Water Quality Modeling Issues in the Delta & San Francisco Bay

G. Fred Lee, Ph.D, P.E., D.E.E.
G. Fred Lee & Associates
El Macero, CA 95618

Water Quality v. Chemical Constituent Modeling

Biological - Water Quality Impacts

Toxics

Metals - Copper SF Bay
Pesticides - Diazinon

Nutrients

N & P - Impact on Domestic Water Supplies and Fishery Resources

Sediment Toxicity and Water Quality

Presented at "Toxics and Water Quality Modeling Workshop," Bay-Delta Forum, Lawrence Berkeley National Laboratory, Berkeley, CA, August 25, 1995

Water Quality Modeling: What It Is & What It Is Not

Water Quality

Is Not a List of the Concentrations of Chemical Constituents in a Water

Is Character Relative to Designated Beneficial Uses of Water

For Chemical Constituent to Impact Aquatic Life - Water Quality, It Must Significantly Adversely Impact Numbers, Types, and Characteristics of Desirable Aquatic Organisms

For Most Chemical Constituents, Cannot Use Total Concentration to Evaluate Impact of Chemical Constituent on Water Quality - Beneficial Uses

Chemical Constituents Exist in Aquatic Systems in Variety of Chemical Forms, Only Some of Which Are Toxic - Available

Most So-Called *"Water Quality Models"* Are Really *"Chemical Constituent Models,"* i.e., Predict Concentrations of Chemicals Constituents at Some Location and Time

True ***Water Quality Model*** Predicts **Impact** of Chemical Constituents on the Numbers, Types & Characteristics of Aquatic Organisms or Other Beneficial Uses of a Water

Must Incorporate Aquatic Chemistry & Aquatic Toxicology of Chemical Constituents to Develop Real Water Quality Models

Issues of Copper in San Francisco Bay

Prime Example of Water Quality Evaluation and Management *Without* Proper Application of Aquatic Chemistry and Toxicology

Only Very Limited Number of Copper Species Are Toxic

Inappropriate to Regulate Cu Based on Total Cu Analyzed

No Chemical Test Directly Measures Toxic/Available Forms

Must Ask Organisms - "Is the Cu in This Water Toxic?"

NAS/NAE 1992 Conclusion - Cannot Regulate Heavy Metals Based on Chemical Concentrations. Must Use Toxicity Tests

US EPA Water Quality Criterion for Cu (2.9 µg/L) Grossly Overprotective for Most Waters

Exceedances of Cu WQO Set Off Regulatory Process

- Site Specific Objectives
- Waste Load Allocation
- TMDL

Arbitrary - Phased Approach
Need Available-Cu-Load - Response Model

- Cu Concentration in San Francisco Bay Water Cannot Exceed WQO by Any Amount More Than Once in 3 Years

WQO Cannot Be Achieved for Total or Soluble Cu Even If All External Sources of Cu Terminated

Cu Stirred into Water Column from Sediments

Is Exceedance of Cu WQO Causing Real Water Quality Problem?

Copper Adversely Affecting Numbers, Types & Characteristics of Aquatic Life in San Francisco Bay and Its Tributaries?

Is Cu Causing Toxicity in Sacramento River, Delta, and San Francisco Bay Waters?

Toxicity Testing Using Sensitive Organisms Including *Mytilus* Larvae (Organisms Basis for 2.9 µg/L Criterion)

What Is the Problem Due to Cu?

Water Quality? - No

Administrative? - Yes

Solution: Develop Different, Appropriate Regulatory Approach

Properly Incorporate Aquatic Chemistry and Aquatic Toxicology into Regulatory Process

Delta Nutrient (N & P) Issues

Fishery Resources of Delta and San Francisco Bay Said to Be Algal/Food Source-Limited

Fewer Algae and Zooplankton Than Desired

Water Utilities Using Delta Water Stored in a Reservoir for Periods Find Excessive Algae-Caused Taste & Odors

Cu Used to Control Algae

TTHM's

Role of Algae as TTHM Precursor

Need to Better Understand Relationships between N & P Loads to Delta & Fishery Resources, & Water Supply Water Quality

Diazinon - Toxicity

Diazinon Concentrations Cause Toxicity Pulses in Delta Each Winter

Issues That Need Attention

- What Do These Toxic Pulses Mean to Fishery Resources of Delta and San Francisco Bay?
- Impact on Endangered Species?

If Unimportant, Then Grossly Over-Regulating Toxicity from Point Source Discharges from Municipal & Industrial Wastewaters

Need to Develop Water Quality Model That Relates Zooplankton Toxicity to Impact on Fishery Resources

Sediment Toxicity - Water Quality

Many Aquatic Sediments Cause Aquatic Life Toxicity in Toxicity Tests (e.g., in San Francisco Bay)

- Due to Natural Causes

Low D.O., Elevated H_2S, Elevated NH_3
Conditions Brought about Ultimately by N & P Loads to Waterbody

- Anthropogenic Contaminants

Metals?
Organics?

Issue: What Does It Mean to Aquatic Life-Related Beneficial Uses of Water That 5 of 10 Test Organisms Were Affected in Sediment Toxicity Test?

Conclusions

Need to Develop True *Water Quality* Models for Delta and San Francisco Bay Waters to:

- Incorporate Aquatic Chemistry and Toxicology into Regulating Heavy Metals Such as Cu
- Understand the Water Quality Significance of Diazinon Toxicity Pulses on Fishery Resources in the Delta and San Francisco Bay
- Impact of Nutrient Loads to Delta on Fishery Resources in Delta and San Francisco Bay, and on Domestic Water Supply Water Quality
- Relationship between Sediment Toxicity in Tests and Water Quality Impacts

Impact of N & P in Delta on Water Supply Water Quality

Delta Waters High in N & P Compounds Available to Support Algal Growth

Have Potential to Cause Algae-Related Water Quality Problems

Using Vollenweider-OECD Eutrophication Models

Predict Planktonic Algal Chlorophyll of 10 to 20 µg/L; Some 50 µg/L

Those Chlorophyll Levels Associated with Algae-Related Water Quality Problems

Tastes & Odors, THM Precursors

Santa Clara Water District - Tastes & Odors

LA Water & Power Silver Lake Reservoir - Algae, THM's

Justification for Evaluating N & P Sources for Delta Waters

- Determine if Algal Growth Can Be Controlled by Reduction of P at Source Using Readily Implementable Technology
- Determine if Reduction in Load of Readily Controllable P Will Result in Reduction in Algal Growth

90% Removal of P in Domestic Wastewaters - 4¢/person/day
Being Practiced for 50 million People around World
Need to Achieve 25 to 30% Reduction in Load of Algal Available P to Waterbody to Effect Significant Reduction in Algal Biomass

- Consider Seasonal Situations of Flows, P Loads, and Impacts
- Preliminary Calculations Show Potential Benefits of Seasonal Control of P Discharged from WWTP's to Delta Tributaries

LA Water & Power - Silver Lake Reservoir

(From: Karimi and Singer, "Thihalomethane Formation in Open Reservoirs," Journal AWWA, March 1991)

LA Water & Power's Silver Lake Reservoir Water Supply Water Quality Problems

Changed Source of Water for Reservoir from Mono Lake Tributary Water to MWD Delta Water

Mono Lake Tributary Low in N & P

Delta Water High in N & P

Found Increase in Algae-Related Water Quality Problems

THM's Increased - Apparently Related to Increased Algae
Chlorinate Silver Lake to Control Algae THM's in Lake Water

Assessment of Limiting Nutrients: N vs P

- Cannot Use Ratios of Total P to Nitrate
- Cannot Extrapolate from One Part of Year to Another
- To Judge if N or P Is Limiting Biomass, Must Evaluate

• Concentrations of Available N & P

• At Peak Biomass

• When Water Quality Problems Are Occurring

See Lee and Jones, "Determination of the Nutrient Limiting Maximum Algal Biomass in Waterbodies," AWWA Quality Control in Reservoirs Committee Report (1980)

Algae, Phosphorus, and Domestic Water Supply
Water Quality in the Delta

Algal Growth in Delta, in Down-Delta Water Supply Reservoirs, and in Aqueduct System Causing *Tastes and Odors and THM's*

Santa Clara Valley Water District

LA DWP Silver Lake Reservoir

MWD Lake Perris, Other Reservoirs, and Aqueduct

Reduction in Algal Growth (Biomass) Will Result in Improvement in Domestic Water Supply Water Quality

For Most Waterbodies, Reduction in Phosphorus Load Reduces Algal Growth in the Waterbody

Other Nutrients Surplus

Domestic Wastewaters from 50 x 10^6 People World-Wide Are Being Treated to Reduce Algal Growth in Lakes and Reservoirs

Removal of 90 to 95% P Costs 4¢/person/day

What Would Be the Benefit to Domestic Water Supply Water Quality from Removing 95% of the P in Domestic Wastewaters Discharged to Delta Tributaries?

Algal Growth in Delta at Clifton Court Forebay

DWR Delta Monitoring Data 1983-1989

Mean Summer Planktonic Algal Chlorophyll: 7 to 20 µg/L
Sometimes > 50 µg/L

Total P Concentration with Vollenweider-OECD Model Predicts

Mean Summer Chlorophyll: 10 to 15 µg/L

Therefore, Delta Waters Growing Algae Proportional to P Loading in Same Way as Lakes and Reservoirs in Other Parts of the World

N Surplus

Hydraulic Residence Time of Delta Waters in Summer about 30 days

Adequate Time for Algal Growth to Occur

Planktonic Algal Chlorophyll Concentrations > 10 µg/L Cause Significant Water Quality Problems for Domestic Water Supplies

Algae, Phosphorus, and Domestic Water Supply Water Quality in the Delta

G. Fred Lee, Ph.D., P.E. (President)
and
R. Anne Jones, Ph.D. (Vice President)
G. Fred Lee & Associates
27298 East El Macero Drive
El Macero, CA 95618(530) 753-9630

Summary of Summer P Mass Exiting Delta

Typical Summer Total P Concentrations at Clifton Court Forebay (Point of Export) and Emmaton (Point of Discharge)

0.1 to 0.15 mg P/L

Typical Summer Flows into Delta about 15,000 cfs

Assume Same as Exit

Total P Mass Exiting Delta during Summer

5×10^9 mg P/day

Summary of Summer P Load to Delta

Based on Typical P Concentrations and Flows during Summer at Greene's Landing (Sacramento River) and Vernalis (San Joaquin River)

Summer Total P Load to Delta: 5×10^9 mg P/day

Therefore, Good Agreement between Summer P Loads to Delta and P Mass Exported and Discharged from Delta

Domestic Wastewaters as P Source

Each Person Contributes about 1 kg P/yr to Domestic Wastewater

Sacramento River Basin Population: 1.87 million

San Joaquin River Basin Population: 1.18 million

Total 3 million People Potentially Contributing P in Wastewaters That Enter Tributary Rivers of Delta

Therefore, about $7x10^9$ mg P/day Could Be Contributed to Delta during Summer from Domestic Wastewater

Agricultural Drainage as P Source

Drainage Areas:

Sacramento River Basin: 16,960,000 acres

Central Sierra Basin: 2,432,000 acres

San Joaquin River Basin: 7,040,000 acres

Total: ~26 million acres of Land in Delta Head Waters Could Contribute P to Delta from Land Runoff Upstream of Delta

Nutrient Export Coefficients:

Forested and Agricultural Lands: 0.001 to 0.05 g $P/m^2/yr$

Assume P Export Coefficient from Land Contributing P in Summer: 0.01 g $P/m^2/yr$

Potential Estimated Summer P Load from Land Runoff if P Exported from Land Evenly over the Year and No P Removal in Basin: $3x10^8$ mg P/day

However, Upstream Reservoirs Typically Remove ~80% P, and Only Small Amounts of P Contributed from Land Runoff during Summer because of Low Runoff

Agricultural Drainage Likely Insignificant P Source during Summer

Sources of P in Delta

- Domestic Wastewater

200,000 People Living in Delta System
Even If All of the P in Their Domestic Wastewaters Discharged to Delta, Insignificant Part of P Load
However, Only Small Part of Wastewater P Load from Delta Residents Is Discharged to Delta

- Agricultural Drainage

520,000 acres Agricultural Lands in Delta
DWR Empire Island Ag Drainage Data for 1987-89: Average 0.13 mg P/L
P Concentrations in Ag Drainage about Same as Concentrations in Channel Water
Therefore, Ag Drainage Not Significant Source of P in Delta
Ag Drainage Potentially Significant Source for Localized Algae-Related Water Quality Problems

Attached Algal and Aquatic Plant Growth

Need to Study Agricultural Sources of P in Delta and Down-Delta Systems to Determine if Any Are Significant

- Role of Agricultural Drains to Aqueduct System as a P Source Unknown

Preliminary Conclusions

- Removal of P from Domestic Wastewaters Contributed to Tributary Rivers of the Delta Could Significantly Reduce Algal Growth in Delta and in Down-Delta Reservoirs
- Essentially All the P Contributed to and Exported from the Delta Is Derived from Domestic Wastewater Sources
- P Removal from Domestic Wastewaters Has Potential to Reduce Planktonic Algal Chlorophyll in Delta during Summer from 10 to 15 µg/L to 2 to 3 µg/L

Very Significant Improvement in Domestic Water Supply Raw Water Quality

- Unlikely That P Removal from Wastewaters Contributed to Delta Tributaries Would Have Significant Adverse Impact on Fisheries of Delta or San Francisco Bay
- If Preliminary Calculations Are Reliable, P Should Be Added to List of Pollutants That Should Be Controlled in the Delta System, through P Removal from Domestic Wastewater Sources

Impact of P Load Reduction on Fisheries

Good Correlation between Normalized P Load and Total Fish Yield Based on Many Waterbodies Worldwide

In Chlorophyll Concentration Ranges of Interest in Delta, 50% Reduction in P Load Could Result in a 40 to 60% Reduction in Total Fish Yield

Are Specific Fisheries Problems in Delta Related to Availability of Appropriate Food?

Questionable That Fish Production Problems in Delta Are Related to Availability of Food

Areas That Need Investigation

Work Should Be Done to Refine Estimates

Calculations Based on
"Average" Flow and Concentrations

Estimated Populations Contributing P in Wastewaters to Delta System

Estimated Land Runoff of P from General Export Coefficients

Work Needs to Be Done to Understand Potential Benefits of Controlling Algal Growth in Delta and in Down-Delta Reservoirs to Domestic Water Supply Water Quality

If Preliminary Calculations Are Reliable, P Should Be Added to List of Pollutants That Should Be Controlled in the Delta System through P Removal from Domestic Wastewater Sources

Reference as:"Lee, G.F., 'Water Quality Modeling Issues in the Delta & San Francisco Bay,' Presented at "Toxics and Water Quality Modeling Workshop," Bay-Delta Forum, Lawrence Berkeley National Laboratory, Berkeley, CA, August 25, 1995."