General Overview: Fish Tissue and Water Quality Standards

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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
  \[ BCF = \frac{[PCB]_{\text{biota}}}{[PCB]_{\text{water}}} \]

- 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
  \[ BAF = \frac{[PCB]_{biota}}{[PCB]_{water}} \]
- 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)

$\text{Bioaccumulation} = \text{bioconcentration} + \text{food chain transfer} - (\text{elimination} + \text{growth dilution})$
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

![Bar graph showing water column PCB levels in pg/l for California, Spokane, Illinois, Michigan, and New York.]

- California: 170
- Spokane: 170
- Illinois: 26
- Michigan: 26
- New York: 1
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?