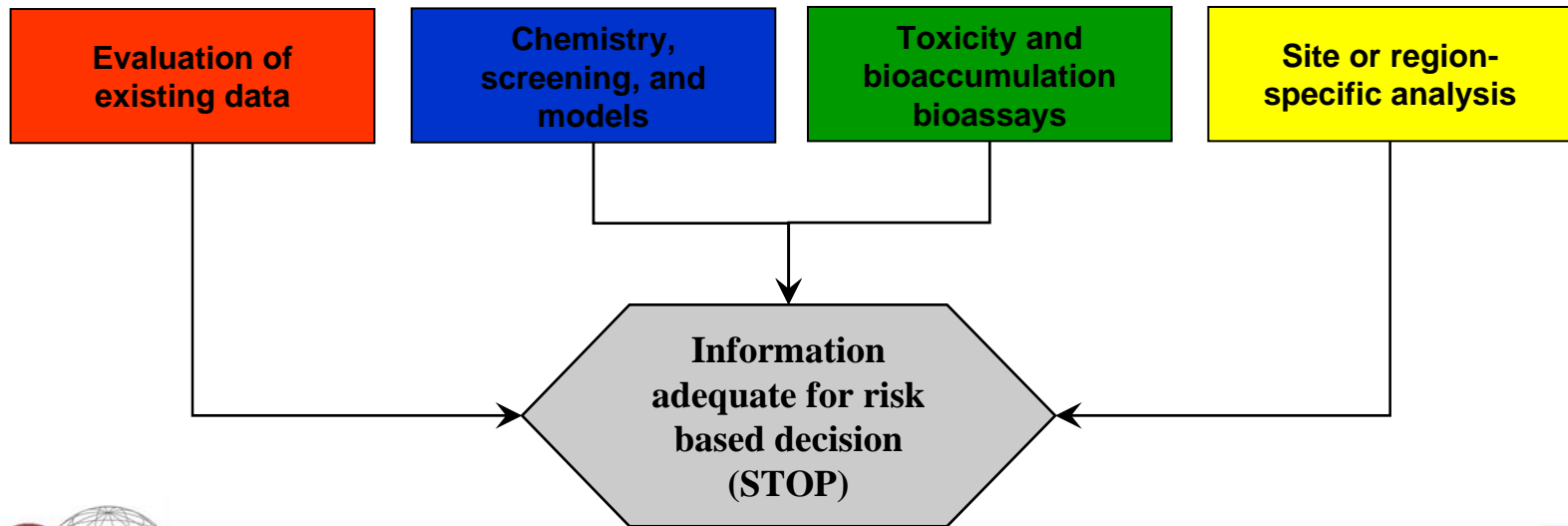


# Bioaccumulation Evaluation

Increasing information and cost

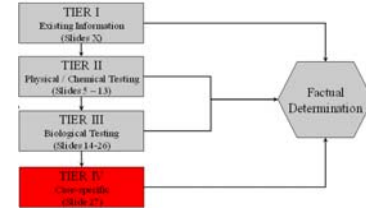


Tiered process → follow as far as necessary to make decision



# Tier IV: Determination of Steady State Bioaccumulation

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Should include:

- Examination of site specific steady state
- *In situ* assessment
- Collection of site specific data
  - (e.g., creel survey, animals)



# Conclusions

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- Bioaccumulation evaluations are one tool to support the estimation of risk of DM
- Should be used along with other lines of evidence (e.g., existing data, aquatic and sediment toxicity) in a weight of evidence approach to determine risk
- The tiered framework is a procedure to aid in the risk assessment process
  - should be followed only as far as necessary to provide adequate information to reliably estimate risk

