Development of Health-Based Sediment Criteria for Puget Sound

Laura B. Weiss
Washington State Department of Ecology, Olympia, Washington

Problem Statement

Discharge of many industrial, agricultural, and domestic chemicals into Puget Sound has resulted in sediments with elevated levels of pollutants, especially in urban bays and estuaries. Many of these pollutants accumulate in fish and shellfish. As a result, there is concern that contaminated sediments pose a health threat to humans through the consumption of seafood that has bioaccumulated chemicals directly or indirectly from sediments.

To address the problem of contaminated sediments, the Washington State Department of Ecology (Ecology) adopted the Sediment Management Standards (SMS) (Chapter 173-204 WAC) in 1991. The purpose of these standards is to "reduce and ultimately eliminate adverse effects on biological resources and significant human health threats."

Sediment Management Standards (SMS) Background

The SMS currently establish 47 chemical-specific sediment quality standards (SQS), which are designed to protect benthic organisms. No human health-based criteria were available for inclusion at the time of SMS adoption. As a result, standards for the protection of human health from contaminated sediments are being developed on a case-by-case basis. To increase consistency and allow for more timely decision-making, Ecology is developing human health-based sediment quality criteria (HHSQC) that will be incorporated into the current SMS.

Once adopted into the SMS, human health criteria will be used in conjunction with existing ecological criteria to make cleanup, source control, and dredging decisions. The rule presently includes two levels of criteria: (1) the Sediment Quality Standards (SQS), which set a goal of "no adverse impacts," and (2) a higher Regulatory Limit (RL), which allows for "minor adverse impacts." Regulatory decisions are made on a site-specific basis in the range between these two levels. The HHSQC will also include two criteria levels, based on different levels of risk.

Implementation Framework

Ecology's proposed construct for human health criteria relies on a tiered approach. "Tier I" is intended to allow for an initial evaluation to determine if sediment chemical concentrations pose a significant human health risk. If so, additional site-specific analysis would be available under "Tier II" to verify the results of the Tier I analysis and to take into account any uncertainties associated with Tier I values. In addition, Ecology is proposing the use of tissue data as a confirmatory step under Tier II to validate assumptions regarding bioaccumulation potential.

Criteria Calculation/Methodology

The primary human route of exposure to contaminated sediments is via the consumption of contaminated fish and/or shellfish. Human health criteria are developed by applying U. S. EPA's risk assessment methodology to calculate risk from consumption of potentially contaminated fish/shellfish. To quantitatively establish the link between sediment and biota, a biota-sediment accumulation factor (BSAF) is used.

The following formula and input parameters are being proposed to develop HHSQC for carcinogenic compounds:

$$HHSQC = \frac{R * BW * AT * 1000}{CPF * ED * IR * BSAF * FL}$$

where:

R = risk level of 10^{-6} for SQS (a 10^{-5} risk level is proposed for the RL)
BW = adult body weight of 70 kg
AT = averaging time of 75 years
CPF = chemical-specific cancer potency factor as defined by EPA (IRIS)
ED = exposure duration of 30 years
IR = fish ingestion rate of 52 grams/day (based on results of consumption studies of Native American populations in the Puget Sound region (Toy, 1995))
BSAF = chemical-specific biota-sediment accumulation factor
FL = fish lipid of 3%

Back

Technical Development Work

Several technical reports have been completed to support the development of HHSQC. One of these, *Tier I Report: Development of Sediment Quality Criteria for the Protection of Human Health*, completed by the Washington State Department of Health (DOH), investigated technical issues related to the development of health-based sediment criteria (DOH, 1995). The report describes four areas of research: (1) determination of background concentrations; (2) a prioritization of chemicals of concern; (3) development of recommended BSAFs; and (4) fish consumption rates and recommendations.

DOH identified over 200 potential chemicals of concern based on data in Ecology's SEDQUAL database. These chemicals were prioritized into one of three groups (Groups 1, 2, and 3) based on whether they had EPA toxicity values (CPFs or RfDs), the frequency with which they were detected in urban areas, and their ability to bioaccumulate in aquatic biota (as measured by their K_{ow}).

Ecology is focusing its efforts on developing HHSQC for six organic chemicals or chemical groups from the Group 1 chemicals of concern list which are of primary human health concern in Puget Sound and for which our confidence in the toxicity and the BSAF is the highest. These chemicals are known to bioaccumulate, have been found in Puget Sound fish or shellfish, and are likely to present a risk to humans at levels that are lower than current ecologically based sediment criteria. These chemicals are:

- DDT and metabolites
- Hexachlorobenzene
- Hexachlorobutadiene
- HPAHs (high molecular weight polycyclic aromatic hydrocarbons)
- PCBs
- Polychlorinated dibenzodioxins and furans

There are other chemicals of concern for which a scientifically defensible BSAF could not be developed at this time, including several inorganic compounds such as mercury. For these chemicals, Ecology is proposing to develop target tissue levels that can be used to make source control and cleanup decisions in the absence of an HHSQC.

BSAF Development

Initial efforts by DOH focused on the use of a bioenergetics-based equilibrium-partitioning model (Thomann et al., 1992). However, an empirically based approach, relying on information from both the published and gray literature, was developed and recommended. This was due to the availability of empirical data as well as a lack of appropriate input parameters for the model. This approach is described in the final DOH Tier I Report (DOH, 1995).

DOH compiled empirically derived BSAF values from a variety of sources for a range of aquatic species and chemicals. Over 1,200 BSAFs for upper trophic level fish were identified for a set of organic chemicals of concern. These BSAFs were primarily field-derived and represent both marine and freshwater species.

DOH derived BSAFs from these literature values using descriptive statistics based on grouping chemicals by chemical class and log K_{ow}. DOH recommended the use of the 75th percentile BSAF values for criteria development.

To provide additional support for BSAF development, Ecology hired an outside contractor (PTI Environmental Services) to analyze the data set compiled by DOH. PTI used linear and nonlinear multiple regression analysis to investigate the effects of chemical-specific and species-specific characteristics on BSAF values and to estimate BSAFs (PTI Environmental Services, 1995).

Based on the results of the multiple linear regression analysis, separate BSAF calculation equations were developed for different chemical classes, feeding types, and taxonomic groups. A variety of upper confidence limits were calculated for these prediction equations. Regressions were found to be statistically significant for PCBs and dioxins in finfish and for PAHs and PCBs in shellfish. However, the R^2 ranged from 0.70 for dioxins in finfish to 0.058 for PAHs in shellfish.

Using the results of the DOH and PTI analyses, Ecology has developed preliminary HHSQC. BSAFs developed by regression analysis for PCBs and dioxins in finfish, as well as those for PAHs in shellfish, are being applied. BSAFs for other compounds, such as DDT and metabolites, are based on the results of a descriptive statistical analysis (using the 90th upper confidence limit on the mean).

Technical/Policy Implications

Several technical and policy issues have been raised in the process of developing HHSQC. Debate over criteria development has focused primarily on three input parameters: (1) level of risk for cancer-causing chemicals, (2) fish consumption rates, and (3) BSAFs. Each of these issues involves both technical and policy decisions.

Because of the controversial nature of these criteria, Ecology has been working closely with an advisory committee made up of representatives from industry, the environmental community, tribes, ports, and other government agencies, in the development of the criteria. The committee has been providing input on Ecology's technical development work and the related implementation issues.

In addition to questions about the technical/scientific methods being applied, concerns about the cost and liability implications of the HHSQC have been expressed by some potentially affected groups. In an attempt to respond to these concerns, Ecology is currently conducting "case studies." These case studies are a review of existing sediment cleanup site decisions to assess the potential impact of the HHSQC on these (and other) sites. The case studies will also allow the agency to improve the implementation strategy based on lessons learned in the field.

After completion of the case studies, Ecology expects to continue with the rule development process, which includes proposal of a draft rule in mid-1997 and

completion of a cost/benefit analysis (as required by state law). Ecology is looking toward adoption of HHSQC by the end of 1997.

References

DOH (Washington State Department of Health). 1995. *Tier I report: Development of sediment quality criteria for the protection of human health.* Office of Toxic Substances, Olympia, WA.

PTI Environmental Services. 1995. *Analysis of BSAF values for nonpolar organic compounds in finfish and shellfish, final report*. Prepared for the Washington State Department of Ecology, Central Program, Environmental Review and Sediments Section.

Thomann, R., J. Connolly, and T. Parkerton. 1992. An equilibrium model of organic chemical accumulation in aquatic food webs with sediment interaction. *Environ. Toxicol. Chem.* (11):615-629.

Toy, K.A., G.D. Gawne-Mittelstaedt, N.L. Polissar, and S. Liao. 1995. *A fish consumption survey of the Tulalip and Squaxin Tribes of the Puget Sound region (draft).* Tulalip Tribes, Natural Resources Department, Marysville, WA.

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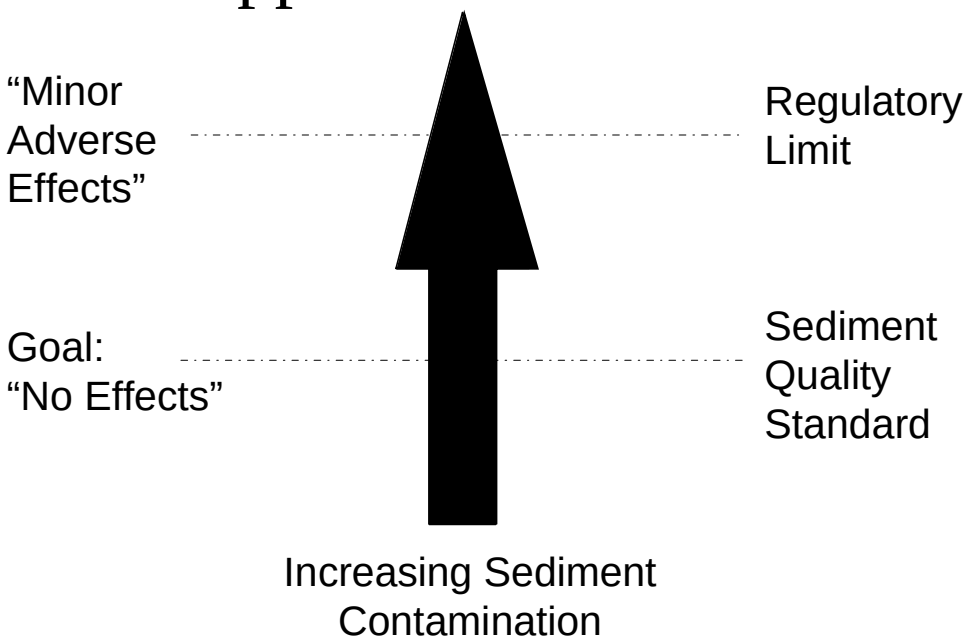
Laura B. Weiss, M.P.H.

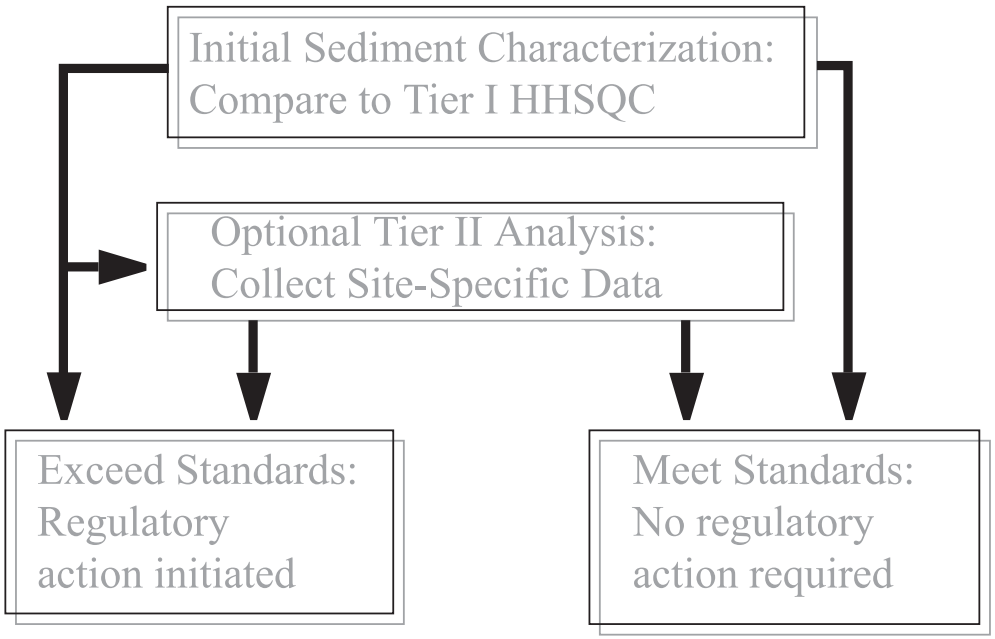
Washington State Department of Ecology

Environmental Review and Sediments Section

Sediment Management Standards Application Model



HHSQC Implementation Framework



Derivation of Health-Based SQC for Carcinogens

$$\text{Sediment Concentration} = \frac{\text{Risk x BW x AT}}{\text{CPF x BSAF x IR x FL x ED}}$$

where:

Risk = 1 in a million (10^{-6}) / 1 in 100,000 (10^{-5})
BW = body weight of 70 kg
AT = lifetime of 75 years
CPF = chemical-specific cancer potency factor (IRIS)
BSAF = chemical-specific biota-sediment accumulation factor
IR = fish ingestion rate of 52 grams/day
FL = fish lipid of 3%
ED = exposure duration of 30 years

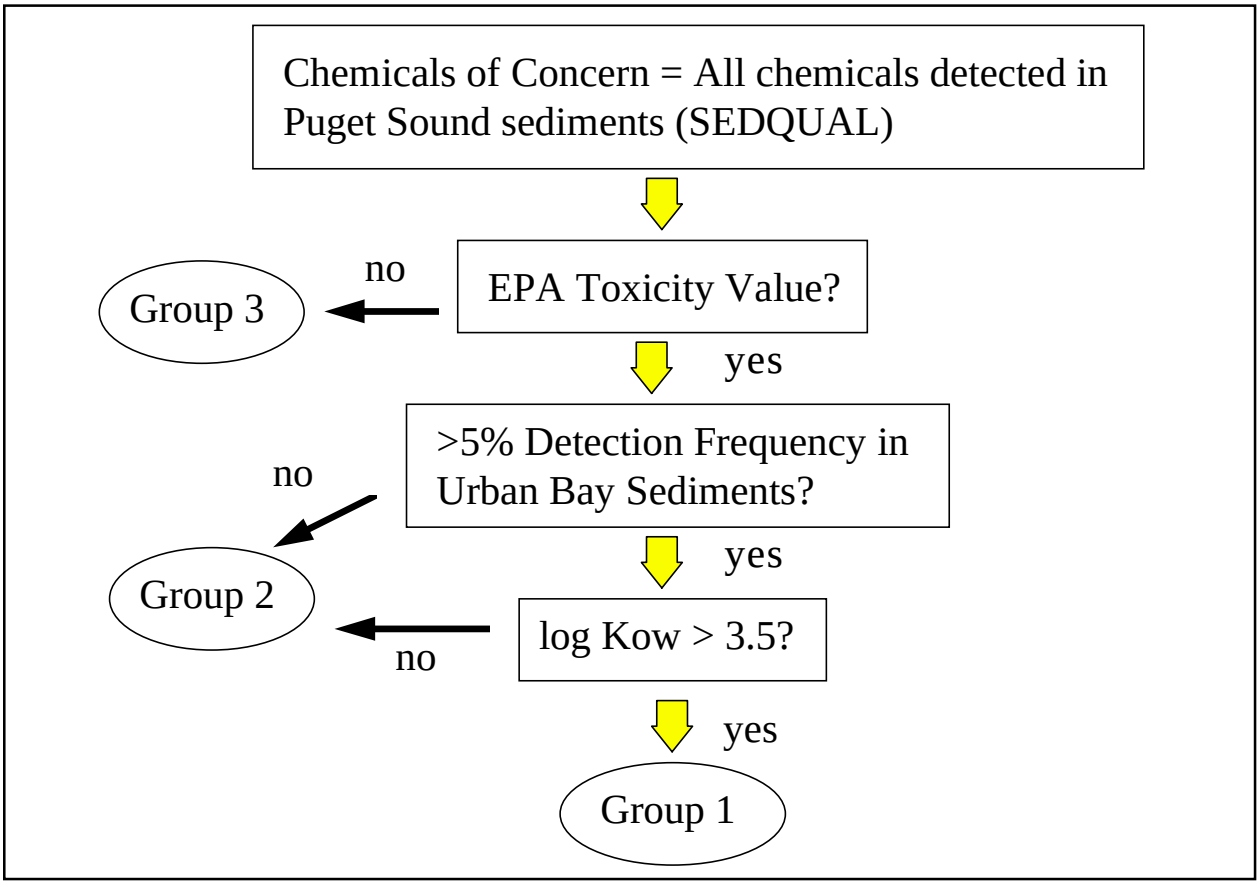
Technical Development Work

- Tier I Report (DOH, 6/95)
- Use of Distributional Analysis (Male, 6/94)
- Fish Tissue Regulatory Options Paper (Male, 9/94)
- Analysis of BSAFs for Metals (PTI, 10/95)
- Analysis of BSAFs for Organics (PTI, 11/95)
- Chemicals of Concern Analysis/Display (PTI, 10/95)
- DOH Tier II Report (DOH, 5/96)
- BSAF Validation for Puget Sound (PTI, 9/96)

Tier I Report (DOH, 1995)

Patrick, McBride, Hardy and LaFlamme

- Areas of Research:
  - Determination of background concentrations
  - Chemicals of concern (3 groups)
  - BSAF development
  - Fish consumption review and recommendations
- SQC calculated based on DOH recommendations



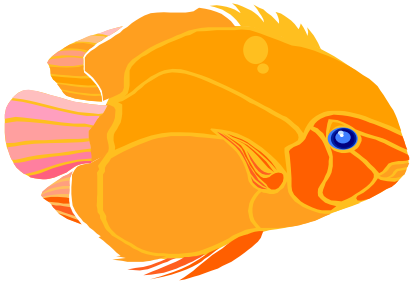
Human Health Chemicals of Concern

- Aldrin
- DDD, DDE, and DDT
- Hexachlorobenzene
- Hexachlorobutadiene
- HPAHs (TEQ)
- PCBs
- Pentachlorophenol
- Polychlorinated dibenzodioxins and furans (TEQ)

*(**Note:** This list includes only Group 1 organic chemicals with the highest bioaccumulation potential. Confidence in calculated BSAF values for these 8 chemicals or chemical groups ranges from high to low.)*

Approaches for BSAF Development

- Thomann Food-Web Model
  - Requires further data collection
  - Validation recommended
- Empirical, Literature-Based Values
  - Regression analysis
  - Descriptive statistics
- Use Fish Tissue Data to Validate



BSAF Analysis for Nonpolar Organics -- DOH

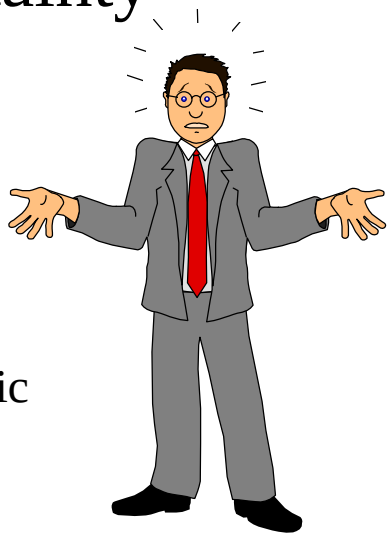
- Compiled data from:
  - Parkerton (1991)
  - COBIAA (1992)
  - EPA GLWQI (1994)
- Mostly field data, from marine and freshwater
- 1,200 BSAF values for upper trophic level fish
  - Grouped by chemical class
    - Found too much variability among chemicals
  - Grouped by Kow and chemical class
    - Accounts for important chemical characteristics

An Alternative BSAF Analysis for Nonpolar Organics

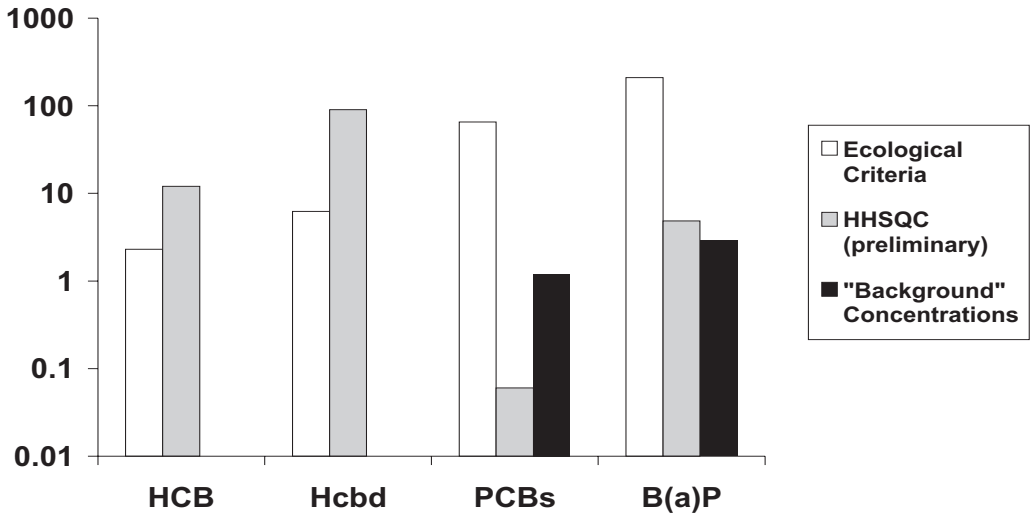
- Alternative statistical analysis of data compiled by DOH (linear and non-linear regression analysis)
- Included a total of 1,591 data points (finfish and shellfish)
- Found significant regressions for PCBs and dioxins in finfish and for PCBs and PAHs in shellfish (variable R^2)
- Results for PCBs in finfish consistent with DOH
- Less consistency for other chemicals of concern

Managing Uncertainty

- Criteria Development
  - Monte Carlo Analysis
- Implementation
  - Two Tiers allow for site-specific data collection and analysis
  - Tissue collection and analysis



HHSQC, Ecological Criteria and Background Concentrations



Issues/Concerns Raised

- Technical/scientific methods
- Consistency between Ecology programs
- Liability and cost associated with cleanup
- Statutory authority
- Implications for source control
- Environmental equity
- Speed of rule development
- Protection of resource and future generations

What Next?

- Case Studies:
  To answer specific questions about implementation and rule impacts
- Draft rule proposal in mid-1997
- Complete cost/benefit analysis
- Rule adoption in late 1997