Quantification of Ecological Risks to Aquatic Biota from Bioaccumulated Chemicals

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Abstract

A simple sounding yet difficult to answer question is "What concentration of a chemical in the tissues of aquatic biota is harmful to the biota itself?" This question is of particular importance in ecological risk assessment, where measurements of chemical residues in aquatic biota are often available, but the interpretation of their effect on biota is difficult. The objective of this work was to define tissue residues for a number of chemicals which, if not exceeded, pose little threat of risk to aquatic biota. These tissue screening concentrations (TSCs) were designed to be nonsite- or species-specific indicators of low risk residue levels. TSCs have been derived for 152 chemicals, both metals and organics, using a one-compartment first-order kinetic model. These TSC values are currently being used in ecological risk assessments to identify chemicals of potential concern, thus narrowing the focus of the risk assessment. To confirm the validity of the TSCs, a literature review of whole body tissue residues associated with adverse toxicological or ecological effects was performed. The review currently contains over 1400 records of tissue residues associated with adverse effects of 120 of the TSC chemicals. For chemicals where the TSC values are applicable, 94 percent of the literature reviewed indicates that adverse effects occur only at tissue residues higher than the TSC values. This is comparable to the U.S. Environmental Protection Agency's (USEPA) ambient water quality criteria, which are designed to be protective of 95 percent of aquatic genera. Analysis of this literature indicates that as groups (1) marine and freshwater biota are equally sensitive to chemical residues in their tissues, and (2) benthic and pelagic biota are equally sensitive to chemical residues in their tissues. Sufficient literature is available for a number of chemicals to permit direct estimates of the likelihood residues in aquatic biota from a site pose adverse risks. The existence of a tissue residue literature database relating adverse effects to residue levels eliminates one of the primary shortcomings preventing the use of the tissue residue approach in sediment quality criteria development: lack of documentation of tissue residues related to adverse toxicological effects. The database also provides indirect confirmation of a primary assumption of the equilibrium partitioning approach to sediment quality criteria development: benthic biota have a similar range of sensitivity to chemicals as do pelagic biota.

Introduction

Historically, the primary use of aquatic biota tissue residue data in ecological risk assessments has been to provide an indication that the biota have been exposed to chemicals at a site. Seldom have efforts been made to directly quantify ecological risks from bioaccumulated chemicals.

The most common approach to quantifying ecological risks to aquatic biota is to divide the concentration of a chemical in water or sediment by a toxicity reference value (TRV), a concentration which if exceeded is expected to result in adverse ecological effects. The resulting hazard quotient is used as a measure of risk to biota, with the likelihood of adverse effects increasing with increasing magnitude of the hazard quotient. TRVs available for use in ecological risk assessment include ambient water quality criteria (AWQC) and sediment quality values from several sources. Unfortunately, there is not a comparable set of TRVs for use in assessing ecological risks from tissue residues in the biota themselves, despite a sizable amount of research relating body burdens to toxic effects and the availability of several literature reviews of this information (McCarty and Mackay, 1993; McKim and Schmieder, 1991; Dillon, 1984).

Chemical concentrations in water and sediment are surrogates for the actual dose of chemical at the site of toxic action in biota. The use of these surrogates for the actual

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dose has many limitations and introduces uncertainties in assessing adverse effects of chemicals on aquatic biota, some of which are outlined below.

- The bioavailable fraction of the total chemical concentration in exposure media may not be known.
- Surrogates do not consider multiple uptake routes of chemicals by biota.
- Intermittent, pulsed, or varied exposures cannot be readily assessed.
- Short exposure times can result in nonsteady-state tissue residues and variable toxicity.
- Metabolic transformations of toxicants which enhance or reduce toxicity are not considered.
- Animal behavior (i.e., seasonal migration or toxicant avoidance) is not accounted for.
- Analytical chemistry limitations (e.g., nondetectable concentrations in exposure media) mean the dose is often unknown.

By quantifying risks based on tissue residues associated with adverse toxicological or ecological effects, the above complicating factors are largely eliminated and a more accurate risk assessment can be performed.

The objectives of this work were as follows:

1. To derive risk-based screening concentrations (RBSCs) for assessing ecological risks from chemical residues in aquatic biota tissues to the aquatic biota themselves.
2. To confirm the utility of the derived RBSCs in ecological risk assessment.

Methodology

USEPA's ambient water quality criteria are designed to be protective of 95 percent of all aquatic genera (Stephan et al., 1985). By extension of this principle, tissue residues bioconcentrated from criteria concentrations should also, if not exceeded, be protective of 95 percent of all aquatic genera. This is the fundamental assumption behind the approach used to derive toxicity reference values for bioaccumulated chemicals in aquatic biota.

Tissue residues in aquatic biota which, if exceeded, may describe residues associated with adverse toxicological or ecological effects are termed tissue screening concentrations (TSCs) in this paper. This is because the primary use of the TSC values is as a screening tool to select chemicals of potential concern (COPCs) in ecological risk assessments. COPC identification shortens the list of chemicals carried through the entire ecological risk assessment process. TSCs are intended to be nonsite- or species-specific indicators of tissue residues which, if not exceeded, pose little threat of adverse risk to aquatic biota.

TSCs were derived from the one-compartment first-order kinetic (1CFOK) toxicological model given in Equation 1.

$$\frac{dC_b}{dt} = (k_u \times C_w) - (k_e \times C_b) \qquad (1)$$

where:

C_b = chemical concentration in biota (mg/kg)
t = time (hours)
k_u = chemical uptake rate constant (L/kg/hr)
C_w = chemical concentration in water (mg/L)
k_e = chemical elimination rate constant ($hour^{-1}$)

If the chemical concentration in water is assumed to be constant, Equation 1 may be exactly integrated to yield Equation 2.

$$C_b = C_w \quad \frac{k_u}{k_e} \quad (1 - e^{-k_e t}) + (C_{b(t=0)} e^{-k_e t}) \qquad (2)$$

If it is further assumed that the animal starts with no tissue residue of the chemical of interest and the tissue residue is at steady state with respect to the water concentration, Equation 2 reduces to Equation 3.

$$C_b = C_w \times \frac{k_u}{k_e} \qquad (3)$$

By redefining the terms in Equation 3, C_b becomes the tissue screening concentration, C_w becomes an ambient water quality criterion (AWQC), k_u/k_e is a bioconcentration factor (BCF), and the redefined Equation 3 can be used to derive tissue screening concentrations, as shown in Equation 4.

$$TSC = AWQC \times BCF \qquad (4)$$

Although the derivation of TSCs is based on sound toxicological concepts, in practice they are derived simply by multiplying a water quality criterion by a bioconcentration factor.

To provide a more conservative screening value, water quality criteria used in the calculations are the lower of USEPA's freshwater or chronic ambient water quality criteria. Since some of USEPA's water criteria documents are for classes of chemicals (e.g. PAHs, chlorinated benzenes, chlorinated phenols), a single criterion value may be used in the derivation of multiple TSC values. For metals with hardness-dependent criteria, a hardness of 50 mg/L $CaCO_3$ was assumed. If only an acute criterion was available for a given chemical, the acute criterion was divided by 8 to estimate a chronic criterion. The bioconcentration factors used were taken from the human health portion of the USEPA water quality criteria documents. For metals, the BCFs are geometric means of measured BCF values, whereas for organics, the criteria BCFs were calculated using a regression equation relating octanol-water partition coefficient to BCF. Most of the BCF values used are found in the *Superfund Public Health Evaluation Manual* (USEPA, 1986).

To confirm the validity of the TSC values, a literature review was performed of papers relating measured whole body, wet weight tissue residues to adverse toxicological or ecological effects. For papers where dry weight tissue residues were reported, a conversion to wet weight was made assuming 80 percent water content if the actual water content was not given in the paper. Effects considered in the review were population and community effects, mortality, reproduction, growth,

behavioral, cellular, biochemical, or physiological changes.

The literature database currently contains the following information for each citation: chemical name, tissue screening concentration, tissue residue associated with effect (or the no effect residue), common and scientific names of the species studied, toxicological or ecological effect, a safety factor (defined in Equation 5), a footnote field that contains information on the exposure conditions of the study, and the full literature citation.

To describe the difference between TSC values and the tissue residues associated with adverse effects, a safety factor (Equation 5) was calculated.

$$\text{TSC safety factor} = \frac{\text{Tissue concentration associated with effect}}{\text{TSC}} \quad (5)$$

The safety factor provides qualitative evidence of the level of protection TSCs provide aquatic biota from adverse effects. Computationally, the safety factor can also be considered a hazard quotient for a measured tissue residue associated with a specified effect as given in the literature.

It must be noted that the TSC values are intended to identify tissue residues which, if not exceeded, pose little or no risk to aquatic biota. They are not intended to define tissue residues that are protective of avian, mammalian, or other wildlife species that prey upon aquatic biota.

Results

Table 1 provides a representative example of the 152 currently available tissue screening concentrations. All tissue residues given in Table 1 have units of mg/kg whole body, wet weight. As shown in Table 1, the TSC values span a wide range of tissue residues predicted to have little or no effect on aquatic biota.

The literature review currently contains nearly 500 citations and 1400 records associating tissue residues to adverse effects. Of these, approximately 10 percent of the individual records describe no observed adverse effect tissue residues. A range of tissue residues have been associated with adverse ecological or toxicological effects. Figure 1 shows the distribution of tissue residues associated with adverse cadmium effects. The distribution in Figure 1 is typical of that for most chemicals, where no or only a few citations indicate that effects occur below the tissue screening concentration, but most adverse effects occur at tissue residues above the tissue screening concentration.

At least one literature citation is available for 120 of the 152 chemicals for which TSCs exist. Ten or more residue-effect records are available for about 40 chemicals. Cadmium has the most literature information available of any chemical in the database, while PCBs have the most information available for any organic chemical. Other chemicals that have a substantial amount of literature available include mercury, copper, zinc, dioxin, pentachlorophenol, and several chlorinated insecticides.

Once the no observed adverse effect residues are removed from the database, 83 percent of the tissue residues associated with adverse effects are concentrations higher than the tissue screening concentrations. Over half of the tissue residues associated with adverse effects at concentrations lower than the TSCs are for chemicals that are rapidly (within a few hours or days) metabolized to more toxic compounds. The rapidly metabolized chemicals are mostly PAH compounds, although the chlorinated insecticide aldrin is also rapidly converted to a more toxic metabolite, dieldrin. Figure 2 shows tissue residues of benzo(a)pyrene associated with adverse effects. For benzo(a)pyrene, every citation available shows an adverse effect at a whole body concentration below its TSC value.

Once chemicals rapidly metabolized to more toxic forms are removed from the literature database, the predictive ability of the TSC values to identify residue levels below which adverse effects are unlikely improves. By performing the TSC to adverse effects literature comparison without chemicals rapidly metabolized to more toxic forms, 94 percent of the tissue residues associated with adverse effects are higher than the tissue screening concentrations.

The calculated safety factors (Equation 5) provide a qualitative indication of the conservative nature of the TSC values. For all residue effect citations in the literature database, the geometric mean safety factor is 15, while the arithmetic mean safety factor is 41. The safety factors for individual literature citations are generally largest for measures of mortality and smallest for biochemical endpoints.

Table 1. Derivation of selected tissue screening concentration values.

Chemical	AWQC µg/L	AWQC Source	BCF L/kg	TSC mg/kg
Aldrin	1.3	Marine acute	4,670	0.71
Benzo(a)pyrene	300	PAH marine acute	11,100	416
Cadmium	0.66	Freshwater chronic	64	0.042
Copper	2.9	Marine acute	200	0.17
4,4'-DDT	0.001	Freshwater chronic	53,600	0.054
Dieldrin	0.0019	Freshwater chronic	4,760	0.0090
Dioxin (2,3,7,8-TCDD)	0.00001	Freshwater chronic	5,000	0.000050
Hexachlorobenzene	3.68	Freshwater chronic	8,690	32
Mercury	0.012	Freshwater chronic	4,994	0.060
PCB	0.014	Freshwater chronic	31,200	0.44
Tributyltin	0.01	Marine chronic	693	0.0069
1,2,4-Trichlorobenzene	50	Freshwater chronic	2,800	140
Zinc	59	Freshwater chronic	47	2.8

AWQC - USEPA Ambient Water Quality Criterion
BCF - Bioconcentration Factor
TSC - Tissue Screening Concentration

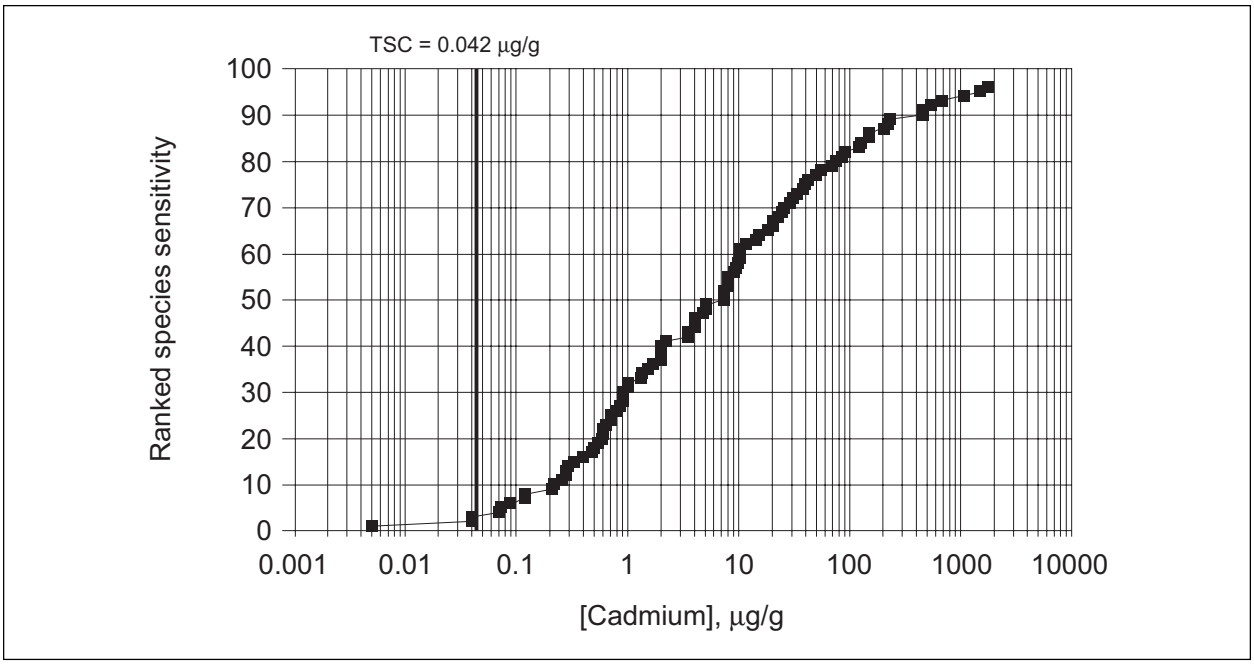

Figure 1. Tissue residues associated with adverse effects: Cadmium.

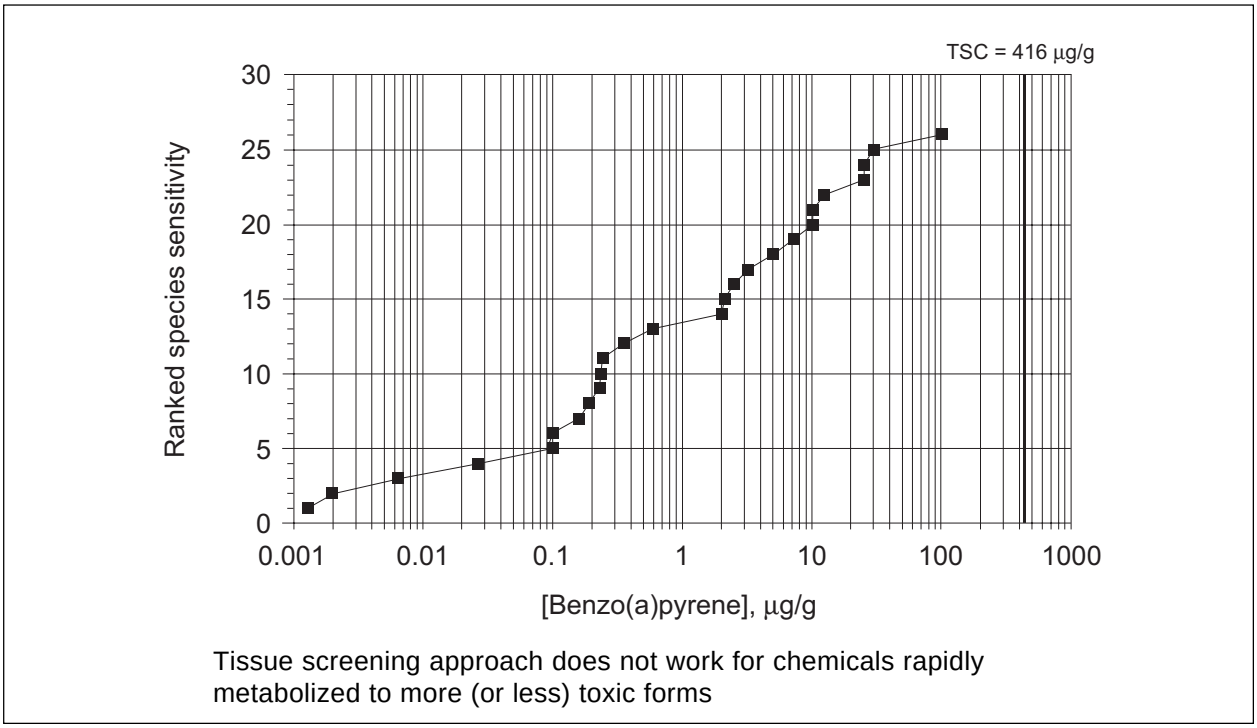

Figure 2. Tissue residues associated with adverse effects: Benzo(a)pyrene.

The safety factors have been used to make several statistical comparisons among various subsets of the literature data. These comparisons have found that, as groups:

1. There are no significant differences in residue levels that cause adverse effects in freshwater or marine biota.
2. There are no significant differences in residue levels that cause adverse effects in benthic compared to pelagic biota.
3. There are no significant differences in the sensitivity of biota to chemicals under field or laboratory exposure conditions.

Although the results given above appear broadly applicable based on the literature review, there are exceptions in some instances. For example, arsenic residues associated with adverse effects in freshwater biota are much lower than arsenic residues that adversely affect marine biota.

Table 2. Human health exposure scenario used to derive toxicity reference values (TRVs) for comparison of TSC values to TRVs for consumers of fish and shellfish.

Exposure Scenario Parameter	Value	Exposure Scenario Parameter	Value
Exposure frequency	350 days/year	Fish and shellfish ingestion rate	6.5 grams/day
Exposure duration	30 years	Target noncancer risk	1
Body weight	70 kilograms	Target cancer risk	1×10^{-6}

Tissue screening concentrations have also been compared to human health toxicity reference values (TRVs) for chemicals in fish and shellfish consumed by humans. The exposure scenario and risk assumptions used to derive the human health TRVs are presented in Table 2. For noncarcinogenic chemicals where comparisons could be made, the ecological TSC values were lower than the human health TRVs in 61 of 67 comparisons (91 percent). For carcinogenic chemicals, the human health TRVs were lower than the ecological TSCs in 36 of 42 comparisons (86 percent).

Discussion

To date, TSCs have been used as a screening tool in ecological risk assessments at several Superfund sites. In all cases, they have identified chemicals of potential concern (COPCs) that have also been identified as COPCs in at least one other human health or ecological risk assessment scenario at the same site. This type of agreement with other risk assessment procedures provides corroborative evidence that the TSCs are successfully identifying chemicals worthy of detailed investigation in ecological risk assessments.

The largest shortcoming of the procedure appears to be its lack of applicability to chemicals that are rapidly metabolized to more toxic forms. Many PAH compounds elicit adverse effects at tissue residues several orders of magnitude below the PAH tissue screening concentrations (Figure 2). Although this may be due in part to the use of an old water quality criterion (USEPA, 1980a) for PAHs, a mechanistic reason for this observation can also be given.

Many PAHs are known to be rapidly metabolized to more toxic compounds (USEPA, 1980a). A tissue screening concentration based on residues of a less toxic parent compound will not represent a safe concentration of a more toxic metabolite. For rapidly metabolized chemicals, a TSC for the more toxic metabolite should be used to assess risks, rather than the TSC for the parent compound. An example of this approach is shown in Figure 3. Aldrin is rapidly metabolized by many species to dieldrin (USEPA, 1980b). The limited amount of

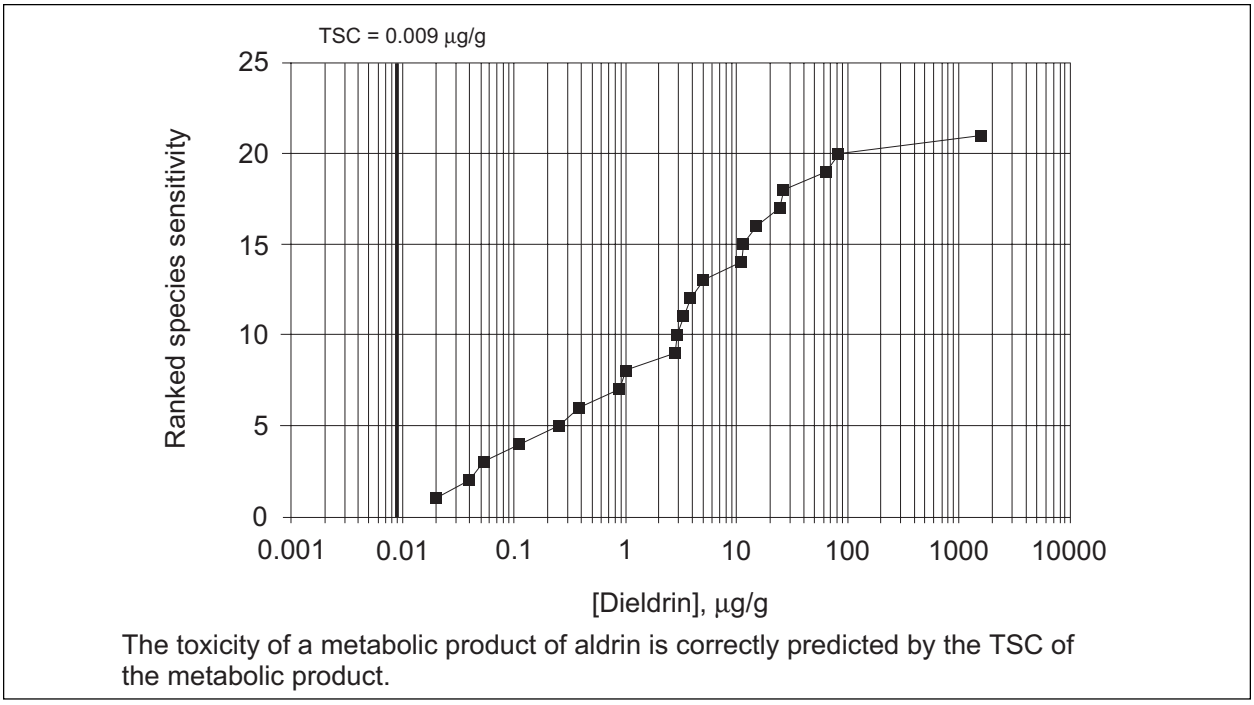

Figure 3. Tissue residues associated with adverse effects: Dieldrin.

aldrin residue data associated with adverse effects brackets the aldrin TSC value. A substantial amount of literature is available for dieldrin residue toxicity (Figure 3). In all cases, dieldrin residues associated with adverse effects are higher than the dieldrin TSC value. Unfortunately, TSC values do not currently exist for PAH metabolites, limiting the utility of the TSC approach to chemically and metabolically stable toxicants.

They are also not applicable for chemicals whose toxicity does not result from an internally absorbed dose. Examples of chemicals in this second category may be aluminum and iron, whose toxicity largely comes from formation, under certain water quality conditions, of a flocculent material that suffocates aquatic biota.

Several of the TSC values appear to be overly conservative based on the literature review. In particular, no adverse effects have been associated with copper residues below 3 mg/kg or zinc residues below 20 mg/kg, considerably higher than the respective calculated TSC values of 0.17 and 2.8 mg/kg. In practice, we are now using the 3 mg/kg copper and 20 mg/kg zinc values as screening concentrations in ecological risk assessments. Many aquatic species can regulate their body burdens of copper and zinc. The 3 and 20 mg/kg screening values for copper and zinc are much closer to the known or estimated physiological requirements of these two elements in aquatic biota (van Tilborg and van Assche, 1996; White and Rainbow, 1985) than are the TSC values in Table 1.

At least one TSC is not sufficiently conservative for use as a screening tool in ecological risk assessment. The hexachlorobenzene TSC of 32 mg/kg is higher than 9 of the 10 literature citations associating hexachlorobenzene residues with adverse effects. If the hexachlorobenzene TSC is recalculated using the bioconcentration factor from Table 1 and the Canadian Water Quality Guideline of 0.0065 µg/L instead of the draft USEPA ambient water quality criterion of 3.68 µg/L, the resulting TSC is 0.056 mg/kg. This recalculated TSC is lower than all 10 hexachlorobenzene adverse effect residue levels reported in the literature. Use of the Canadian Water Quality Guidelines is currently under investigation for use in calculation of additional TSC values for chemicals where USEPA currently has no ambient water quality criteria.

The availability of a literature database of tissue residues associated with adverse effects permits the use or derivation of several other ecological risk estimation methods. The hazard quotient approach has already been discussed. For aquatic species where a substantial amount of literature is available, the best approach may be the direct identification of tissue residues associated with adverse effects. Rainbow trout (*Oncorhynchus mykiss*) and blue mussels (*Mytilus edulis*) are the freshwater and marine species with the most tissue residue information available in the literature. By comparing the distribution of tissue residues associated with adverse effects (Figures 1-3) to the residue distribution in animals from a site of interest, probabilistic risk assessments could be performed. Other endpoints analogous to sediment or water quality criteria or guidelines, such as apparent effects thresholds (AETs), lowest observed adverse effect levels (LOAELs), or tissue residues above which effects on a defined percentile of species occur could all be calculated from the literature database. The defined percentile approach could be the tissue residue equivalents of the Long and Morgan (1991) effects range-low (ER-L) and effects range-median (ER-M) sediment quality guidelines.

Although the primary focus of this paper has been on the use of tissue residue information to define ecological risks to aquatic biota, the tissue residue approach also has applicability to the derivation of sediment quality criteria. USEPA (1993) has identified the tissue residue approach as a technically valid approach for the derivation of sediment quality criteria. One of the major identified shortcomings of the tissue residue approach to sediment criteria development is the absence of a database of residue levels associated with toxicity (USEPA, 1993). The database developed to confirm the utility of the TSC values could also serve to eliminate this identified shortcoming of the tissue residue approach to sediment criteria development. The database also provides indirect evidence that benthic biota, as a group, are equivalent in their response to toxicants to pelagic biota, a fundamental assumption of the equilibrium partitioning approach to deriving sediment quality criteria.

Summary and Conclusions

Although the literature database compiled during this study allows a number of hypotheses to be tested and conclusions to be drawn, the three primary conclusions that have been drawn to date are:

1. Tissue residues of chemicals in aquatic biota can, for many chemicals, be used to directly assess ecological risks to aquatic biota.
2. Chemicals for which tissue residues cannot be used to quantify risks can be identified from mechanistic considerations.
3. The level of protection from adverse risk provided by the tissue screening concentration approach is comparable to that provided by USEPA's ambient water quality criteria.

The TSC method appears to provide a conservative initial screen capable of eliminating from an ecological risk assessment chemicals that do not pose significant risks to aquatic biota. Exceedance of a tissue screening concentration does not automatically imply that an observed tissue residue poses an adverse risk to biota. It does, however, identify those chemicals which require more detailed investigation in an ecological risk assessment.

The existence of an interpretive tool for assessing risks or hazards to aquatic biota from bioaccumulated chemicals has many potential applications in addition to ecological risk assessment. Environmental assessments, dredging bioassessments, and criterion and standard development are three of the many possible uses. Interpretation of tissue residues has the potential to provide substantially more information than its current primary use, which is as an indicator of exposure to chemicals.

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Question

Can contaminant tissue residues in aquatic biota be used to define ecological risks to aquatic biota?

Objectives

❶ **To derive risk-based screening concentrations (RBSCs) for assessing ecological risks of chemical residues in aquatic biota tissues**

❷ **To confirm the utility of the RBSCs in ecological risk assessment**

A Newer Objective

❸ To directly quantify ecological risks from chemical residues in aquatic biota tissues

Available Toxicity Reference Values in Aquatic Toxicology

- Ambient water quality criteria (AWQC)
- Sediment quality criteria

The Fundamental Principle of Toxicology

The magnitude of the toxic response is proportional to the toxicant concentration at the site of toxic action

Tissue Screening Concentrations (TSCs)

Whole body, wet weight tissue residues of chemicals which, if not exceeded, pose little chance of causing adverse toxicological or ecological harm to aquatic biota. TSCs are intended to be non-site or species specific.

Uses of Tissue Screening Concentrations

- Primary use is as a screening tool to select chemicals of potential concern in ecological risk assessment
- Can also be used as the denominator in hazard quotient calculations

Toxicological Basis for Tissue Screening Concentrations

1CFOK model
(integrating form assuming constant water concentration)

$$C_b = C_w \times (k_u/k_e) \times (1 - e^{-k_e t}) + (C_{b(t=0)} e^{-k_e t})$$

Where:

- C_b = chemical conc. in biota (mg/kg)
- t = time (hours)
- C_w = chemical conc. in water (mg/L)
- k_u = chemical uptake rate constant (L/kg/hr)
- k_e = chemical elimination rate constant ($hour^{-1}$)

Toxicological Basis for Tissue Screening Concentrations

If it is further assumed that:

❶ **The initial tissue residue is zero, and**

❷ **The animal is at steady state**

The 1CFOK model reduces to . . .

Calculation of Tissue Screening Concentrations

$$TSC = WQC \times BCF$$

Where:

TSC = tissue screening concentration
WQC = water quality criterion (mg/L)
BCF = 3% lipid normalized bioconcentration factor (L/kg)

Example TSC Values

(All values mg/kg whole body, wet weight)

Chemical	TSC
Arsenic	1.6
Cadmium	0.042
4,4'-DDT	0.054
Dioxin (2,3,7,8-TCDD)	0.00005
Mercury	0.12
PCB	0.44
Tributyltin	0.006
1,2,4-Trichlorobenzene	140

TSCs currently available for over 150 chemicals

"The direct prediction of chronic toxic effects from measured or predicted tissue residues requires validation before it can be widely endorsed."

p.7-7, USEPA Sediment Classification Methods Compendium (1993)

Performed literature review of measured tissue residues associated with toxicological effects. It currently contains about 1400 records, 490 literature citations, and information on 118 of the 152 chemicals for which TSCs exist

Database Structure

1. Chemical name
2. TSC value
3. Residue concentration associated with effect
4. Species
5. Toxicological or ecological effect
6. Safety factor
7. Footnote
8. Literature citation

Safety Factor

Effect tissue concentration
TSC

Provides qualitative evidence of the level of protection TSCs provide aquatic biota from a specific effect. Also could be considered a hazard quotient for the specified effect at a given tissue residue.

Criteria for Inclusion in Database

- **Had to report measured tissue residues**
- **Only papers reporting whole body residues**
- **No limitation on toxicological endpoint**
- **No limitation on route of exposure**
- **Included both laboratory and field studies**
- **Minor limitations on aquatic species included**

Distribution of Tissue Residue Literature

Range of citations	No. of chemicals
1 - 9	82
10 - 19	20
20 - 29	8
30 - 39	3
40 - 49	1
50 - 59	2
60+	2

Assumptions in Validating Utility of TSCs

- No difference in sensitivity of freshwater, estuarine or marine biota
- No differences in sensitivity of benthic, epibenthic or pelagic biota
- No differences in response of laboratory and field exposed biota
- Interested only in identifying risks to aquatic biota—TSCs not designed to be protective of piscivorous birds and wildlife

IT WORKS!

(At least for most chemicals)

Results of Literature Review

- About 10% of results describe no observed effect at a given tissue residue
- For the entire database, 83% of adverse effects occur at concentrations above TSC values
- When chemicals which are rapidly metabolized to more toxic compounds are removed, 94% of reported effects occur at concentrations above TSC values

Results of Literature Review

- Geometric mean TSC safety factor for entire database is 15
- Arithmetic mean TSC safety factor for entire database is 41

Possible Approach for Chemicals Rapidly Metabolized to More Toxic Compounds

Aldrin

TSC = 0.71 mg/kg

2 of 2 records show adverse effects below TSC (4 no effect records)

Dieldrin

TSC = 0.009 mg/kg

0 of 19 records show adverse effects below TSC (1 no effect record)

Care Must be Taken When Using TSCs in Risk Assessment

Hexachlorobenzene

- TSC = 32 mg/kg
- Derived from USEPA AWQC of 3.68 ug/L
- 9 of 10 records show adverse effects below TSC (11 no effect records)
- Deriving a TSC from the Canadian Water Quality Guideline of 0.0065 ug/L
- TSC = 0.056 mg/kg
- 0 of 10 records show adverse effects below TSC

Care Must be Taken When Using TSCs in Risk Assessment

Copper and zinc are two examples where TSCs may be overly conservative

Copper

TSC = 0.17 mg/kg, toxicity threshold at 3 mg/kg

Zinc

TSC = 2.8 mg/kg, toxicity threshold at 20 mg/kg

Many aquatic species can regulate their Cu and Zn burdens

Methods for Quantifying Ecological Risks of Tissue Residues

1. Hazard quotients
2. Apparent Effects Threshold (AET)
3. Effects on defined percentile
4. Direct assessment
5. Probabilistic risk assessment

Results from Risk Assessments Performed to Date

Tissue residue approach and TSCs have identified only chemicals of concern (COCs) which have also been identified as COCs by one or more other human health or ecological risk scenarios

Results Derived from Literature Review and Analysis of Safety Factors

- No significant difference in residue levels causing adverse effects in freshwater and marine biota (arsenic an exception)
- No significant difference in residue levels causing adverse effects in benthic and pelagic biota
- No significant difference in response of biota in field and laboratory exposures

Comparison of Human Health Toxicity Reference Values to Ecological TSCs

Compared TSCs to TRVs for a defined human health exposure scenario for seafood consumers

Exposure frequency	350 days/year
Exposure duration	30 years
Body weight	70 kg
Target noncancer risk	1
Target cancer risk	1×10^{-6}
Seafood ingestion rate	6.5 grams/day

Results of Comparing Human Health TRVs and Ecological TSCs

1. Ecological TSCs were lower than human health TRVs for 61 to 67 (91%) of chemicals where a comparison could be made
2. Human health TRVs were lower than ecological TSCs for 36 of 42 (86%) of chemicals where a comparison could be made

Conclusions

1. Tissue residues of chemicals in aquatic biota can, for many chemicals, be used to directly assess ecological risks to aquatic biota
2. Chemicals for which tissue residues cannot be used to quantify risks can be identified from mechanistic considerations
3. The level of protection from adverse risk provided by the tissue residue approach is comparable to that provided by USEPA's ambient water quality criteria

Next