
Bioaccumulation Evaluations

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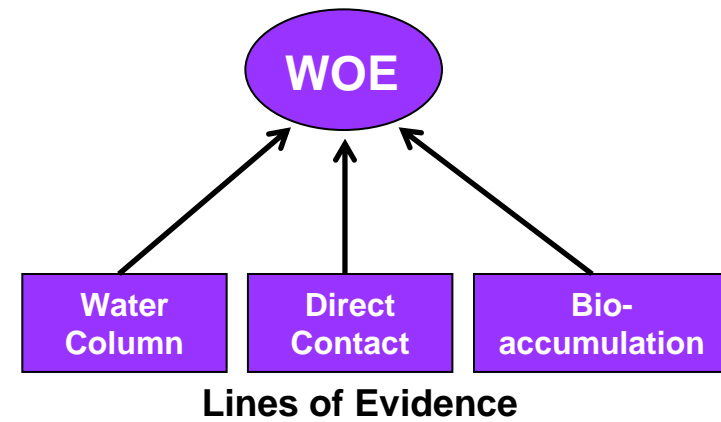
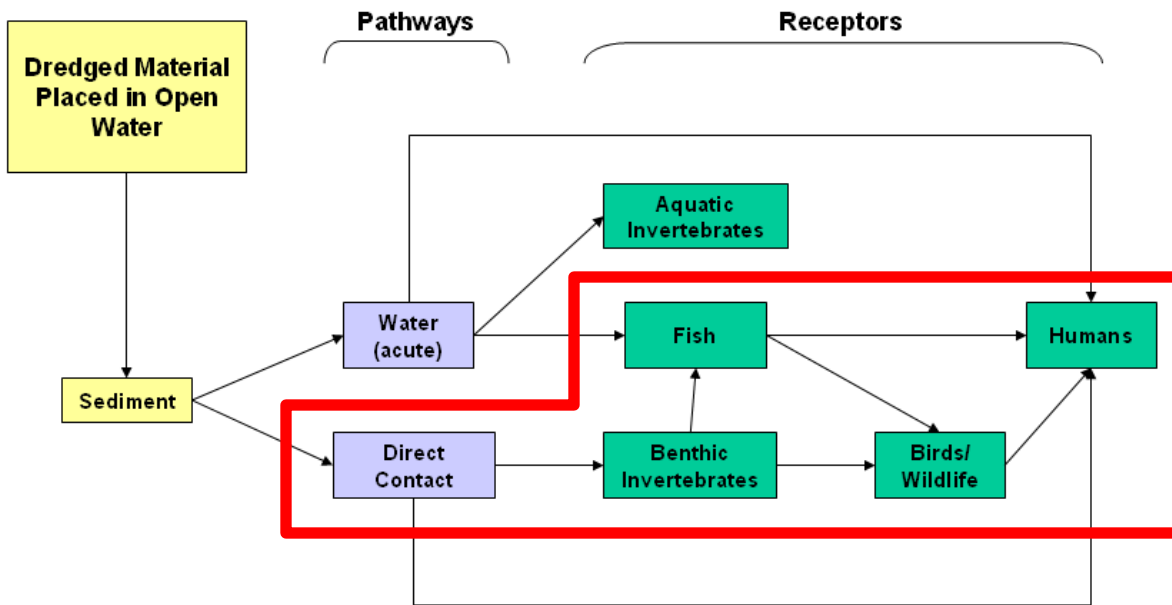
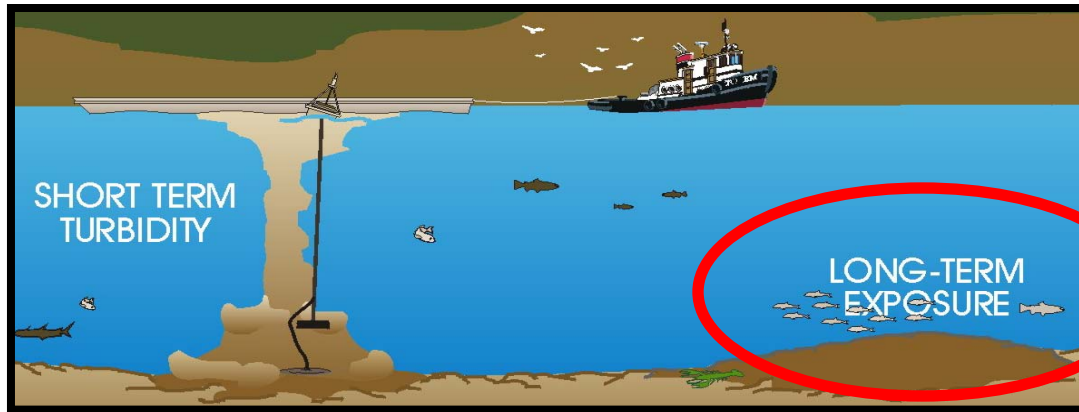


Bioaccumulation Evaluations

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

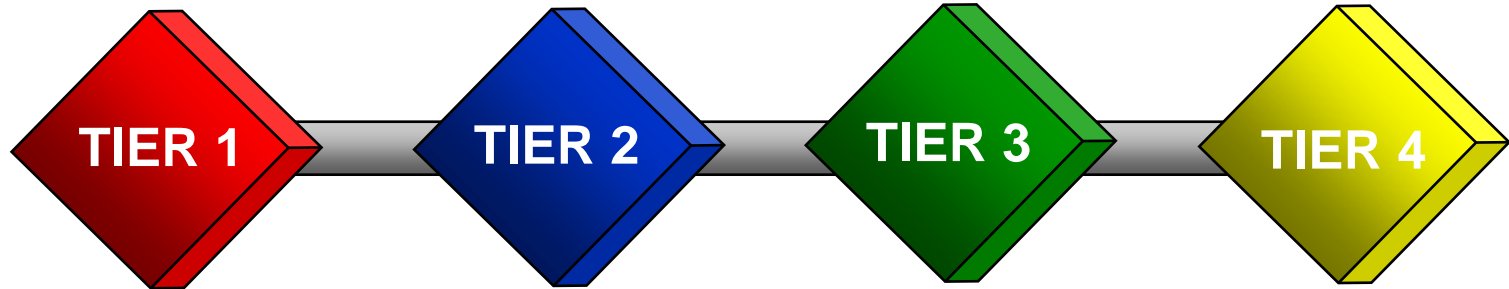


Conceptual Model

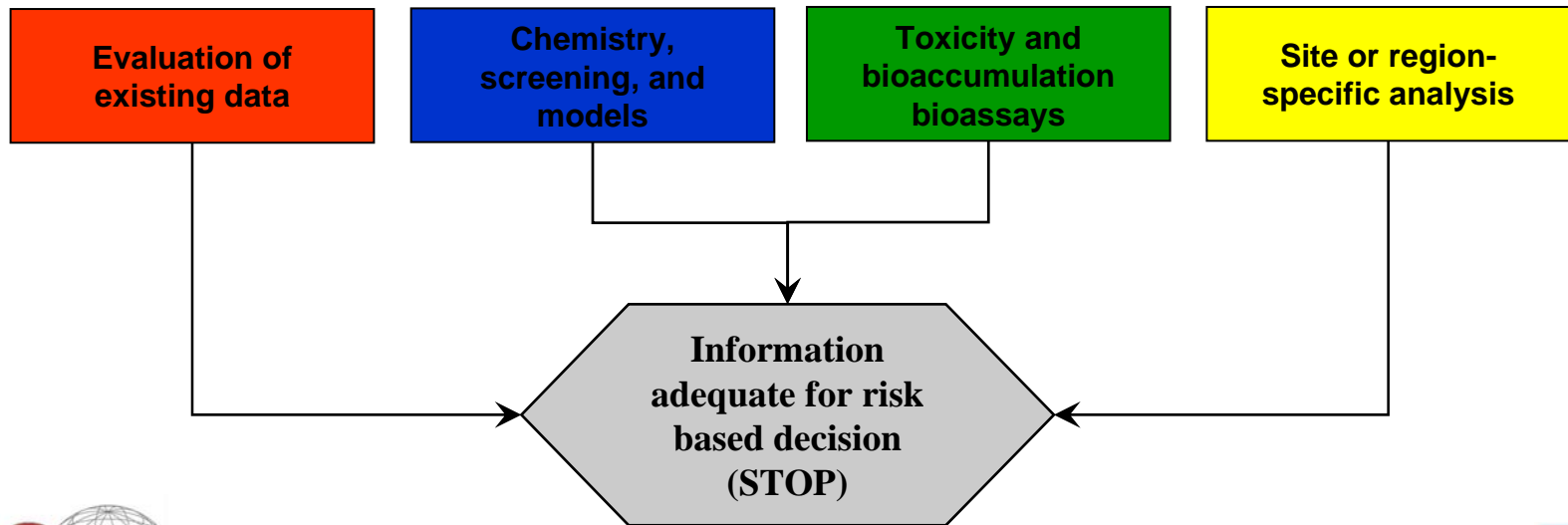


Bioaccumulation Evaluation

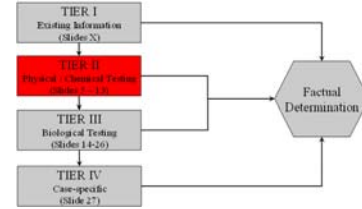
→
Increasing information and cost



Tiered process → follow as far as necessary to make decision



Tier II: Predicting Bioaccumulation

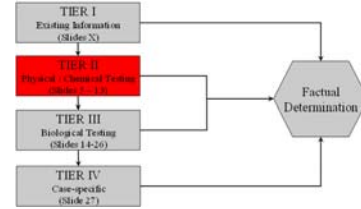


Thermodynamically-based Theoretical Bioaccumulation Potential (TBP)

- 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_s = 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
(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">By OrganismBy ChemicalBenthic BSAFs with Statistics	<ul style="list-style-type: none">By Organism	<ul style="list-style-type: none">Search For A ReferenceDisplay All References

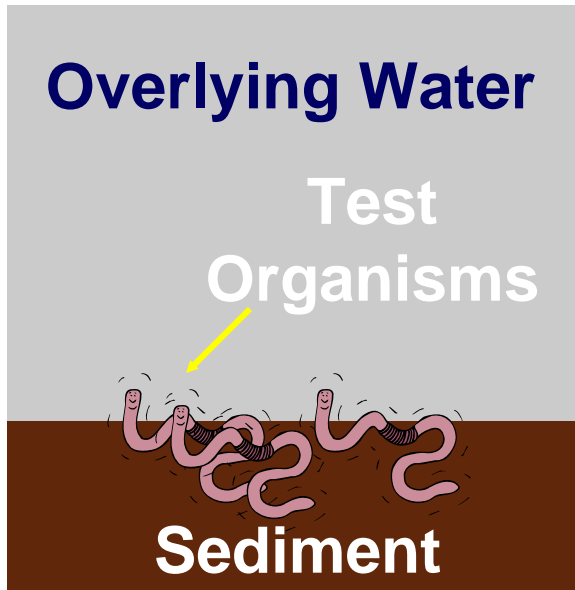
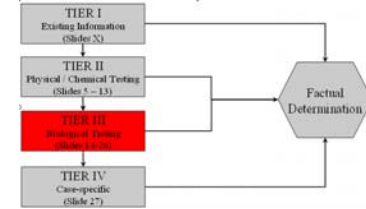
[BSAF Background Information](#)

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

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



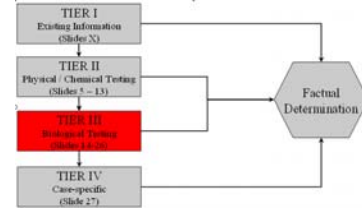
Tier III: Bioaccumulation Test



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



Tier III: Bioaccumulation Test

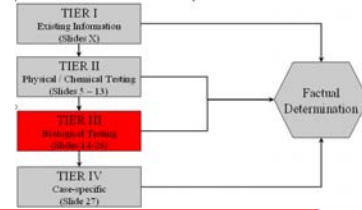


Test Design

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

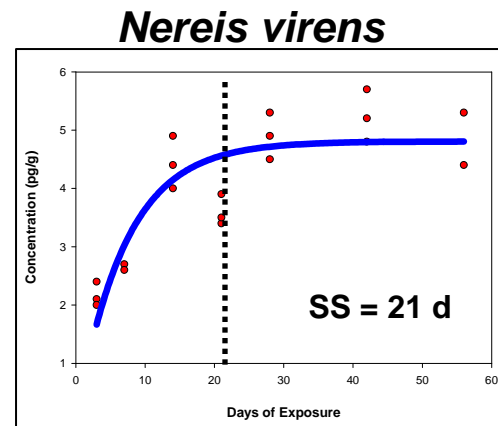
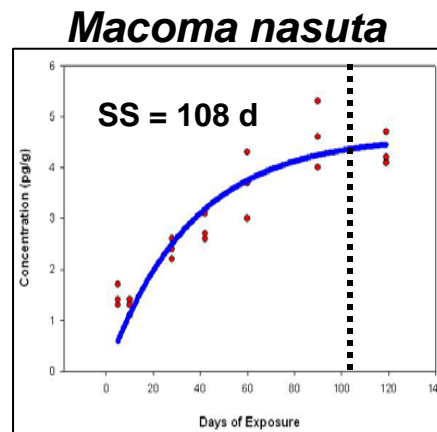


Exposure duration



- **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

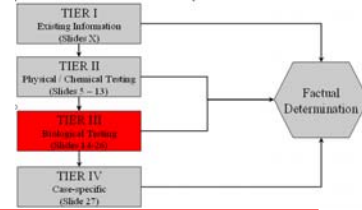
Example: 2,3,7,8 TCDF



- 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

Oligochaete



Lumbricus variegatus

Amphipod



Diporeia sp.

Clam

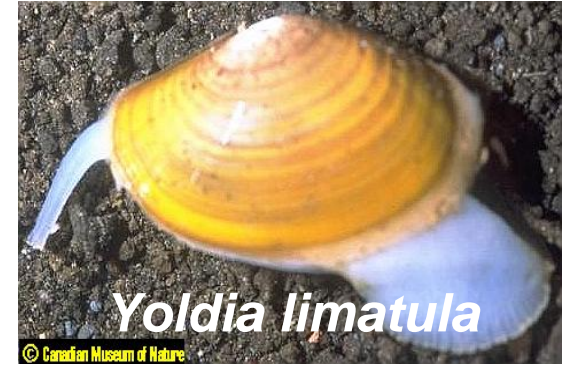


Corbicula sp.

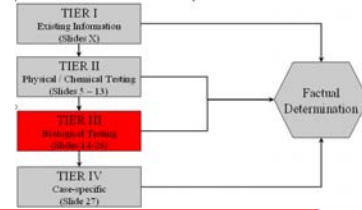


Bioaccumulation Test Species

Marine / Estuarine



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



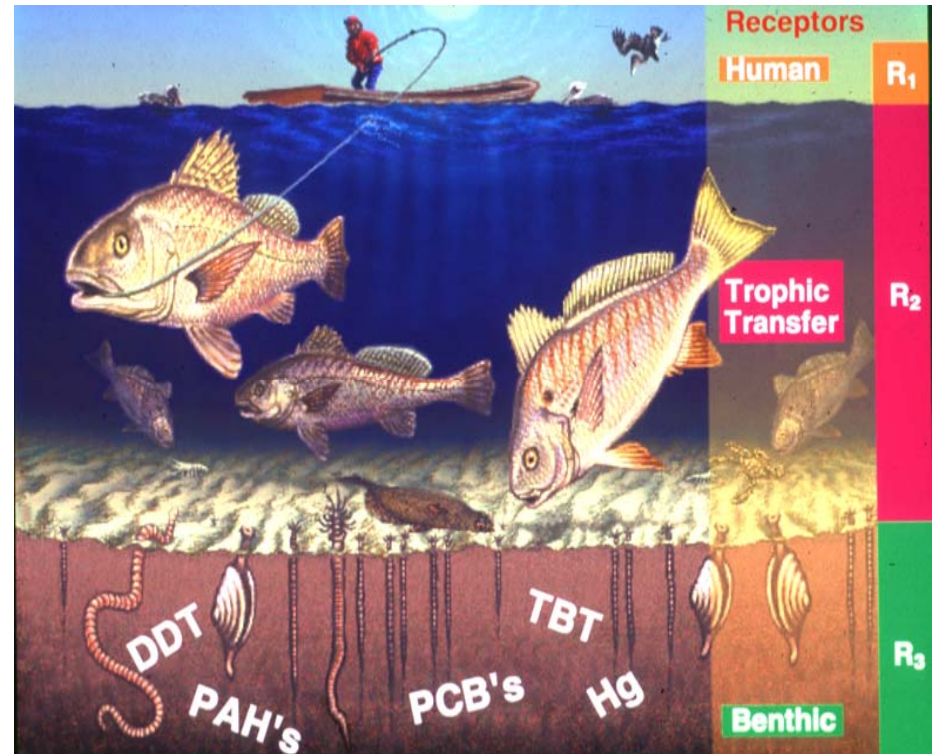
Interpreting Bioaccumulation Data

- 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”

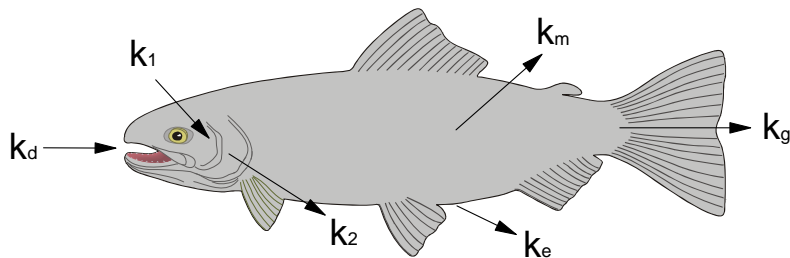


“all models are wrong and some are useful”



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 a food web diagram with nodes for Piscivorous Bird, Human, Piscivorous Fish, Forage Fish, Invertebrate, and Sediment. Arrows indicate the flow of contaminants. A 'Database' menu on the right lists categories: Chemicals, Environment, Invertebrates, Fish, Human Exposure, Mammals, and Avian. Buttons for 'Help' and 'Create Output' are visible at the bottom.

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

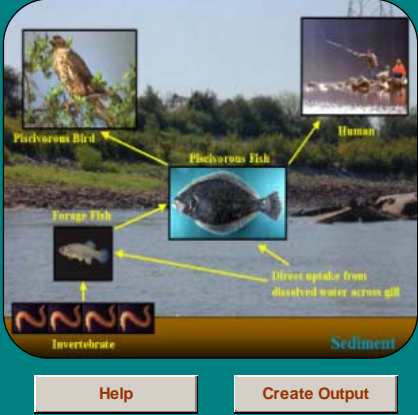
The TrophicTrace program calculates human health and ecological risks associated with potential exposure to contaminants via fish consumption based on user provided inputs. No warranties are assumed or implied.



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>



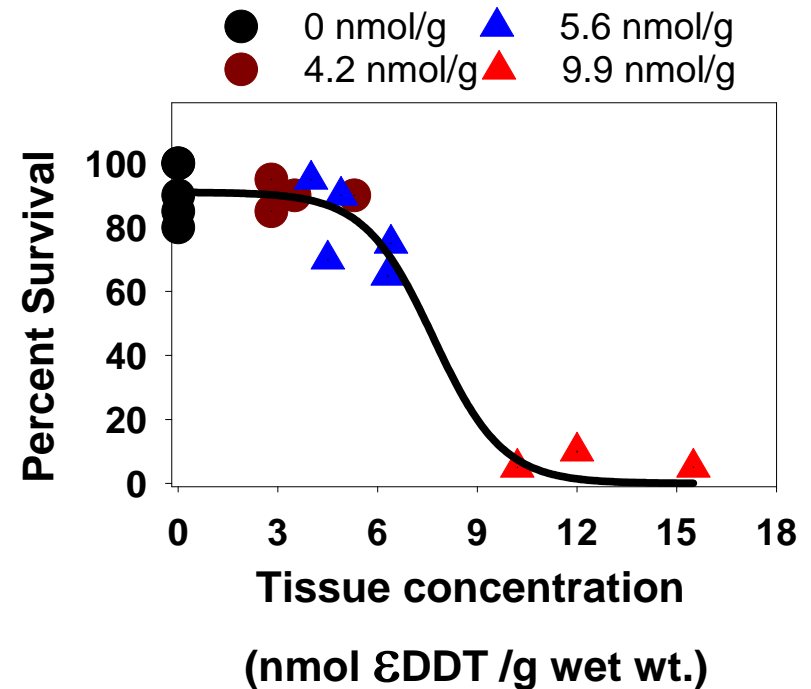
Interpretation of Tissue Residue

- 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)



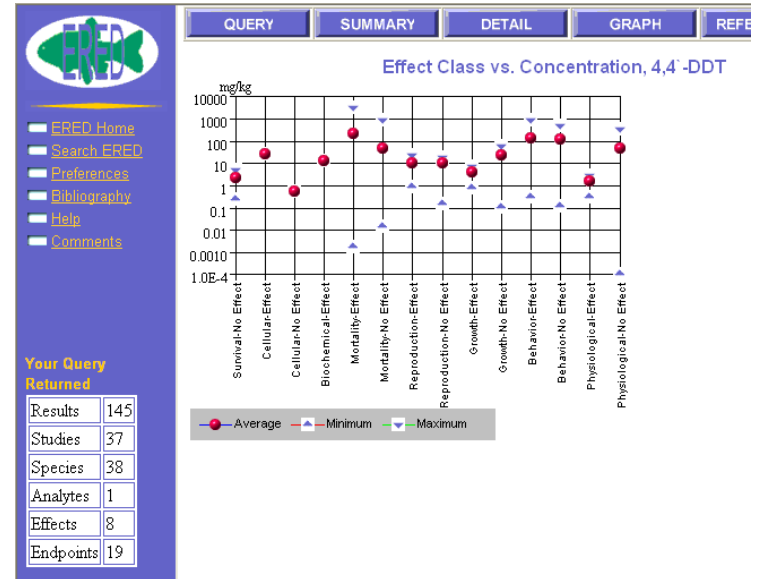
Interpretation of Tissue Residue


- **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

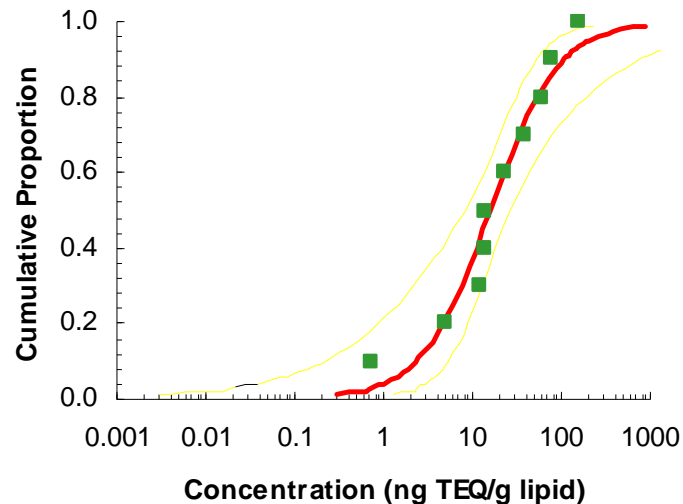
ERED found at: <http://el.erdc.usace.army.mil/ered/>



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

- **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

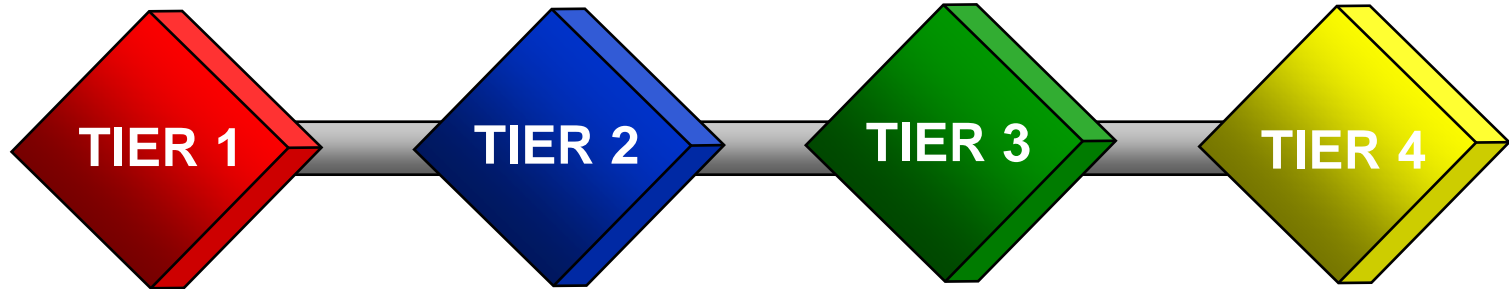
$$TotalCR = \sum_{COC=1}^y = \frac{(\sum_{sp=1}^x [EPC_{sp} \times AF_{sp} \times F_{sp}]) \times MS \times EF \times ED \times CSF \times CF}{AT \times BW}$$

- 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

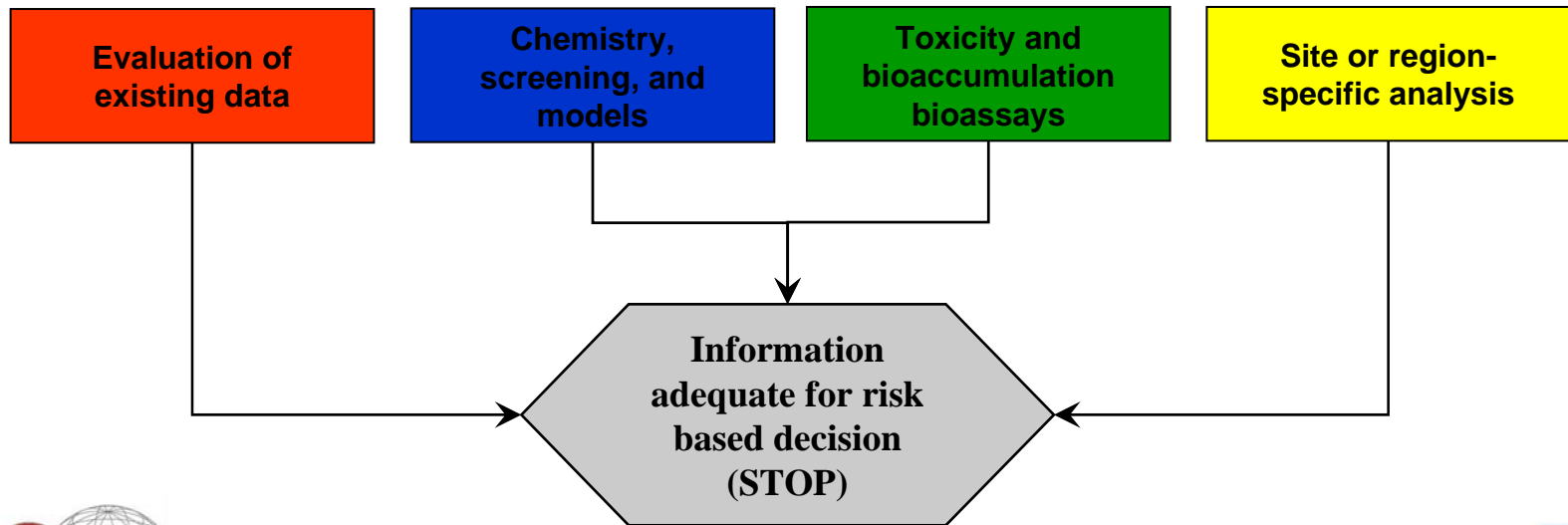


Bioaccumulation Evaluation

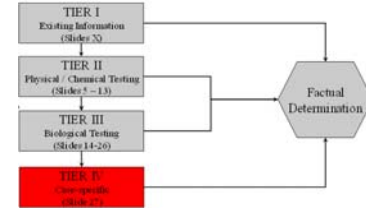
Increasing information and cost



Tiered process → follow as far as necessary to make decision



Tier IV: Determination of Steady State Bioaccumulation



Should include:

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



Conclusions

- 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

