Wisconsin's Surface Water Quality Criteria

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Contaminated Sediments External Advisory Group
March 30th 2016

Introduction

- This committee has expressed interest in a standardized process for setting clean-up goals for sediment
  - Currently, neither EPA nor states have standardized process
- Today I am going walk through process used to set surface water quality criteria
  - Please think about which components could be applied to the development of contaminated sediment standards

Outline

Clean Water Act

Water Quality Standards
- Antidegradation
- Designated Uses
- Water Quality Criteria

Deriving Water Quality Criteria
- EPA guidance
- Water Quality Guidelines for the Great Lakes
- NR 105

WI's Fish and Aquatic Life Criteria
- Species sensitivity distribution
- Standard test methods
- Example calculation

WI's Human Health Criteria
- Human health criteria equation and parameters
- Example calculation

The Clean Water Act and Water Quality Standards

The Clean Water Act

- Federal Water Pollution Control Act
- Goal: *Restore and maintain the chemical, physical and biological integrity of the Nation's waters*
- Established the basic structure for regulating pollutants discharged into the waters.
- Required states to adopt water quality standards and provided for EPA review and approval or disapproval.

Water Quality Standards
1. Antidegradation
2. Designated Uses
3. Water Quality Criteria

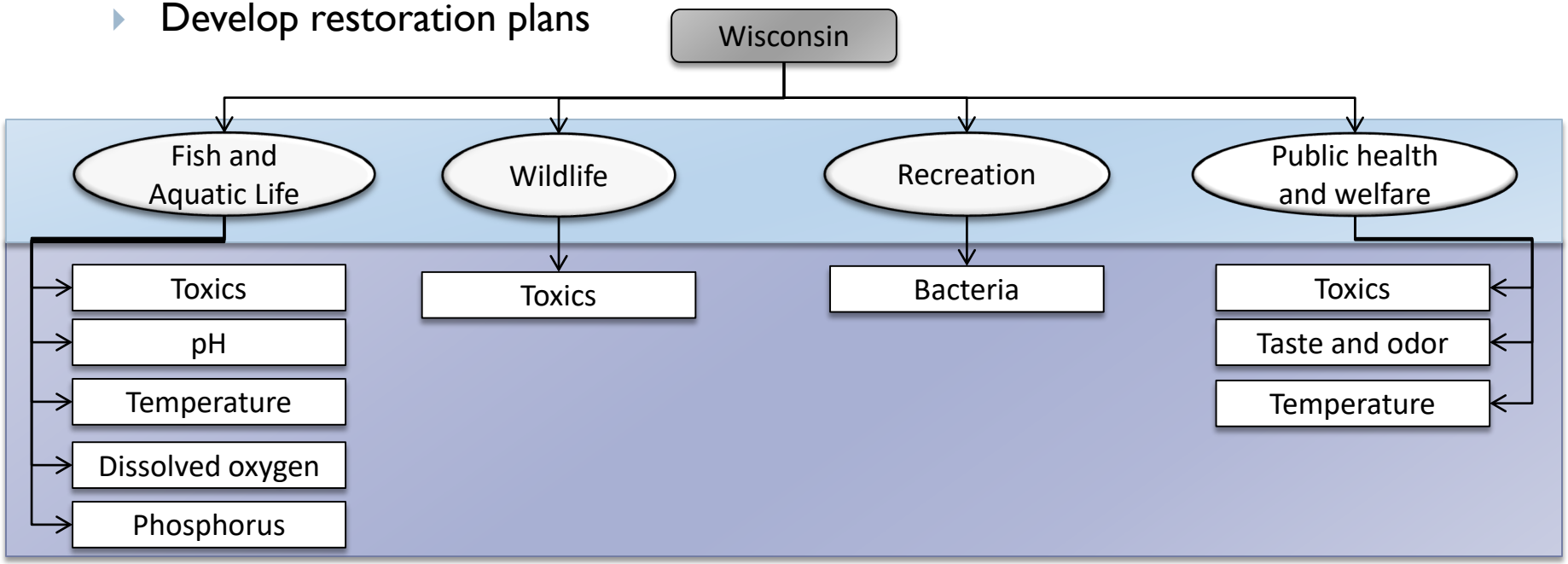
1. Antidegradation

- A policy and implementation procedures designed to protect waters from degradation
- Three tiers of protection

Tier 1:	All waters	water quality must not be lowered below levels necessary to protect fish and aquatic life, wildlife, and recreation.
Tier 2:	High quality waters	Must demonstrate that lowering of water quality is "necessary" to accommodate "important" social or economic development in the area where the waterbody is located
Tier 3:	Outstanding national resource waters	No lowering of water quality allowed*

3. Water Quality Criteria

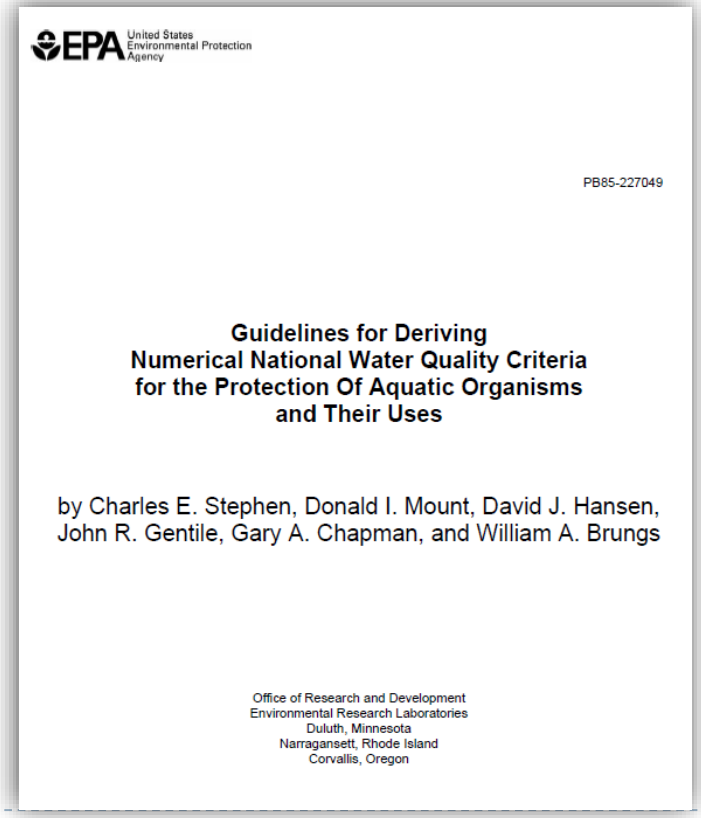
- A number or narrative statement representing water quality that supports a particular designated use.
- Must be based on sound scientific rationale and contain sufficient parameters to protect the designated uses
- Used to
  - Establish permit limits for point sources
  - Assess waters and make impairment decisions
  - Develop restoration plans



Deriving Water Quality Criteria

Wisconsin's Water Quality Criteria

- EPA guidance
  - Aquatic life


United States Environmental Protection Agency

PB85-227049

Guidelines for Deriving Numerical National Water Quality Criteria for the Protection Of Aquatic Organisms and Their Uses

by Charles E. Stephen, Donald I. Mount, David J. Hansen, John R. Gentile, Gary A. Chapman, and William A. Brungs

Office of Research and Development
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Narragansett, Rhode Island
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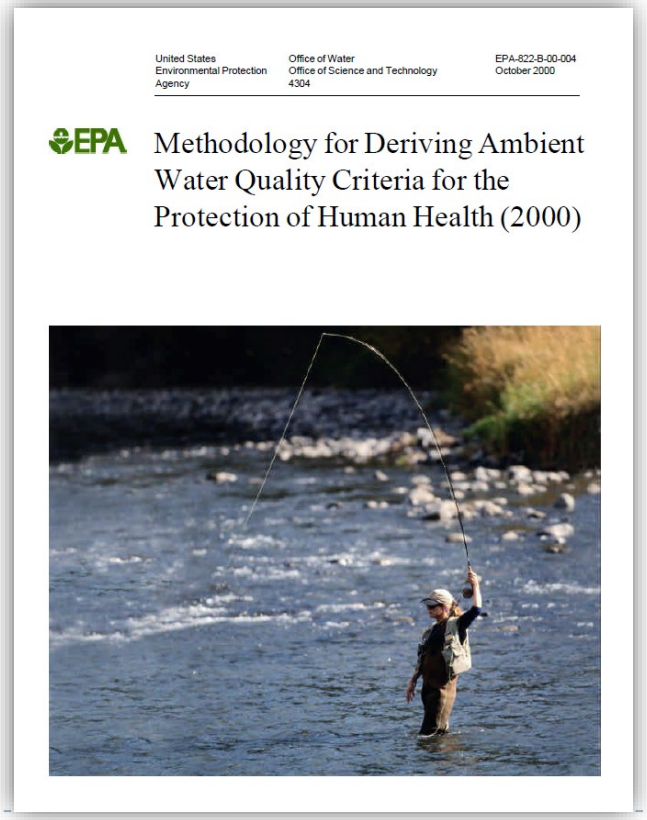
  - Human Health


United States Environmental Protection Agency | Office of Water, Office of Science and Technology, 4304 | EPA-822-B-00-004, October 2000

EPA Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000)

Water Quality Guidance for the Great Lakes System

- Published in March 1995
- This regulation consists of:
  - Water quality criteria for 29 pollutants
  - Detailed methodologies to develop criteria for additional pollutants
  - Implementation procedures for developing water quality based effluent limits (WQBELs) and total maximum daily loads (TMDLs)
  - Antidegradation policies and procedures

NR 105: Surface water quality criteria and secondary values for toxic substances

- Contains the methods used by Wisconsin to derive fish and aquatic life, wildlife, and human health criteria for toxic substances
  - Aquatic Life
    - Acute Toxicity Criteria
    - Chronic Toxicity Criteria
  - Wildlife Toxicity Criteria
  - Human Health Criteria
    - Human Threshold Criteria
    - Human Cancer Criteria
- Contains numeric criteria for a number of substances that were calculated using the described methods

Number of Numeric Criteria in NR 105 for Each Designated Use and Endpoint Type				
Aquatic Life		Wildlife	Human Health	
Acute	Chronic		Threshold	Cancer
20	18	4	46	40

Wisconsin's Fish and Aquatic Life Criteria

Fish and Aquatic Life Criteria

- Highest concentration of a toxicant to which organisms can be exposed without causing an adverse effect
- Both acute and chronic toxicity criteria are typically derived to protects aquatic animals and plants from short- and long-term exposure.

http://www.clker.com/clipart-pouring-water-1.html

http://dvcart-160.blogspot.com/

Species Sensitivity Distribution

- Aquatic organisms are ranked by their sensitivity to the pollutant of interest.
- The concentration of the pollutant that protects 95% of organisms is extrapolated
  - Because aquatic systems can tolerate some stress and occasional adverse effects

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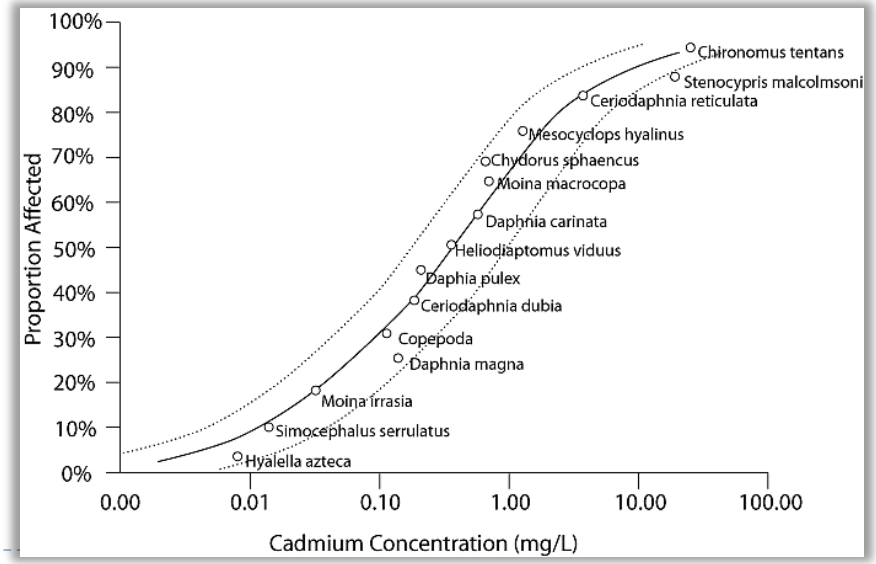
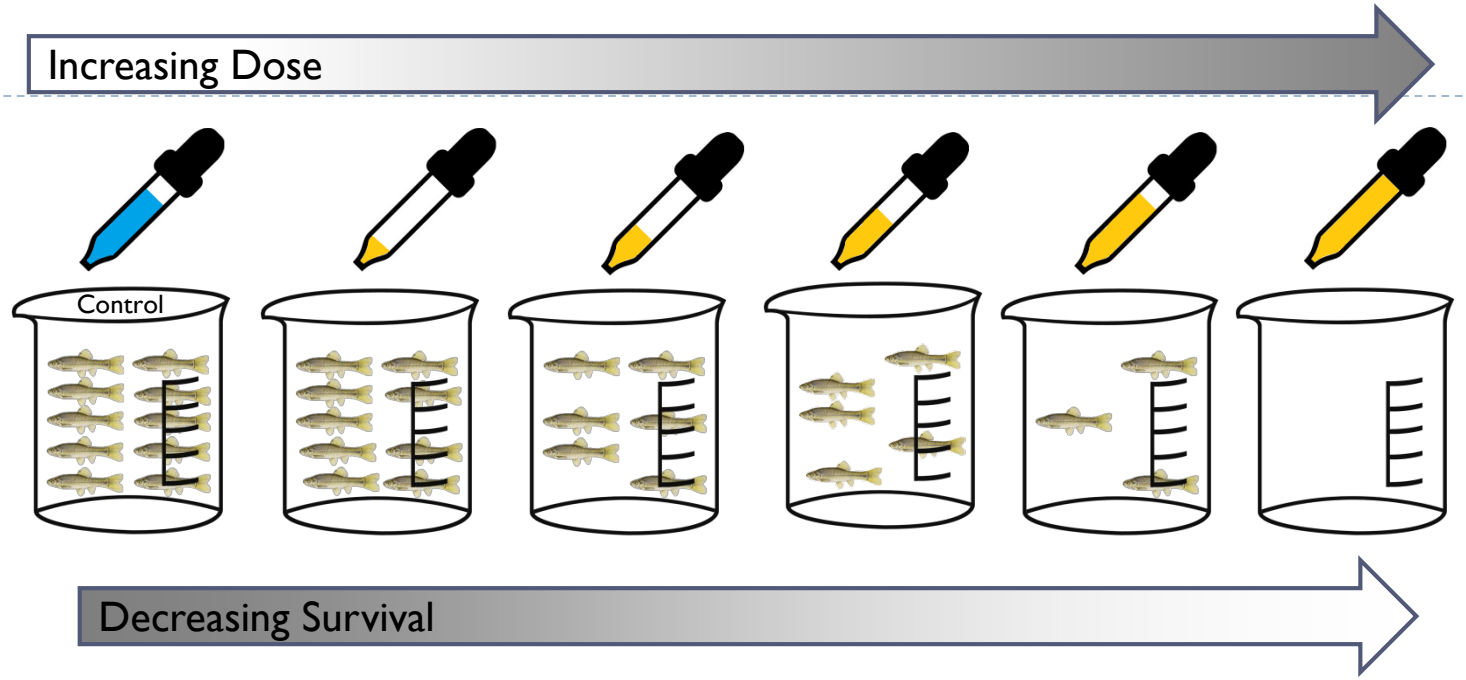
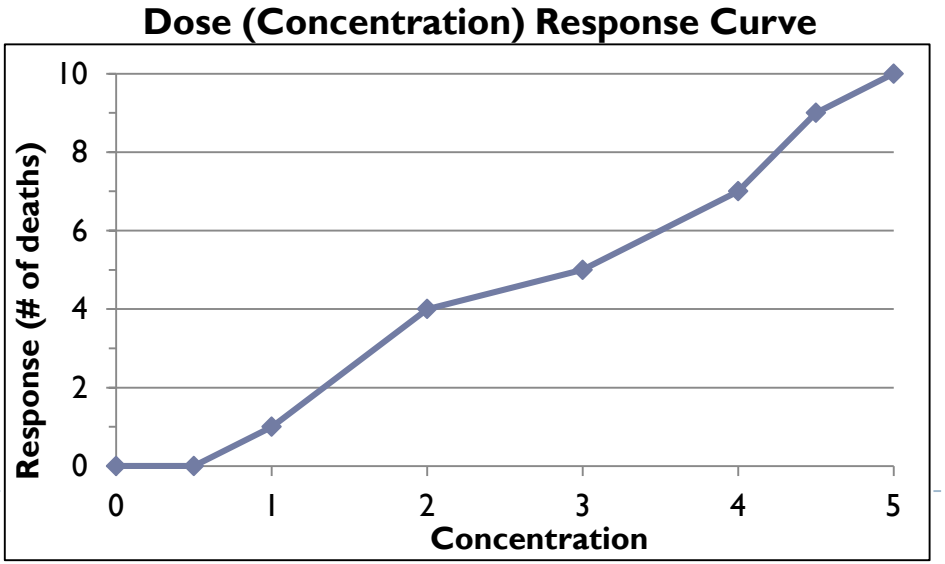


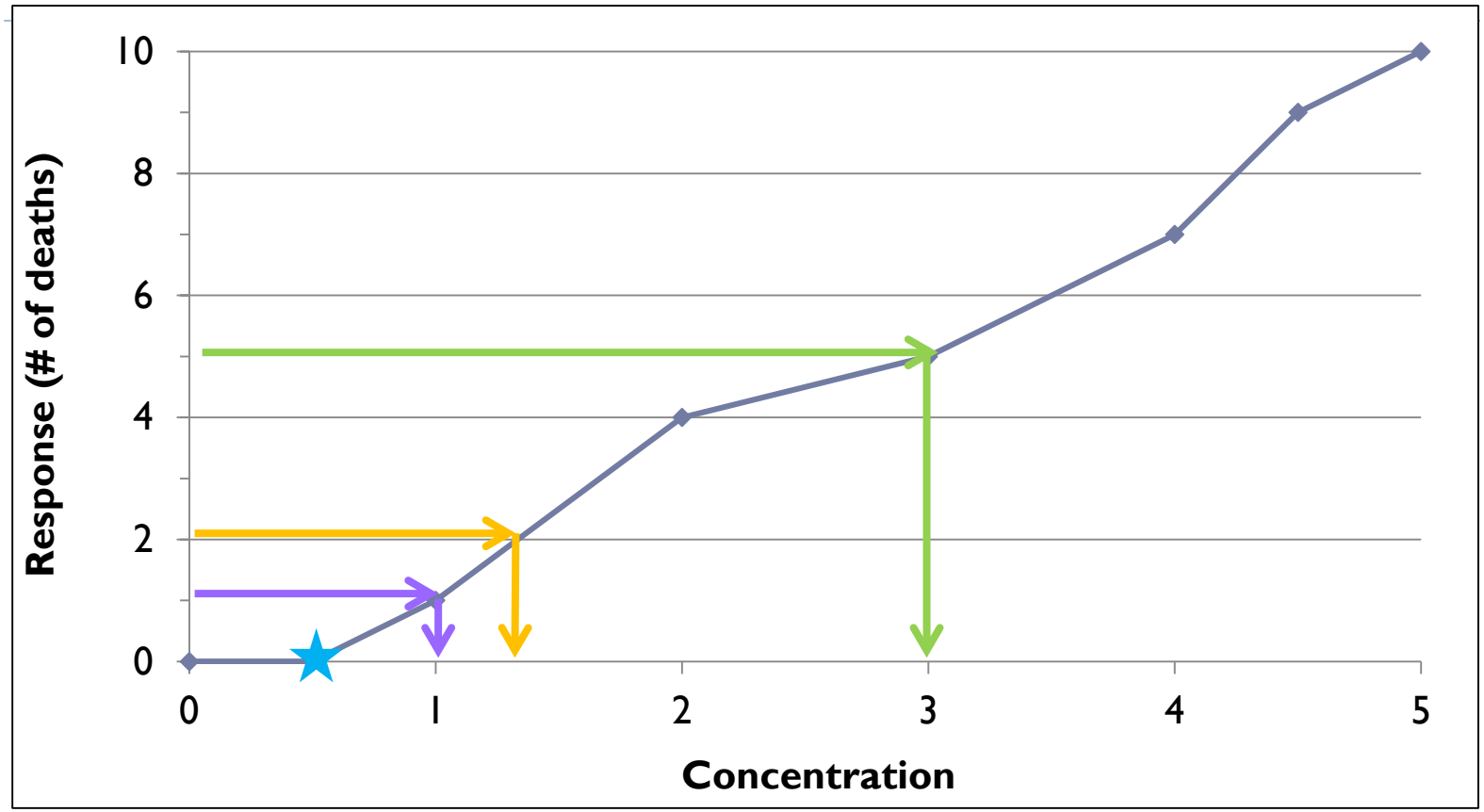
http://www3.epa.gov/caddis/da_advanced_2.html

Typical Aquatic Toxicity Test Setup





Typical Aquatic Toxicity Test Endpoints



LC50 = concentration that causes lethality in 50% of the population

EC20 = concentration that causes the effect of interest in 20% of the population

LOAEL = lowest concentration that caused an adverse effect

NOAEL = highest concentration that did not cause an adverse effect

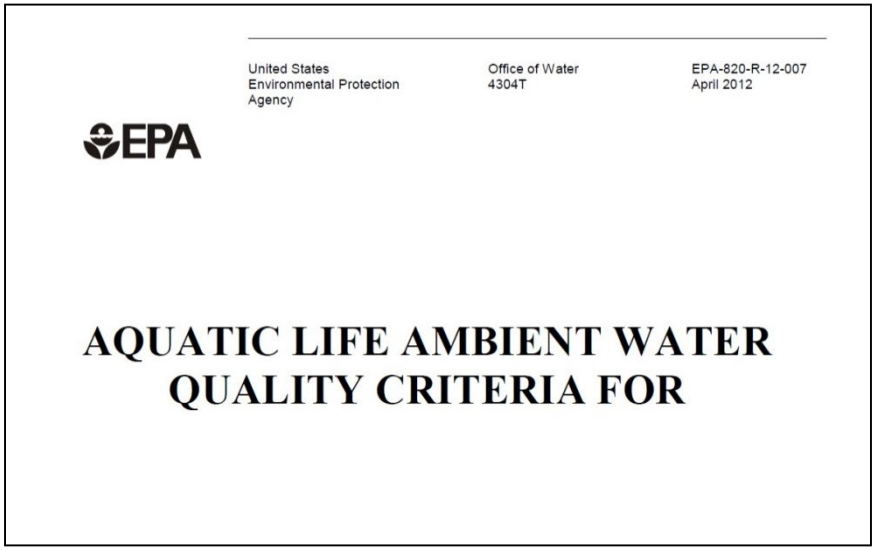
Acceptable test results

- Acute toxicity
  - Test duration:
    - 48 hr toxicity test for daphnid species
    - 96 hr toxicity test for all other species
  - Effects:
    - Mortality for all species
  - Endpoints:
    - LC50 for all species
- Chronic toxicity
  - Test duration:
    - Species specific
    - Early, partial, or full life stage tests acceptable
  - Effects:
    - Long term mortality, reproduction, or growth
  - Endpoints:
    - No observable adverse effect level (NOAEL)
    - Lowest observable adverse effect level (LOAEL)
    - EC20

Wisconsin's Fish and Aquatic Life Criteria

Example: Calculate the acute toxicity criterion for "Substance X"

Step 1) Find all acceptable toxicity data



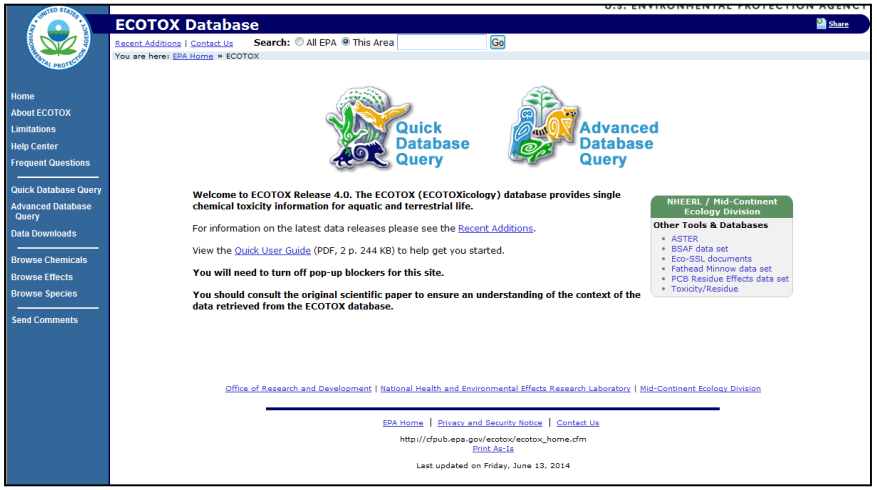
United States Environmental Protection Agency

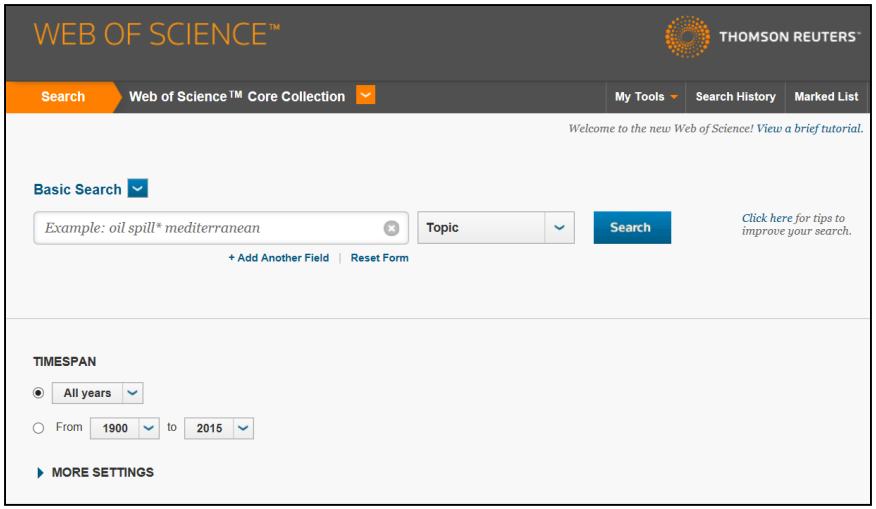
Office of Water 4304T

EPA-820-R-12-007 April 2012

EPA

AQUATIC LIFE AMBIENT WATER QUALITY CRITERIA FOR





Step 2) Determine if database requirements are met

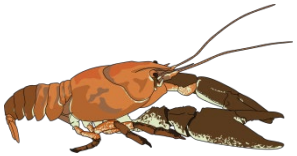
Salmonid

Planktonic Crustacean

Insect

Species in the family Chordata

Non-salmonid



Benthic Crustacean

Species in a family other than Chordata & Anthropoda

Species in a phylum not already represented

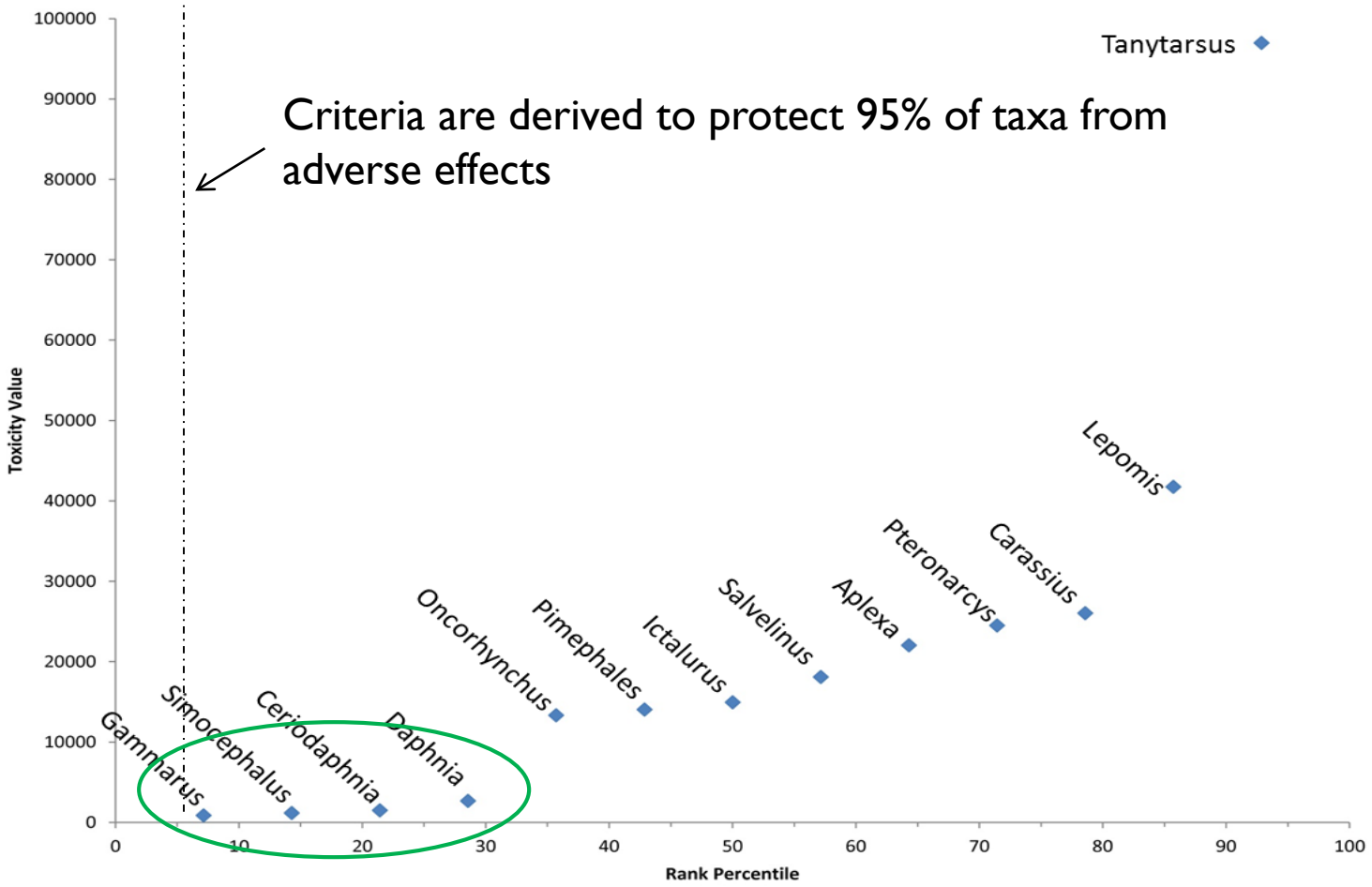
Step 3) Order and rank toxicity data from least to most sensitive

Genus	Common Name	GMAV	Rank
Tanytarsus	Midge	97000	13
Lepomis	Bluegill	41760	12
Carassius	Goldfish	26040	11
Aplexa	Snail	24500	10
Pteronarcys	Stonefly	22040	9
Ictalurus	Catfish	18100	8
Salvelinus	Trout	14960	7
Pimephales	Minnow	14065	6
Oncorhynchus	Salmon/Trout	13340	5
Daphnia	Cladoceran	2690	4
Ceriodaphnia	Cladoceran	1511	3
Simocephalus	Cladoceran	1175	2
Gammarus	Amphipod	874	1

Least Sensitive

Most Sensitive

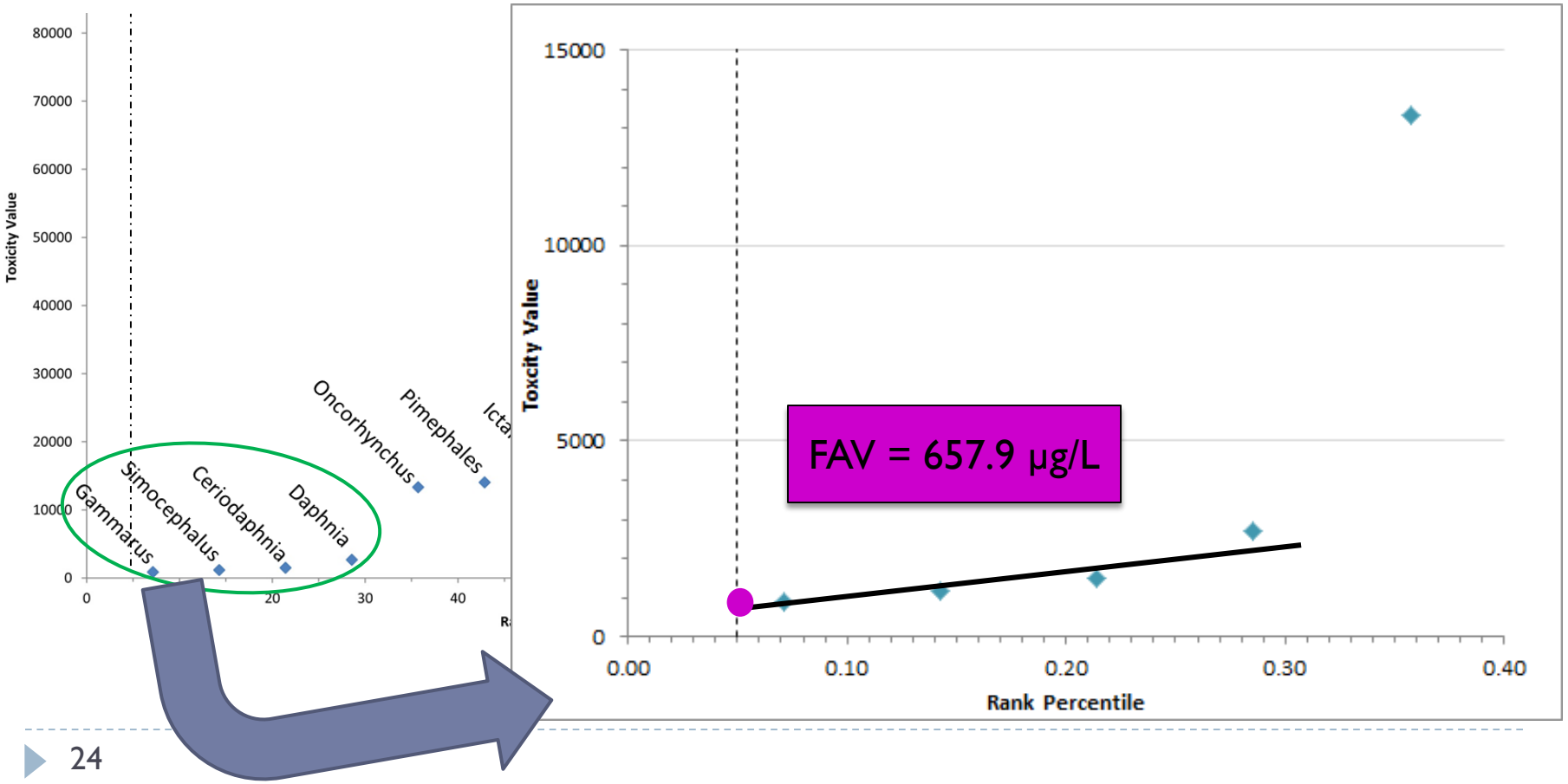
Step 4) Plot species sensitivity distribution (SSD) and select four most sensitive genera



Most Sensitive ← → Least Sensitive

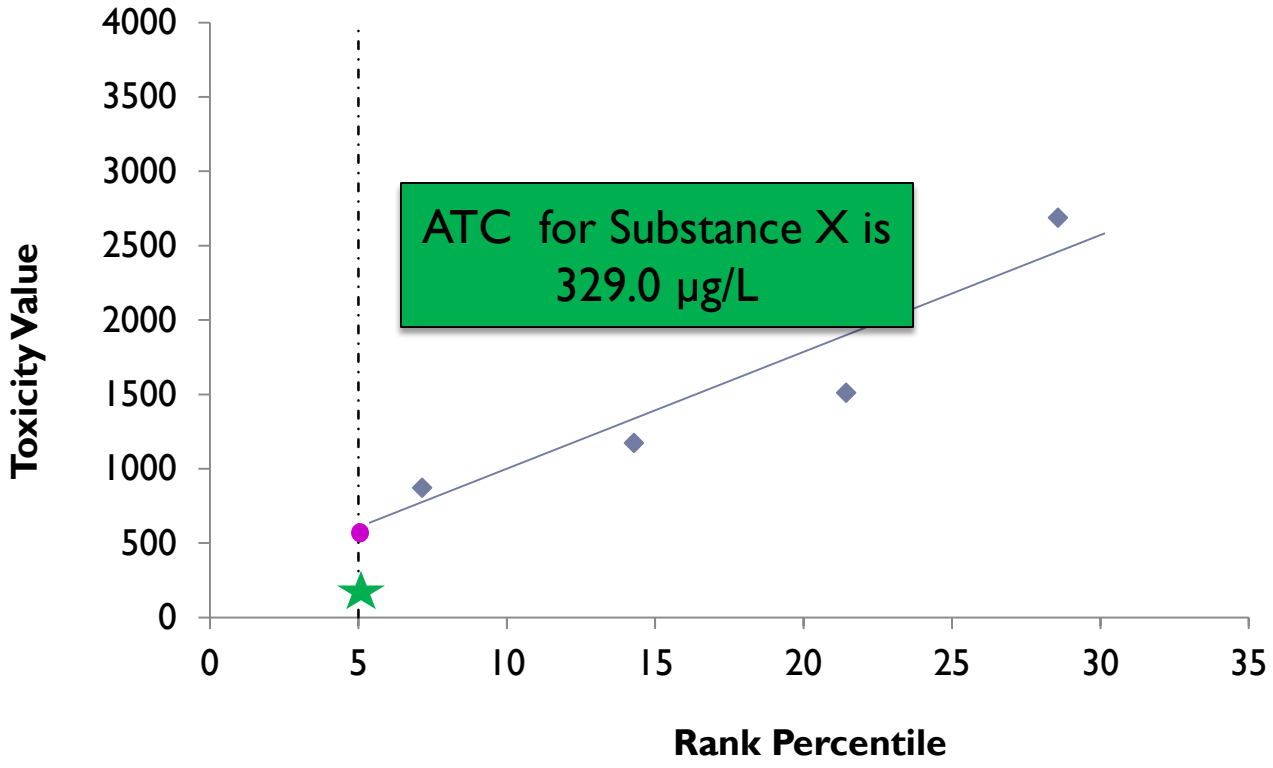
Step 5) Calculate Final Acute Value (FAV)

- FAV = the concentration that would cause the effect (50% mortality) in 5% of organisms



Step 6) Calculate Acute Toxicity Criterion (ATC)

- The Acute Toxicity Criterion (ATC) equals half the Final Acute Value (FAV)
  - The FAV is the concentration that would cause the effect in 5% of the population
  - Divided in half for an extra margin of safety



Wisconsin's Human Health Criteria

Human Health Criteria

- Highest concentration of a toxicant that can be in surface water and protect humans from adverse effects resulting from contact with or ingestion of surface waters or ingestion of aquatic organisms
- Separate criteria are derived for carcinogenic and non-carcinogenic effects.

Generalized Human Health Criteria Equation

$$HHC = \frac{TV \times BW}{W_H + (F_H \times BAF)}$$

- Standard Parameters
  - Body Weight (BW)
    - Average weight an of adult male (70 kg)
  - Water Consumption Rate (W_H)
    - Average daily consumption of water (2.0 L/d for public water supply waters and 0.01 L/d for all other waters)
  - Fish Consumption (F_H)
    - Average daily consumption of sport-caught fish by WI anglers (0.02 kg/d)
- Chemical-Specific Parameters
  - Toxicity Value (**TV**)
    - Maximum amount of a substance that would not cause harm to humans if consumed via drinking water or fish consumption daily for a lifetime
  - Bioaccumulation Factor (BAF)
    - The ratio of a substance's concentration in the tissue of an aquatic organism to its concentration in the ambient water (L/kg)

Toxicity Values

Human Threshold Criteria

- Non-carcinogenic effects

$$\mathbf{TV} = \mathrm{ADE} \times \mathrm{RSC}$$

- Average daily exposure (ADE)
  - Maximum amount of a substance which if ingested daily for a lifetime results in no adverse effects to humans (mg/kg-d)
  - EPA's oral reference dose (RfD) is often used as the ADE
- Relative source contribution (RSC)
  - Factor used to account for routes of exposure other than consumption of contaminated water and aquatic organisms (default = 0.8)

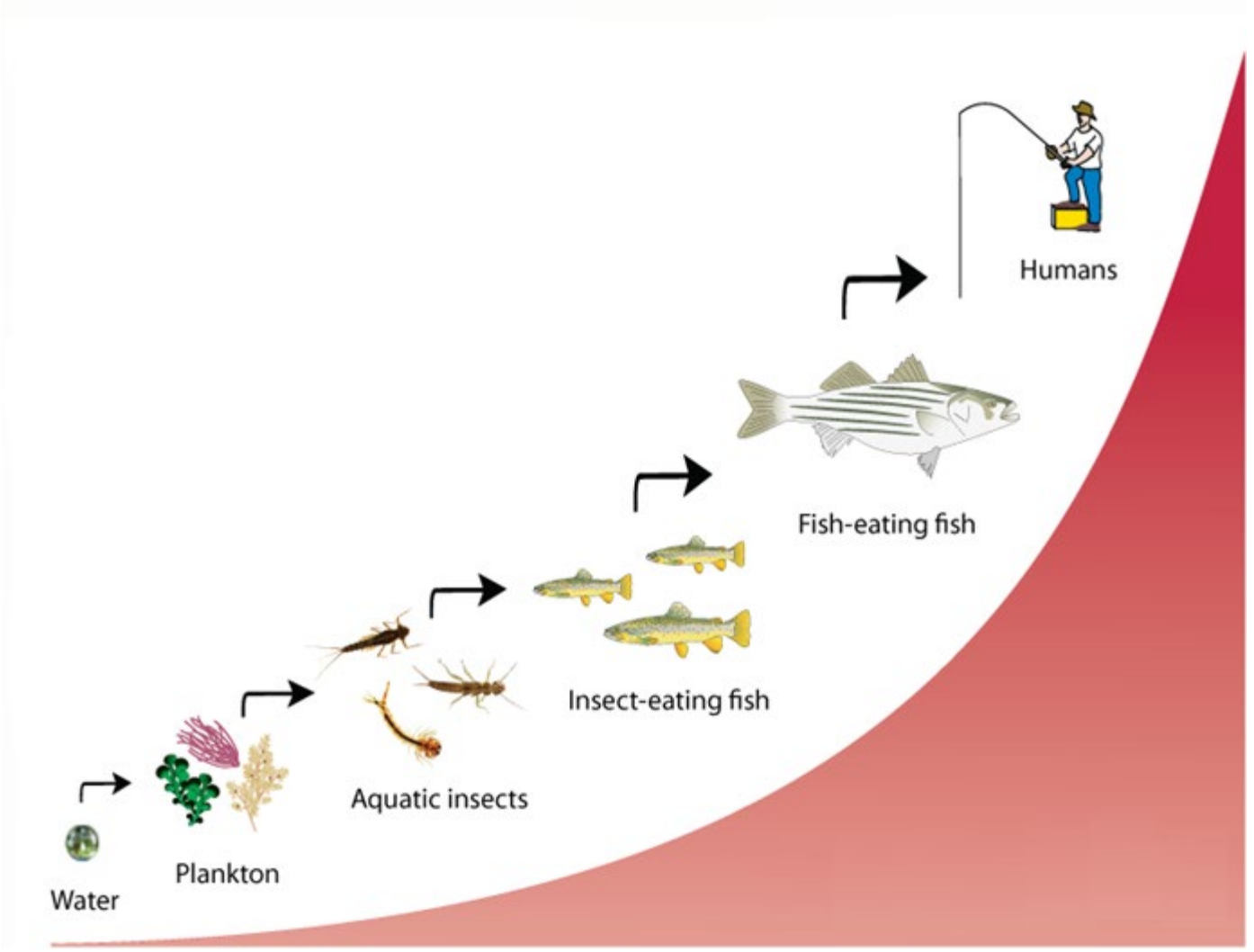
Human Cancer Criteria

- Carcinogenic effects

$$\mathbf{TV} = \mathrm{RAD} = \frac{1 \times 10^{-6}}{q_1^*}$$

- Risk associated dose (RAD)
  - Maximum amount of a substance which if ingested daily for a lifetime has an incremental cancer risk equal to 1 case of cancer in a population of 100,000 (mg/kg-d)
- Cancer potency factor (q_1^*)
  - Incremental rate of cancer development (d-kg/mg)

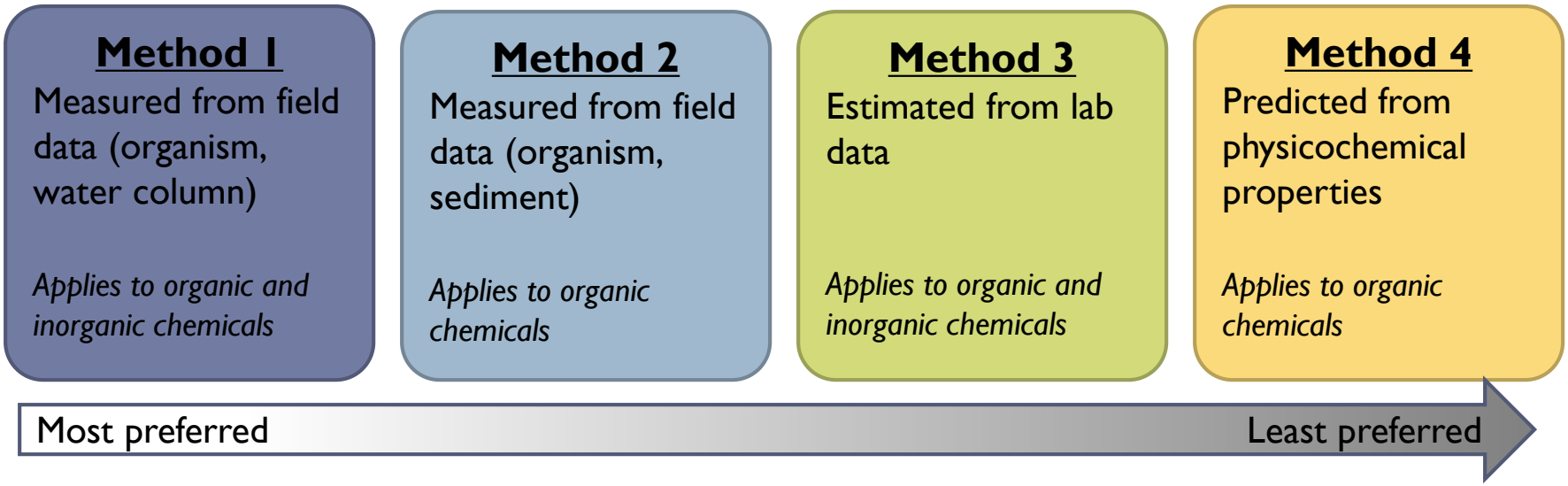
Bioaccumulation



Adapted from http://www.livehealthynaturally.info/foodrisks.htm

Bioaccumulation Factor (BAF)

- Determine baseline BAF



- Determine human health BAF
  - Organic Substances:

    Human Health BAF = [(baseline BAF)(lipid fraction) +1] x (f_{fd})
  - Inorganic Substances:
    - Human Health BAF =Baseline BAF x FCM

Human Health Criteria

Example: Calculate the human threshold criteria for "Substance X"

Human Threshold Equation

Standard parameters

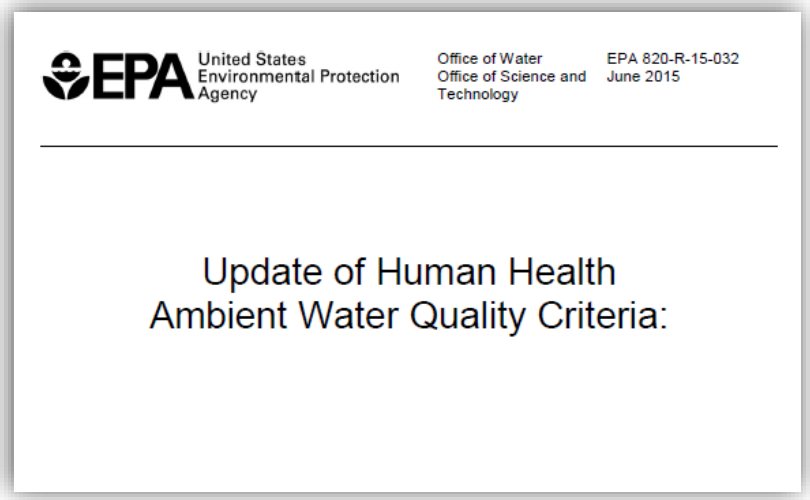
- Body Weight (BW) = 70 kg
- Water Consumption Rate (W_H) = 2.0 L/d
- Fish Consumption (F_H) = 0.02 kg/d

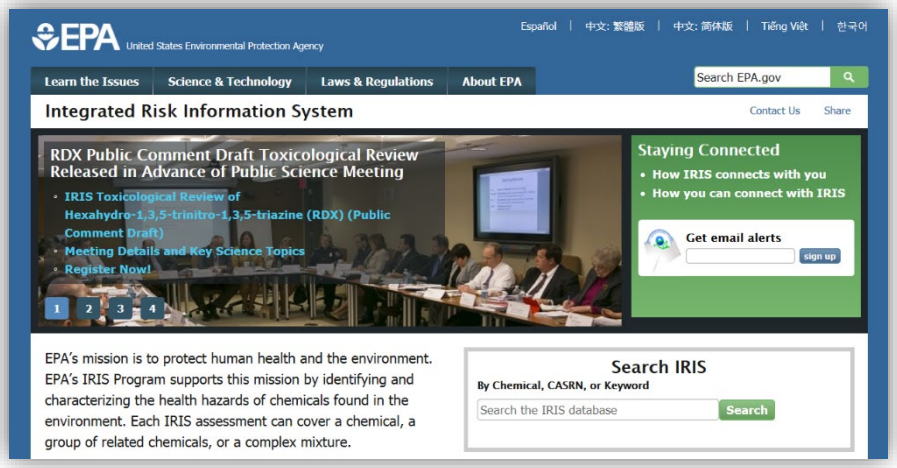
Chemical specific parameters

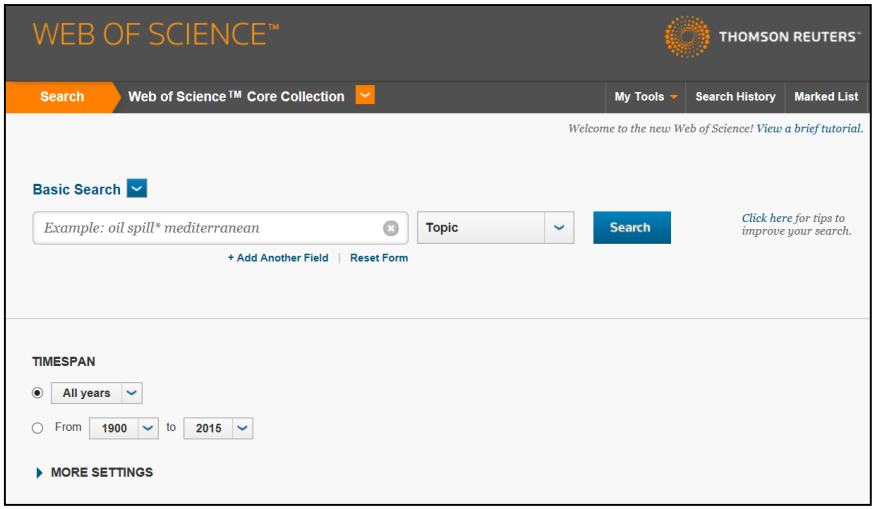
- Acceptable daily exposure (ADE)
- Relative source contribution (RSC)
- Bioaccumulation Factor (BAF)

$$HTC = \frac{ADE \times RSC \times BW}{W_H + (F_H \times BAF)}$$

Step 1) Determine the Acceptable daily exposure (ADE) level







EPA's IRIS database has oral reference dose (RfD) of 7.1×10^{-4} mg/kg-d for Substance X

Step 2) Determine the relative source contribution (RSC)

- A RSC can be calculated for a substance by determining how much of the total exposure to a substance occurs from drinking contaminated water and eating contaminated aquatic organisms.

$$RSC = \frac{Exposure_{Fish} + Exposure_{Water}}{Exposure_{Total}}$$

- Often a default value is used

No exposure data for Substance X was available.
RSC = default = 0.8

Step 3) Determine the bioaccumulation Factor (BAF)

- Step 3A) Calculate the baseline BAF

Method 1
Measured from field data (organism, water column)

Applies to organic and inorganic chemicals

Baseline BAF = 137.40 L/kg

- Step 3B) Calculate the human health BAF
  - Substance X is inorganic
    - Human Health BAF =Baseline BAF x FCM

Human Health BAF for Substance X = 7.046 L/kg

Human Threshold Equation

Standard parameters

- Body Weight (BW) =

  70 kg
- Water Consumption Rate (W_H) =

  2.0 L/d
- Fish Consumption (F_H) =

  0.02 kg/d

Chemical specific parameters

- Acceptable daily exposure (ADE)

  7.1×10^{-4} mg/kg-d
- Relative source contribution (RSC)

  0.8
- Bioaccumulation Factor (BAF)

  7.046 L/kg

$$HTC = \frac{7.1 \times 10^{-4} \times 0.8 \times 70}{2.0 + (0.02 \times 7.046)}$$

HTC for Substance X is 18.6 µg/L

Discussion

Which components of surface water quality criteria derivation could be applied to the development of contaminated sediment standard?

Questions?
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