LimnoTech
Water Environment | Scientists Engineers

General Overview: Fish Tissue and Water Quality Standards

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Spokane Regional Toxics Task Force Workshop

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Recurring Questions

- What endpoint should the SRRTTF use as a basis for their control efforts?
  - Water column PCB concentration?
  - Fish tissue PCB levels?
- Why are existing Spokane River PCB concentrations:
  - Greatly above fish tissue targets; but
  - Near the water quality standard?

Calculation of Human Health Criteria for PCBs

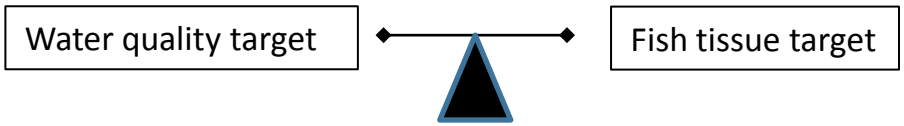
- The objective of the Human Health Criterion for bioaccumulative carcinogens like PCBs is to limit the risk of cancer from eating contaminated fish

(Some) Factors Considered in Setting Criteria

- Many important decisions are required in setting criteria, including:
  - Fish consumption rate
  - Cancer potency
  - Acceptable risk level
  - Body weight

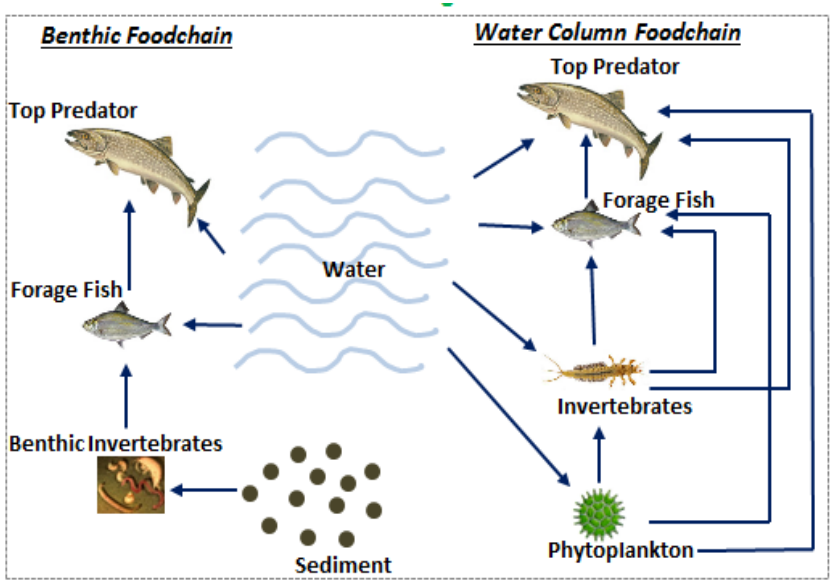
Calculation of Water Quality Target

- Also need some mechanism to relate fish tissue concentration to water column concentration
  - Compliance with one results in compliance with the other



How Do We Relate Water Column Concentration to Fish Tissue Concentration?

- Multiple methods, ranging in complexity
  - Bioconcentration factors
  - Bioaccumulation factors
  - Food web models



Bioconcentration

- Bioconcentration is the process of accumulation of water-borne chemicals *solely through non-dietary routes*

Bioconcentration factor

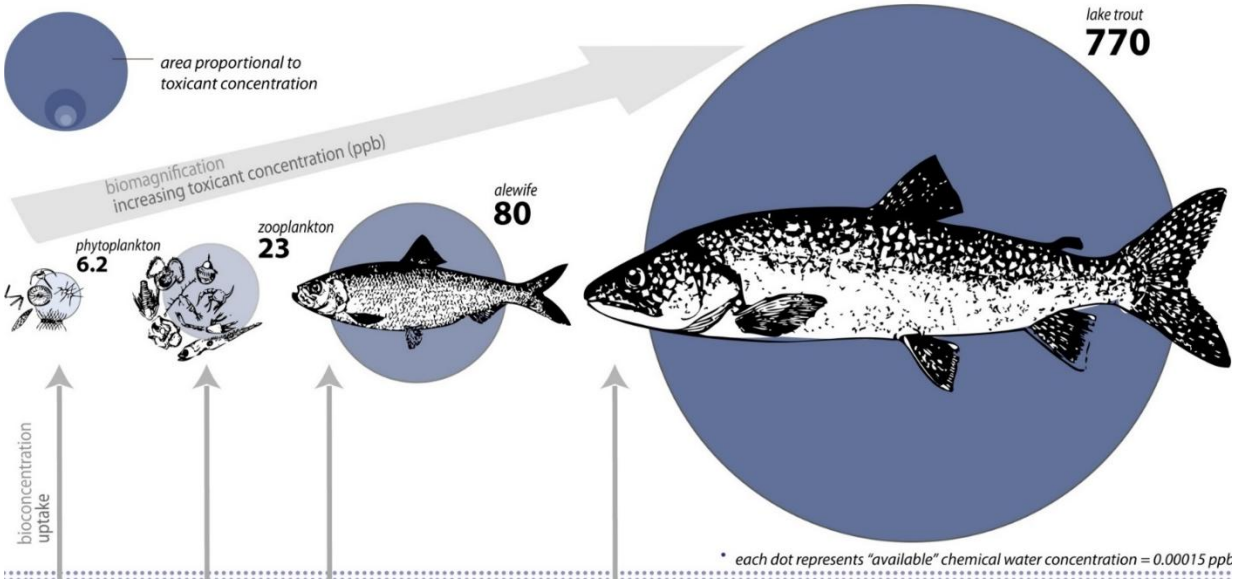
- Bioconcentration factor (BCF) is the ratio of the chemical concentration in biota to the concentration in water
  - $BCF = [PCB]_{biota} / [PCB]_{water}$

– BCFs can be determined in one of two ways
  - Direct laboratory measurement
  - Indirect estimation from:
    – Chemical properties (Octanol-water partition coefficient)
    – Lipid content of fish*

*Chemicals like PCB are assumed to be stored in lipids

Bioaccumulation

- Bioaccumulation is the process by which chemicals are taken up by an organism *either directly from exposure to a contaminated medium or by consumption of food containing the chemical*
  - *Can result in concentrations orders of magnitude higher than from bioconcentration*

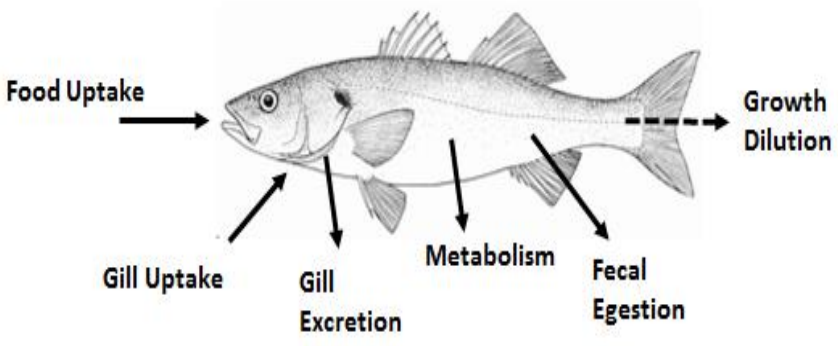


Bioaccumulation factor

- Bioaccumulation factor (BAF) is calculated using the same formula as used for the BCF
  - $BAF = [PCB]_{biota} / [PCB]_{water}$
  - Sole difference is that $[PCB]_{biota}$ reflects food chain uptake
- BAFs not as easily determined as BCFs
  - Can't replicate entire ecosystem in the laboratory
  - Level of bioaccumulation depends on the site
- Can be determined empirically for situations with:
  - numerous fish tissue samples, plus sufficient water column PCB measurements to estimate average

Food Web Modeling

- Tools exist that allow fish tissue concentrations to be estimated from water column concentration (and food web structure)



  - *Bioaccumulation = bioconcentration + food chain transfer – (elimination + growth dilution)*

Bioaccumulation in Spokane

- Ecology's PCB Source Assessment (Serdar et al, 2011) conducted some screening level bioaccumulation modeling using a food web model

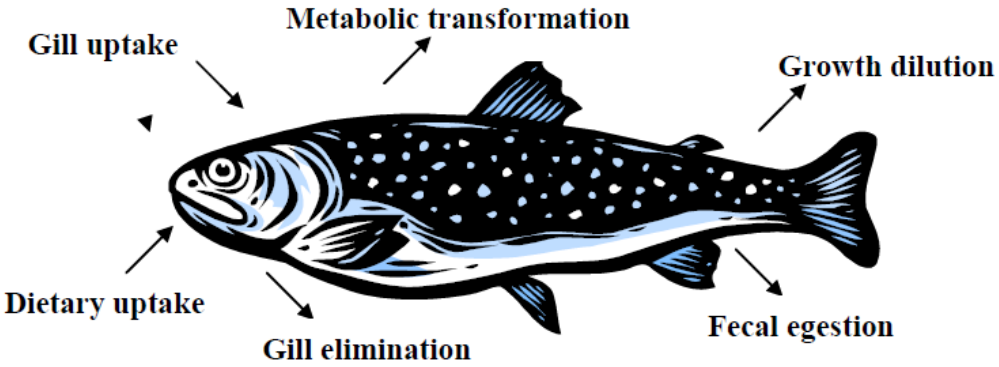


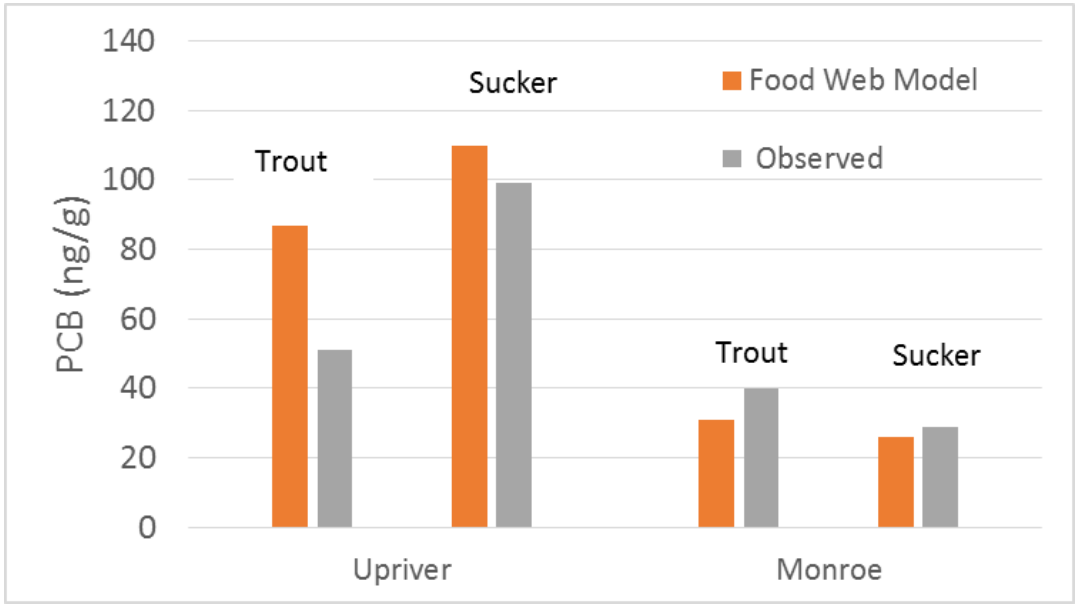
Figure H-1. Conceptual Diagram of the Major Routes of Contaminant Uptake and Depuration (Adapted from Arnot and Gobas, 2004).

Inputs to Food Web Model

- Water Column
  - Organic carbon content, suspended solids
- Sediment
  - TOC
- Diet
  - Zooplankton, benthic species, trout, suckers:
    - e.g. benthic species assumed to eat 50% phytoplankton, 50% sediment
- Fish weight and lipid content
- PCB characteristics

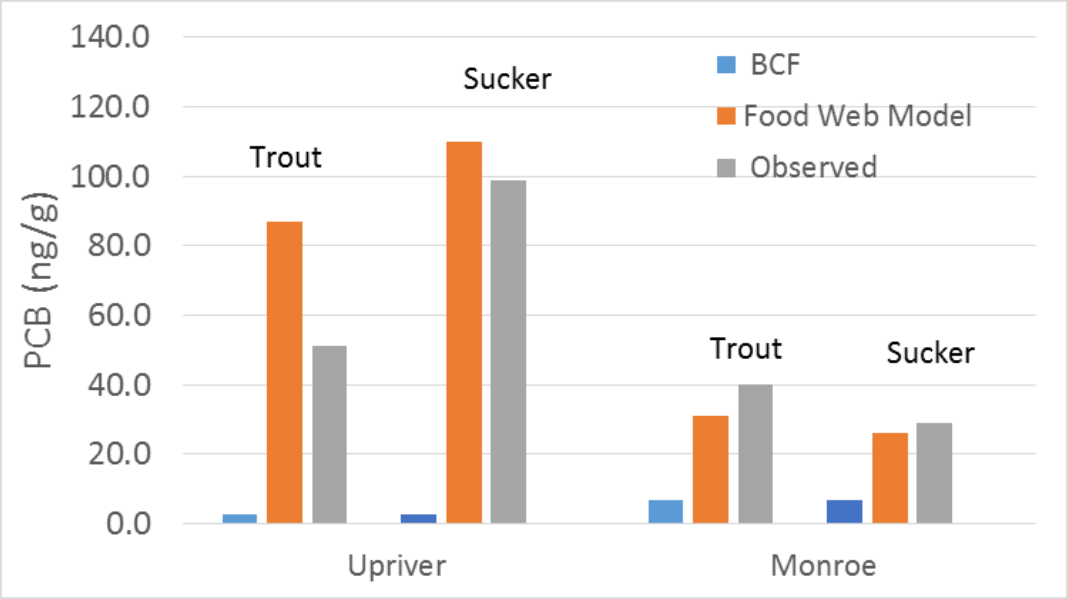
Food Web Model Results

- Food web model results were consistent with observed fish tissue PCB concentration
  - Spokane River not particularly “unique” in terms of bioaccumulation



Comparison to BCF

- Bioconcentration factor does not accurately predict fish tissue PCB
  - Off by as much as a factor of 40

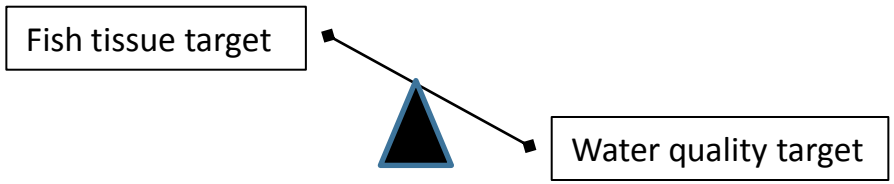


Why Does This Matter?

- Ideally, the fish tissue target will be consistent with the water quality criterion for human health
- Many water quality standards (including Washington's) for PCBs are both based on a bioconcentration factor
- Bioconcentration factor under-predicts fish tissue concentration
  - Not surprising that water column concentrations near the water quality standard result in fish tissue concentrations much higher than the target

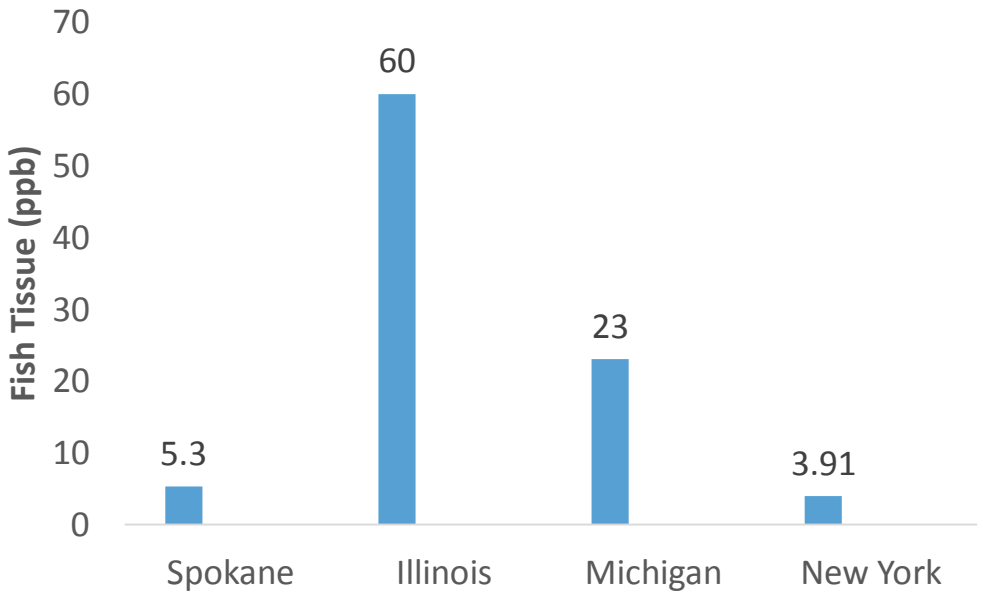
Why Does This Matter?

- As long as the water quality standard is based on a BCF, the water quality standard will be less protective than fish tissue targets



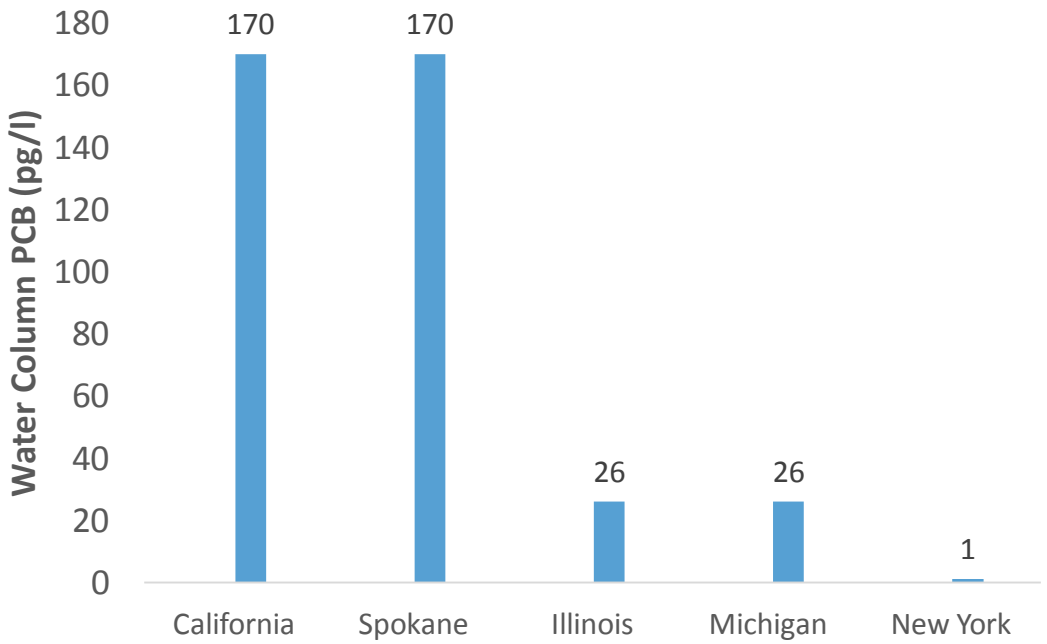
Comparison to other Sites

- Some have higher fish tissue targets, some lower



Comparison to other Sites

- Water column standards at sites that consider bioaccumulation are much lower



Why Aren't Water Quality Targets based on BAFs?

- BAFs not as easily determined as BCFs
  - Can't replicate entire ecosystem in the laboratory
  - No simple indirect calculation
    - Level of bioaccumulation depends on the site-specific food web
- Need a relatively robust data set to estimate empirically from field data
  - Made difficult by the fact the water column PCB concentrations are near the detection limit

Summary

- There is a logical explanation for why the Spokane River is near water quality targets, but not close to fish tissue targets
- We are farther away from compliance with targets than water quality data alone would imply
- Outstanding questions
  - Are fish getting the majority of PCBs from the water column or sediment?
  - Does it matter?
  - Are certain types of load more important to control than others?