

Development of Sediment Quality Objectives for California

G. Fred Lee, PhD, PE, DEE & Anne Jones-Lee, PhD

G. Fred Lee & Associates

El Macero, CA

gfredlee@aol.com  www.gfredlee.com

- Need for Sediment Quality Criteria/Objectives (SQO)
- Difficulty Developing Technically Valid SQOs
 - Summary of Experience of Other
 - Unreliability of Chemical Concentration-Based Criteria
- CA Failure to Develop SQO during BPTCP
- Problem with Current CA Approach for Developing SQOs
- Recommended Approach for Developing SQOs
 - BPJ Triad Weight-of-Evidence Approach

Need for Sediment Quality Criteria/Objectives

- Many Potential Pollutants Tend to Accumulate in Sediments
 - Heavy Metals: Cu, Pb, Cd, Zn, Hg, etc.
 - Larger Organics:
 - Organochlorine Pesticides – DDT, Chlordane, Toxaphene
 - PCBs, Dioxins
 - PAHs
 - Pyrethroid Pesticides
 - Nutrients
 - Some Nitrogen and Phosphorus Compounds
 - Organic N, Particulate Phosphorus Forms
 - Ammonia & Soluble OP in Higher Concentrations in Sediments Related to Slow Rates of Sediment/Water Exchange

Sediment Concentration/ Binding Issues

KEY ISSUE:

- Potential Pollutant Chemicals Exist in Sediments in Variety of Chemical Forms
 - Only Small Portion Are in Toxic/Available Forms
 - Most of Forms of Potential Pollutants in Sediments Inert – i.e., Not Pollutants
- No Relationship between Total Concentration of a Potential Pollutant in Sediment and Its Impact on Water Quality

Sediment Concentration/ Binding Issues

- Concentration of Potential Pollutant in Sediment Not Analogous to That in Water
 - Water: $\text{Mass of Chemical} / \text{Mass (kg) (Volume - L) of Water}$
 - The Liter (i.e., kg) of Water Is of Constant Composition – 55 moles/kg of water
 - Sediment: $\text{Mass of Chemical} / \text{Mass of Sediment}$
 - The Bulk Mass of Sediment Is of Variable Composition Depending on
 - Input of Erosional & Other Material from Watershed
 - Precipitates (CaCO_3), Sulfides
 - Aquatic Vegetation Remains (Detritus)

Sediment Concentration/ Binding Issues

- Important Because Bulk Composition of Sediments Determines the Binding of Pollutant to Sediment
 - TOC Binds Many Large, Hydrophobic, Organic Molecules
 - Sulfides Bind Heavy Metals
 - Carbonates Bind Some Heavy Metals Such as Cu
 - Clays Bind Metals & Organics
 - Iron Oxides Bind Metals & Organics

Sediment Concentration/ Binding Issues

- Must Conduct Toxicity Identification Evaluations (TIEs) to Determine Toxicity of Forms of Potential Pollutants Present to Identify Cause of Toxicity
- Must Conduct Organism-Based Bioavailability Studies to Determine Amount of a Chemical That Can Be Accumulated in Food Web
 - Some Try to Regulate Chemicals in Sediment as They Regulate Chemicals in Water – with Chemical Concentration-Based Criteria/Standards
 - Not Technically Valid

Approaches for Regulating Sediment Pollutants

Chemical Concentration vs Biological Impact

- Chemical Concentration Approach
 - Single, Numeric Concentration Criterion/Standard Not Valid
- Must Use Biological Impact-Based Approaches
 - Toxicity
 - Excessive Bioaccumulation in Edible Organisms
- 1970s COE Conducted 5-yr, \$30-million DMRP (Dredged Material Research Program) to Develop Open Water Dredged Sediment Disposal Criteria

Approaches for Regulating Sediment Pollutants

- G. F. Lee Conducted >\$1million Studies on Dredged Sediment Disposal Criteria
 - About 100 Sediment Sites across US
 - At Each: 30 Parameters
 - ~50,000 Data Points Describing Chemical Release from Sediments and Toxicity
- COE & US EPA Developed Biological Impact Regulatory Approach
 - Based on Toxicity & Bioavailability
 - Worked Well for Regulating Dredged Sediment Disposal for >25 yrs

Approaches for Regulating Sediment Pollutants

Chemical Concentration vs Biological Impact

- US EPA Tried for Decade to Develop Chemical Concentration-Based Sediment Quality Criteria in 1990s
 - Found Approach to Be Unreliable
 - Has Indicated That It Is Adopting Biological Effects-Based Approach Instead
- Some State Regulatory Agencies Try to Develop Chemical Concentration-Based Sediment Quality Criteria
 - Analyze Sediment for Total Chemical Concentration; Compare Concentration to SQC/SQO
 - Ignore/Disregard the Literature & Aquatic Chemistry /Toxicology
 - Administratively Simple to Implement
 - Technically Invalid

Co-Occurrence Approaches

- Late 1980s Long & Morgan Developed “Co-Occurrence” Based Sediment Quality Guidelines (SQG)
 - MacDonald Subsequently Proposed His Co-Occurrence-Based SQG
 - Based on Relating Total Concentration of Chemical in Sediment to Some Biological Characteristic Such as Sediment Toxicity
 - Same Endpoint Presumed Associated with Each Chemical in Sediment
- Obviously Not Technically Valid
 - Based on Total Concentration
 - No Cause / Effect Evaluation of Toxicity
 - Toxicity Could Be Due to Chemical Not Measured
 - Ignores Literature, Aquatic Chemistry & Aquatic Toxicology
 - Relies on Coincidence of Chemical Concentrations and Unrelated Impacts

Co-Occurrence Approaches

- T. O'Connor of NOAA Found That Flipping a Coin More Reliable for Predicting Sediment Toxicity Than Long & Morgan SQG
- Summed Quotients Not More Reliable for Predicting Whether a Chemical in Sediment Is Cause of Toxicity
 - Results Depend on Number of PAHs Included in Summary

Co-Occurrence Approaches

- Use of Long & Morgan as “Screening Values”
 - Unreliable Approaches Are Also Unreliable for Screening
 - Does Not Consider All of the Chemicals That Are Common in Sediments and Known to Cause Sediment Toxicity
 - Ammonia * Sulfide * Low DO
 - Pyrethroid Pesticides
 - Under-Regulate
 - Miss Pollutants Not Measured
 - Ignores Additive & Synergistic Effects
 - Over-Regulate
 - Leads to Control of Non-Pollutants
- Give False Sense of Reliability to Those Who Want a Number to Proceed with Project &/or to Regulate a Sediment

Co-Occurrence Approaches

- E. Long Now States That SQG Should Not Be Used in Regulatory Programs
 - However, SQG Being Used by Agencies in Multi-Million Dollar Projects
- “Horror Stories” from Misuse of Long & Morgan or MacDonald SQGs
 - Santa Monica Bay Restoration Project - \$42 million to Control Lead in Urban Stormwater Runoff Because Pb Found in Bay above Long & Morgan Co-Occurrence “Effects Level”
 - US EPA TMDL Goals for Sediment Remediation in Upper Newport Bay for Bioaccumulatable Chemicals (PCBs, DDT, Chlordane)
 - CA DFG Regulating Hg in Gold Dredging Sediments Used for Fish Habitat Restoration

Co-Occurrence Approaches

- Even Though Well-Recognized as Unreliable, Chemical Concentration SQOs Will Be Used by Regulators
 - “Just Give Me a Number so I Can Regulate Sediments”
 - “Don’t Confuse Me with Aquatic Chemistry and Toxicology”
- Recognized Experts in Sediment Quality Evaluation Recommend Against Use
 - A. Burton, P. Chapman, D. DiToro, T. O’Connor, R. Engler, T. Bridges, P. Wenning, and Many Others

California Approach for Developing Sediment Quality Criteria

- 1989 CA Legislature Developed Bay Protection & Toxic Cleanup Program (BPTCP)
 - Required That CA State Water Resources Control Board (SWRCB) Develop SQO
 - SWRCB Staff Misdirected & Poorly Implemented
 - Tried to Develop Chemical Concentration-Based SQOs
 - BPTCP Effort Failed to Develop SQO
- 1999 Lawsuit Caused SWRCB to Try Again to Develop SQO
 - Compliance Schedule
 - June 30, 2003 SWRCB Must Adopt Scoping Document (Workplan)
 - August 5, 2005 SWRCB Must Circulate Draft Objectives
 - February 28, 2007 SWRCB Must Adopt Objectives & Policy and Submit to Office of Administrative Law

California Approach for Developing Sediment Quality Criteria

- Definitions

- Section 13391.5(d) of CWC Defines SQOs:

- “Sediment Quality Objective’ means that level of a constituent in sediment which is established with an adequate margin of safety for the reasonable protection of the beneficial uses of water or the prevention of nuisances.”*

California Approach for Developing Sediment Quality Criteria

- Section 13393(b) of CWC Further States,
 - *“that the SWRCB shall adopt the sediment quality objectives pursuant to the procedures established by this division for adopting or amending water quality control plans. The sediment quality objectives shall be based on scientific information, including, but not limited to, chemical monitoring, bioassays, or established modeling procedures, and shall provide adequate protection for the most sensitive aquatic organisms. The state board shall base the sediment quality objectives on a health risk assessment if there is a potential for exposure of humans to pollutants through the food chain to edible fish, shellfish, or wildlife.”*

California Approach for Developing Sediment Quality Criteria

- CA SQO to Be Used to
 - Identify Sediments That Need to Be Remediated in Aquatic Superfund – “Aquafund” Program
 - Modify NPDES Wastewater Discharge Permits for Discharges That Could Be Source of Chemicals That Violate the SQO
 - Unless Appropriate TIEs Used, Could Fail to Identify Real Source of Pollutants

California Approach for Developing Sediment Quality Criteria

- SWRCB Staff Again Trying to Develop SQOs Using Chemical Concentrations, Long & Morgan SQG, and CA BPTCP Database
- BPTCP Database Not Adequate to Develop SQOs
 - Failed to Collect Required Information for Evaluating Causes of Sediment Toxicity
- \$2.5 million Available for SQO Development
 - Too Little Money, Too Little Time to Develop Reliable SQOs

California Approach for Developing Sediment Quality Criteria

- Lower Priority Given to Developing Guidance for Regulating Excessive Bioaccumulation of Hazardous Chemicals Such as Hg, PCBs, Dioxins, and “Legacy” Organochlorine Pesticides (DDT, Chlordane, Dieldrin, Toxaphene)
 - Highest Priority Should Be Given to Regulating These Chemicals as Human Health Problems
- CA SWRCB Approach Will Again Fail to Develop Reliable SQOs for a Sediment Regulatory Program
- For Further Information on Problems with SWRCB SQO Development Approach see
 - Lee (2003a, b, c) Comments
 - SWRCB Website www.swrcb.ca.gov in BPTCP Section for Comments by Others

Weight-of-Evidence Approach

- Integrated Use of Multiple Lines of Evidence (LOE) to Develop a Best Professional Judgment (BPJ) Assessment of Water Quality Impact of Chemicals in a Sediment
 - LOE Include
 - Sediment Aquatic Life Toxicity
 - Sediment as Source of Hazardous Chemicals That Bioaccumulate
 - Benthic Organism Assemblages
 - Chemical Information on Cause of Toxicity
 - Cannot Reliably Use Any Component Alone
 - Must Integrate Adequate Information on All Four Aspects
 - No Short-Cut to Adequate, Reliable Chemical Information

Weight-of-Evidence Approach

- Chemical Information Must Be Based on TIEs, NOT on Total Chemical Concentrations in Sediments
 - See Lee & Jones-Lee (2002) for Incorporation of Chemical Information into WOE Evaluation of Sediment Quality
- Toxicity Assessment Should Be Made Using Several Types of Test Organisms with Appropriate Sensitivity
- Organism Assemblage Assessment Should Include Appropriate Reference Site Information and Gradient Analysis from “Hot Spot” or Source of Pollutant

Weight-of-Evidence Approach

- WOE Should Be Implemented as Non-Numeric, BPJ by Expert Panel in Public, Interactive Peer-Review Process
- Use of WOE to Regulate Sediments Supported by Experts in Sediment Quality Evaluation
 - See Burton *et al.* (2002) and Chapman *et al.* (2002) for Further Information on WOE Approach for Regulating Sediment-Related Water Quality Impacts
- SWRCB Should Spend the \$2.5 million and 2 yrs Allowed for Developing SQO to Develop Guidance on WOE Approach
 - Evaluate/Demonstrate Guidance at Several Locations in State

Issues That Need to Be Evaluated in Regulation of Sediment Water Quality Impacts Caused by Chemicals

- Many Aquatic Sediments Are “Toxic” Due to Low DO, Sulfides and Ammonia Yet Those Waterbodies Have High-Quality Fisheries
- Significance of “Sediment Toxicity” to Beneficial Uses of Waterbody Not Understood
- Is There Need to Control “Sediment Toxicity” Caused by Any/All Chemicals or Can Toxicity Due to Low DO, Ammonia, & Sulfides Be Ignored?

Conclusions

- There Is Need for a Regulatory Approach for Controlling the Water Quality Impacts of Chemical Constituents in Sediment That Are Real, Significant Pollutants
- Cannot Use Chemical-Concentration-Based SQOs to Reliably Regulate Sediment Quality
- Should Use Non-Numeric BPJ Triad Weight-of-Evidence Approach to Regulate Sediment Quality
- Those Concerned with Properly Regulating Sediment Quality Should Become Involved in Current CA SQO Development Effort

Further Information
Consult Website of
Drs. G. Fred Lee and Anne Jones-Lee



<http://www.gfredlee.com>

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Abstract

- In 1989 the California Legislature adopted the Bay Protection and Toxic Cleanup Program (BPTCP). This program was to be organized by the State Water Resources Control Board (SWRCB). In addition to designating and ranking “toxic hot spots,” i.e., areas where toxic chemicals had accumulated or where toxicity was present in water and/or sediments in the State’s waterbodies, the BPTCP was also to develop sediment quality criteria/objectives (SQO). These SQO are to serve as a basis for designating sediments that contain sufficient concentrations of chemicals to cause adverse impacts on water quality and thereby require remediation and/or source control. The SWRCB did not develop the SQO) as required by the BPTCP. In 1989 an environmental group obtained a judgment from the state court which requires that the SWRCB comply with the BPTCP requirements of developing SQO.
- The SWRCB SQO workplan has a number of significant problems which are primarily related to the fact that the current regulations focus on chemical-concentration-based SQC. This approach could lead to the same problems that developed in the previous attempt to develop SQO, where the SWRCB staff tried to oversimplify the complex interrelationships of sediment chemical concentrations and toxicity to aquatic life. It is not possible to use the concentration of a chemical in sediments to assess the water quality impact of the chemical on aquatic life and other waterbody beneficial uses. The problem with this approach is that chemicals exist in aquatic sediments in a variety of forms, only some of which are toxic. Instead of the chemical concentration approach, the focus on sediment quality evaluation should be on chemical impacts. The SWRCB should develop a Best Professional Judgment Triad Weight of Evidence approach for evaluating sediment quality. The triad should be based on an integrated use of aquatic life toxicity information using a suite of sensitive test organisms, an assessment of the potential for the sediment-associated chemical to be a source of chemicals that bioaccumulate to excessive levels in higher trophic level edible organisms, and chemical information that defines the amount of the toxic, bioavailable chemical in the sediment that is adverse to beneficial uses.

Surface and Groundwater Quality Evaluation and Management and Municipal Solid & Industrial Hazardous Waste Landfills <http://www.gfredlee.com>

Dr. G. Fred Lee and Dr. Anne Jones-Lee have prepared professional papers and reports on the various areas in which they are active in research and consulting including domestic water supply water quality, water and wastewater treatment, water pollution control, and the evaluation and management of the impacts of solid and hazardous wastes. Publications are available in the following areas:

- Landfills and Groundwater Quality Protection
- Water Quality Evaluation & Management for Wastewater Discharges
 - Stormwater Runoff, Ambient Waters and Pesticide Water Quality Management Issues, TMDL Development, Water Quality Criteria/Standards Development and Implementation
- Impact of Hazardous Chemicals—Superfund
 - LEHR Superfund Site Reports to DSCSOC
 - Lava Cap Mine Superfund Site Reports to SYRCL
 - Smith Canal
- Contaminated Sediment—Aquafund
 - BPTCP, Sediment Quality Criteria
- Mine Waste Management
- Domestic Water Supply Water Quality
- Excessive Fertilization/Eutrophication, Nutrient Criteria
- Reuse of Reclaimed Wastewaters
- Watershed-Based Water Quality Management Programs:
 - Sacramento River Watershed Program
 - Delta—CALFED Program
 - Upper Newport Bay Watershed Program
 - San Joaquin River Watershed DO and OP Pesticide TMDL Programs