The Tissue Residue Approach for Toxicity Assessment (TRA): Potential Application for Contaminated Sediment

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Premise – That tissue concentrations are a better surrogate for characterizing toxicity than external exposure concentrations (water, sediment/soil, or diet).
TQGs can be used as Environmental Quality Standards (EQS) or converted to sediment concentrations for use as SQGs.

Abstract

The tissue residue approach for toxicity assessment (TRA) associates tissue concentrations of chemicals with adverse biological effects in a dose-response fashion that can be used to determine critical body residues. These CBRs can then be used to develop tissue quality guidelines (TQGs), which may be used as the primary metric or translated into water or sediment guidelines with bioaccumulation factors. Not all toxicants are amenable to this type of analysis; however, some appear to exhibit relatively consistent results that can likely be applied in a regulatory framework. The strongest feature of this approach is causality; hence, guidelines derived with tissue residues are based on a relationship between the acquired dose and biological effects. The TRA has utility for assessing contaminated sediment. This approach allows us to consider toxic potency, variable bioaccumulation, and bioavailability separately when developing SQG values. The TRA approach is also useful for mixture assessment and for developing broad-scale interim guidelines.

What are the advantages of using TRA?

- Frequently observe a large reduction in variability
- Causally based dose-response relationships
- Reduction in spatial and temporal variability
- Simplified analysis for mixtures
- Combine freshwater and marine toxicity data
- More direct examination of toxic mechanisms
- Fewer toxicity studies needed
- Field monitoring and remediation evaluation

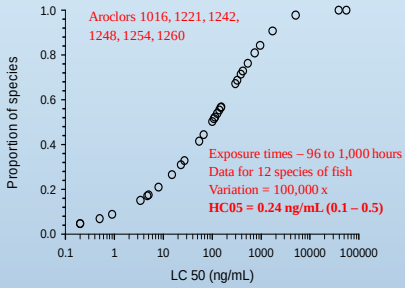
Works
Most compounds where a [tissue] is representative of the [target] and the mechanism is reversible. (e.g., baseline toxicants, organometallics, chlorophenols). Includes chemicals that are metabolized.

Doesn't work well
Compounds where a [tissue] is not proportional to the [target] (e.g., highly metabolized compounds, metals, mutagens, cyanide, et al.)

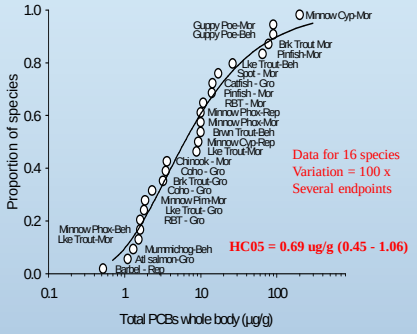
Some promise
A large number of organic compounds acting by a specific mechanism

Tissue Quality Guidelines

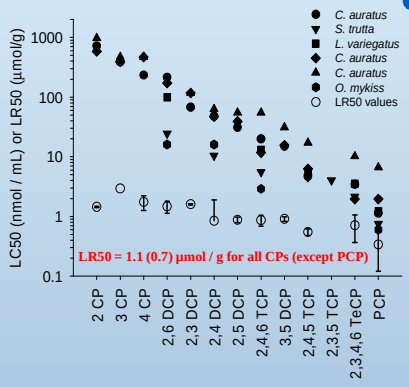
Example – PCBs LC50s



Example – PCBs tissue residue toxicity



Example - Chlorophenols



Toxicity metrics for [tissue] and [exposure] related via bioaccumulation factor

The LCp or ECp is often directly proportional to the toxicity value based on tissue concentrations (LRp or ERp). This relationship can also be used to determine response metrics based on tissue residues using any time-matched response metric and BAF or BSAF values. This equation holds for any CBR (e.g., LOER, ER_{25}). For example:

$$ER_{25} = BCF * EC_{25}$$

Taxa and response specific (e.g., fish growth)

Sediment Quality Guidelines

A TQG can be converted to water or sediment values using bioaccumulation factors. These simple equations relating toxicity and bioaccumulation can be solved for sediment concentration. Similar to Equilibrium Sediment Benchmark (ESB).

Advantages

- Includes all modes and mechanisms of action & all responses
- Considers bioavailability, bioaccumulation, & toxicant potency separately
- Can be applied for mixtures
- Useful for interim broad scale guidelines as more detailed values are developed.

SQG using Koc and BCF

The equation is:

$$[sedoc] = Koc\frac{TQG}{BCF} = SQG$$

where sedoc is the organic-carbon normalized sediment concentration, TQG is the tissue concentration selected for protecting species, Koc is the organic-carbon normalized sediment–water partition coefficient, and BCF is a high percentile value (e.g. 95th ptile) from the empirical CDF for all species or each measured value.

SQG via BSAF

The sediment quality guideline can be determined by:

$$[sedoc] = \frac{TQG}{BSAF * f_{lipid}} = SQG$$

where f_{lipid} is the lipid content and sedoc is the organic carbon normalized sediment concentration

µg chemical / µg organic carbon

Sediment Quality Guideline (SQG) acute baseline ("narcosis") toxicity

$$[sedoc] = \frac{TQG}{BSAF * f_{lip}} = SQG$$

Baseline toxicity = 2 – 8 µmol/g
Assuming a max BSAF ≈ 4

$$\frac{5 \mu mol/g}{4 * 0.02} = 62.5\ \mu mol/gOC$$

62.5 µmol/g OC *0.015 = 0.94 µmol/g dry wt.
Average MW ≈ 200 daltons
0.94 µmol/g dry wt. ≈ 188 µg/g dry wt. sediment
for all compounds acting as baseline toxicants

- Sublethal toxicity – 10x lower? 100x lower?
- SQG would be additive for all baseline toxicants

Chlorophenol - SQG for mortality via BSAF

The sediment quality guideline for the sum of all chlorophenols (minus PCP) can be estimated by the equation above. (Also a good example for assessing mixture toxicity)

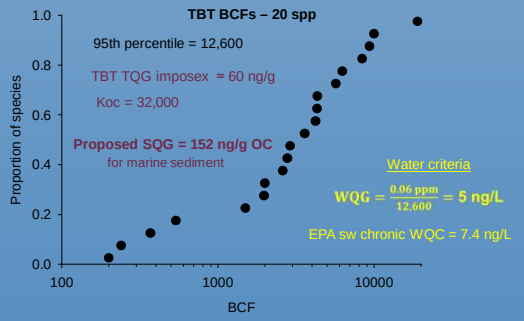
TQG = 1 µmol/g tissue, BSAF = 4, f_{lip} = 0.01
Sedoc = 25 µmol/g OC

For a 1% TOC sediment = 250 nmol/g dry sed

If MW approx. 200 daltons = 50 µg/g dry sed for ∑of all CPs

Sublethal "chronic" values will be lower.

Tributyltin - SQG for chronic toxicity via BCF



Supporting literature

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