Aquatic Chemistry/Toxicology in Watershed-Based Water Quality Management Programs

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There is considerable discussion today about implementing the "watershed approach" for point and nonpoint sources of pollutants in a region. There is, however, considerable confusion about what is meant by the "watershed approach" in water quality management. There is even greater confusion on how the watershed approach should be implemented. U.S. EPA (Perciasepe, 1994) has adopted a Watershed Protection Approach which purports to promote integration of water quality problem solutions in surface waters, ground waters and habitats of concern on a watershed basis. According to Perciasepe, the Watershed Protection Approach is an essential priority for U.S. EPA's Water Program, however little guidance is given on how this approach is to be implemented so that it properly addresses the management of real water quality problems-designated use impairment within a watershed without significant waste of public and private funds controlling chemical constituents from point and nonpoint sources that have little or no impact on the designated beneficial uses of waters. This paper summarizes some of the issues that need to be considered in developing a technically valid, cost-effective watershed approach for managing water quality in a region focusing on the importance of properly incorporating aquatic chemistry and aquatic toxicology of chemical constituents that are to be managed in a watershed-based approach.

Implementation of the Watershed Approach

A watershed approach should be adopted where both point and nonpoint source dischargers work with the regulatory agencies to evaluate the real water quality problems in a particular waterbody. After the real water quality problems-use impairment have been identified then the specific source(s) of the specific pollutant form(s) that is responsible for use impairment should be required to control the input of the pollutants to the degree necessary to protect the designated beneficial uses of the waterbody independent of the nature of the source, i.e. point or nonpoint, agriculture, industry or urban, etc.

As discussed by Lee and Jones-Lee (1995a,b), in assessing water quality use impairment it is important not to assume that an exceedance of a water quality criterion or standard represents such a use impairment. U.S. EPA water quality criteria and state standards based on these criteria are designed to protect aquatic life and other beneficial uses under plausible worst-case or near worst-case conditions. It is indeed rare that those conditions occur. This leads to "administrative exceedances" of water quality standards that do not represent real use impairments but instead reflect the inability of the regulatory agencies to develop and implement water quality criteria and standards that will protect uses without significant over-regulation of the chemical constituents in a watershed.

It is important that those responsible for implementing the watershed approach recognize that all sources of a particular type of chemical constituent, such as copper or phosphorus, do not contribute that chemical constituent to the waterbody that impacts designated beneficial uses to the same degree per unit total concentration. Copper from automobile brake linings/pads in urban storm water runoff will be significantly different in its potential impact on receiving water quality than copper from copper sulfate used to control algae in a water supply reservoir or the copper that is used to kill roots that have penetrated a sanitary sewer system. In one case (the brake linings/pads) the copper originates as a metallic element that is unavailable and non-toxic to aquatic life. In the other cases, the specific form of copper (copper sulfate) is designed to be highly toxic to plant life. Before it is assumed that all sources of copper to a waterbody have equal adverse impacts on the beneficial uses of the waterbody proportional to the total concentration of chemical constituents, site-specific studies should be conducted to determine whether this unexpected situation is occurring. These studies would focus on the use of aquatic life toxicity testing using organisms that are known to be highly sensitive to copper.

The assumption that all sources of copper or other chemical constituents are of equal adverse impact is strongly contrary to aquatic chemistry and aquatic toxicology. Based on the authors' experience it will be indeed rare, if ever, that all sources of copper, phosphorus, or for that matter other chemical constituents, will have equal adverse impact per unit total concentration of a chemical constituent on the designated beneficial uses of a waterbody. It is, therefore, important in developing a watershed approach for water quality management to focus pollutant control on those chemical constituents that are actually significantly impairing the designated beneficial uses of the waterbody(s) within and downstream of the watershed. This is the technically valid, cost-effective approach that should be followed in implementing the watershed approach.

Pollutant Versus Chemical Constituent

Significant problems exist today in the water quality management field because of a failure to recognize the difference between *pollutants* and *chemical constituents*. Chemical constituents are any chemicals added to water, irrespective of the impact. Pollutants by tradition and national regulations are those constituents that are present in a water in sufficient concentrations of available/toxic forms for a sufficient duration to adversely impact the designated beneficial uses of the waterbody.

To assume that pollutants and chemical constituents are the same, as is sometimes done, can be and usually is highly wasteful of public and private funds in "water pollution" management programs. This will be especially true as attempts are made to control pollutants from nonpoint sources. In order to determine whether a chemical constituent is a pollutant it is necessary to develop a site-specific understanding of the aquatic chemistry and aquatic toxicology of the chemical constituent of concern as well as the key components of the designated beneficial uses of a waterbody.

Lee and Jones-Lee (1995c) have discussed that every chemical is toxic to aquatic life and man at some concentration and duration of exposure. The primary issue in water *pollution* control from various point and nonpoint sources in a particular watershed is the evaluation of the concentrations of the chemical constituents in the discharge/runoff that are, because of their chemical forms, significantly impacting the designated beneficial uses of the receiving waters for the discharge/runoff. Paulson and Amy (1993) have suggested that thermodynamic models, such as U.S. EPA's MINTEQ model, can be used to determine the toxic forms of chemical constituents in urban storm water runoff. However, such an approach is not technically valid and will, in general, greatly over-estimate the toxic forms of chemical constituents, such as heavy metals, in storm water runoff.

Pollutant Trading

As part of developing the watershed approach there is discussion of "pollutant" trading, where one source of pollutants in a watershed could be controlled to a greater degree at less cost than required based on allowed total maximum daily loads, thereby enabling another source of the same chemical constituent in the same watershed to control the chemical constituent to a lesser degree. There are a number of examples of watershed-based nutrient trading programs that have been and/or are being developed today that have significant technical problems with the way in which the "pollutant" (nutrient) trading has been established.

Hall and Howett (1994) have discussed "pollutant" (nutrient) trading in the Tar-Pamlico River Basin of North Carolina. They point out that rather than requiring point source dischargers to remove nutrients to a greater degree than currently being achieved, that the use of the funds that could be devoted to nutrient control for point source discharges could be used more effectively to control nutrients from nonpoint discharges. However, the Hall and Howett discussion fails to address one of the most important issues in eutrophication management, namely that various sources of nutrients, especially phosphorus from POTWs and agricultural land runoff, contribute algal available phosphorus to a waterbody to a significantly different degree per unit total phosphorus concentration.

This is a common, widespread problem that is occurring today with the implementation of the watershed approach where those responsible for developing such programs fail to properly incorporate reliable evaluation of the aquatic chemistry and aquatic toxicology of the chemical constituents of concern from various sources in a watershed. As discussed by Lee and Jones-Lee (1992), pollutant trading programs should be implemented where it can be shown that each of the sources of chemical constituents which are to be traded contribute chemical constituents in the same specific chemical forms and amounts to the overall waterbody of concern and thereby enable an improvement in the designated beneficial uses to develop to the same degree based on the control of the pollutant of concern from either source to the same degree. This situation will almost never occur for potentially toxic chemical constituents such as heavy metals, organics, nutrients, and other chemical constituents from point and nonpoint sources. It is highly unlikely that it will ever be possible to reliably trade pollution loads between point and nonpoint sources because of the differences in the chemical forms/impacts of most chemical constituents from these two types of sources without extensive pre-trade evaluation of the actual amounts and impacts of chemical constituents from each source of potential concern.

Another potentially significant problem with pollutant trading is that pollutants may adversely impact waterbodies in two overall ways; near the discharge and in the overall waterbody. Pollutant trading,

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as it is being discussed today, does not adequately consider localized adverse impacts near the discharge point on the beneficial uses of the waterbody. Local impacts on large waterbodies can be quite significant to the public that utilizes the beneficial uses of the waters near the point of discharge. This point is discussed further by Lee and Jones-Lee (1994a) in evaluating the economic aspects of pollutant trading.

Control of Chemical Constituents at Source-Pollution Prevention

One of the frequently advocated components of a watershed management approach is pollution prevention, i.e. the control of chemical constituents at their source. One of the major areas of concern in regulating urban storm water runoff and other sources of chemical constituents for a waterbody is the presence of elevated concentrations of a number of heavy metals and other chemical constituents in the storm water runoff/discharges that are potentially controllable at the source. Copper is one of the elements of greatest concern in urban storm water runoff. Copper and many other heavy metals are present in urban storm water runoff at concentrations considerably above U.S. EPA water quality criteria. It has been found that one of the principal sources of copper is its use in brake linings/pads for some types of automobiles. This has led some to call for copper source control by requiring that the manufacturers of brake linings/pads stop using copper where some other material would be substituted for the copper that is being used today. Numerous studies have shown, however, that the heavy metals, including copper, in urban storm water runoff are not a source of toxicity to aquatic life (see Mangarella, 1992).

There are significant questions, therefore, about whether voluntary or imposed national or regional bans on the use of copper in brake linings/pads is an appropriate best management practice for storm water runoff water pollution control. While adoption of this approach would likely reduce some of the administrative exceedances of copper at some locations, such as for San Francisco Bay, it would not likely address any real water quality problems (use impairment) associated with the presence of copper in storm water runoff to the Bay or its tributaries. Further, since some other material will have to be substituted for copper, concern should be raised on the potential public health and environmental impact of the substitute material.

In formulating a point and nonpoint source chemical constituent control program, it is important to reliably evaluate the aquatic chemistry and aquatic toxicology of the chemical constituents that are to be controlled through best management practices. It is also important to understand that the current suite of structural best management practices, such as detention basins, grassy swales, etc., were not based on a technically valid assessment and that their implementation would solve real water quality problems (Lee and Jones-Lee, 1996). An example of this situation is the use of detention basins where low flow storm waters are retained in a basin for a period of time where large particulate forms of chemical constituents settle out. However, particulate forms of chemical constituents are generally non-toxic and non-available to aquatic life. Detention basins typically do not remove the soluble/toxic forms of chemical constituents. Lee and Jones-Lee (1995c) have discussed the importance of properly selecting best management practices for chemical constituent control in a watershed, including control at the source, so that the control focuses on addressing real water quality problems rather than wasting public and private funds controlling chemical constituents which have little or no impact on the beneficial uses of the waters in the watershed.

Conclusion

Water pollution control programs should be based on a watershed management-based control program in which all chemical constituent sources to a waterbody are reliably evaluated as to their potential impact on the designated beneficial uses of a waterbody. The focus of the watershed approach should be on protection and, where degraded, enhancement of the designated beneficial uses of the waterbody. For aquatic life-related uses, the focus should be on the numbers, types, and characteristics of desirable aquatic organisms. The mechanical approach that is being adopted today in some watershed approaches for water quality management of considering all chemical constituents from all sources of equal impact on the designated beneficial uses per unit total chemical constituent concentration derived from the source is technically invalid. In implementing the watershed approach, proper evaluation of the chemical constituent aquatic chemistry and aquatic toxicology as it may impact the designated beneficial uses of a waterbody must be made in order to avoid waste of public and private funds in controlling chemical constituent inputs that are not adversely impacting water quality within the watershed and downstream thereof.

Pollutant trading should be based on the trading of real pollutants, i.e., those that impact designated beneficial uses at a particular location in a waterbody. Consideration should be given to waterbody-wide effects as well as those that can occur near the point of discharge/runoff.

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Watershed Approach for Water Quality Management

What Should a Watershed Based Water Quality Management Approach Involve?

All Stakeholders Working Together to Identify, Prioritize and Manage All Significant Water Quality Problems in a Waterbody and Its Tributaries

Broaden the Scope of Water Pollution Control to Address All Impairment of Uses and All Sources of Pollutants that Impair Uses

Ag No Longer Exempt from Practicing Full Water Pollution Control

Consider Both Near-Field (Near Point of Discharge-Runoff) and Far-Field (Waterbody-Wide) Impacts

Definitions

Water Quality - Impairment of Designated Beneficial Uses: Fish and Aquatic Life, Domestic Water Supply, Wildlife Habitat, Contact Recreation, Etc.

Chemical Constituent - A Chemical Added to or Present Within Water

Pollutant - A Chemical Constituent That Impairs the Beneficial Uses of a Waterbody

Chemical Constituent ≠ Pollutant

Most Chemicals Exist in a Variety of Chemical Forms, Only Some of Which Are Toxic - Available to Impact Water Quality

Waterbody - Water Column Including the Sediments

Watershed is the Area That Contributes Water to a Waterbody; Includes Airshed - Atmosphere and Groundwater

Deficiencies in Current Watershed-Based Water Quality Management

Current Watershed Approach for Water Quality Management Largely Ignores Aquatic Chemistry and Toxicology - Real Water Quality Issues

Brute Force Approach

Assumes That All Forms of Chemical Constituents Equally Important

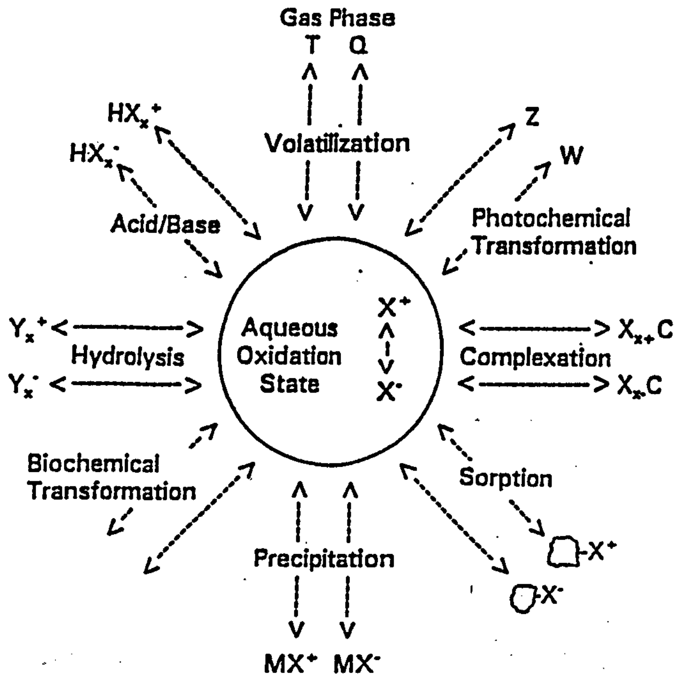
All Copper, Mercury, Other Heavy Metals, Pesticides, PCBs, Phosphate Are in Forms That Adversely Impact Water Quality
Well Known Not To Be True

Assumes All Aquatic Organism Exposure a Chronic Exposure

Aquatic Toxicology - Adverse Impacts Such as Toxicity, Excessive Bioaccumulation, Tumors, Etc.

Aquatic Chemistry - Chemical Transformations; Kinetics (Rates) and Thermodynamics (Energy - Equilibrium)

Aquatic Chemistry of Chemical Contaminants



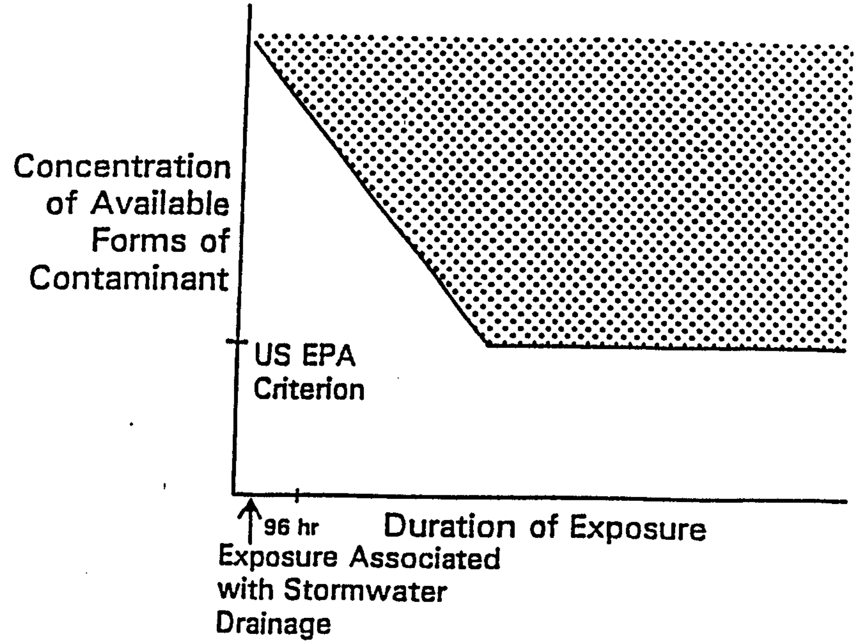
Distribution Depends on Kinetics & Thermodynamics of Reactions in a Particular Aquatic System

Each Chemical Species Has Its Own Toxicity Characteristics

Many Forms Are Non-Toxic

Toxic Forms Are Typically Aqueous Aquo-Species of Metals

Aquatic Toxicology



US EPA Criteria List 1-hr-Average Maxima and 4-day-Average Maxima

Not Valid for Assessing Potential Impacts of Urban Stormwater Drainage

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What Makes a Chemical Constituent Deleterious to Water Quality - Beneficial Uses?

Aquatic Toxicology and/or Bioaccumulation
- Organism Sensitivity to Potential Adverse Impacts
  - Acute and Chronic Toxicity
- Duration of Exposure

Aquatic Chemistry
- Chemical Reactions That Determine the Composition and Specific Chemical Species Present
- Factor Controlling Composition and Changes in Composition
- Kinetics (Rates) and Thermodynamics (Energy - Equilibrium)

Technically Appropriate Use of Water Quality Criteria and Standards

US EPA Water Quality Criteria and State Standards Numerically Equal To These Criteria Are Based On Worst-Case or Near Worst-Case Assumptions With Respect To Impacts On Aquatic Organisms

Chronic Exposure to 100% Available Forms

Rarely Will These Conditions Occur

Not To Be Exceeded For More Than Once In Three Years At the Edge Of Mixing Zone

Leads to Significant Over-Estimation of Both Near-Field and Far-Field Impacts

Chemical Specific Water Quality Criteria and State Standards Should Be Used to Indicate Potential Adverse Impacts

Allow Discharger and the Public To Determine If Exceedance Of Standards Represents a Real Impairment of Water Quality

Impairment of Uses or an Administrative Exceedance

Human and Ecological Risk Assessment: Vol. 1, No. 1, pp. [illegible]

Appropriate Use of Numeric Chemical Concentration-Based Water Quality Criteria

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INTRODUCTION

Increasing attention is being given to the cost-effectiveness of chemical contaminant control programs established to reduce toxicity to aquatic life in the watercolumn and sediment, and excessive bioaccumulation of contaminants in aquatic life. Evaluation and control of chemical contaminants has generally focused on either the effects of the contaminant(s) on aquatic organisms (biological effects-based approaches), or on concentrations of individual chemical contaminants with extrapolations to their impact on aquatic organisms (chemical concentration-based approaches).

Owing to their comparative simplicity and ostensible ease of application, chemical concentration-based state water quality standards based on or equivalent to US EPA numeric water quality criteria are being increasingly relied upon as independently applicable regulatory tools for the assessment, protection, and/or enhancement of designated beneficial uses of aquatic systems. However, the present-day use of such criteria and standards largely ignores the aqueous environmental chemistry and toxicology of contaminants, the worst-case or near-worst-case foundation of those criteria, and the fact that there is a large body of contaminants for which numeric concentration criteria do not exist. Each of these factors diminishes the reliability of the extrapolation of chemical concentrations to impacts on aquatic organisms/beneficial uses of water, and tends to make them more stringent than necessary to protect designated beneficial uses of waters. That notwithstanding, the US EPA has adopted the policy of Independent Applicability for chemical concentration criteria in which chemical-specific concentration values are applied independent of biological effects-based approaches for regulating "water quality". They are presumed to be independently reliable even when they indicate an "effect" that is not supported by biological effects-based approaches, such as toxicity testing and actual measurements of bioaccumulation evaluated on a site-specific basis.

Inappropriate Regulatory Approaches

US EPA Independent Applicability Policy

Contrived to Ease Administration of Water Quality Standards
Technically Invalid

Requires Compliance With Chemical Specific Standards For Potentially Toxic or Bioaccumulatable Chemicals Even if Site-Specific Investigations Show That the Constituents Of Concern Are in Non-Toxic Forms and Excess Bioaccumulation is Not Occurring

Leads to Gross Over-Regulation and Potentially Massive Waste of Public Funds in Regulating Urban Area, Highway and Rural Stormwater Runoff

Must Focus Watershed Approach for Water Quality Management On Toxic Available Forms Where Toxicity and Actual Bioaccumulation Are the Primary Tools Used for Defining Water Quality Impacts

Independent Applicability Policy Should Be Terminated

Independent Applicability of Chemical and Biological Criteria/Standards and Effluent Toxicity Testing

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In 1985 the U.S. Environmental Protection Agency (EPA) advocated a two-part approach for water pollution control involving chemical concentration-based effluent limits for those parameters for which water quality criteria had been developed and toxicity test-based effluent limitations. The chemical-specific component was designed to prevent exceedances of water quality criteria values in ambient waters receiving point and non-point source discharges or runoff; the water quality criteria were, in large part, developed to be chronic-exposure, safe concentrations for sensitive aquatic organisms. The toxicity test component was designed to indicate potential toxicity effects associated with an activity, to account for the possible presence of a toxic contaminant that did not have a water quality criterion, and to provide the opportunity for site-specific tuning of the chemical-specific criteria for synergism, antagonism, chemical availability, and exposure situations.

EPA has since expanded its recommended approaches to include a direct measure of biological characteristics (biological criteria) of surface waters. The biological criteria focus on the numbers, types and characteristics of organisms present downstream of a discharge or runoff compared with the numbers, types and characteristics expected based on the aquatic life habitat characteristics. A number of states have developed biological criteria and have been using them in water pollution control programs.

At a 1992 EPA workshop on water quality criteria and standards, EPA representatives revealed that the Agency would soon be releasing a position paper announcing the policy of "Independent Applicability." The June 1992 issue of EPA's "Newsletter Water Quality Criteria & Standards," however, stated that Independent Applicability is EPA's present position, and it is detailed in several documents. That inconsistency notwithstanding, the policy and/or practice of independent applicability and its ramifications for water pollution control in the country truly deserves a thorough examination.

The Problem with Independent Applicability

According to EPA in 1992, the three above-mentioned regulatory approaches for the regulation of toxics would be applicable to all waters, and the approach that was most "sensitive," (most limiting) for a particular waterbody would guide management. This led to many questions about how the policy would handle a situation in which:

- Biological studies of the receiving waters showed healthy and wholesome fish and other aquatic life populations, the same as those that would be expected based on habitat characteristics, and
- Short-term chronic toxicity testing of the waters in the region showed no aquatic life toxicity, but
- Numeric water quality criteria (or standards equivalent to them) were exceeded.

At that time, EPA stated that even under such circumstances, the discharger or source of runoff would have to implement control programs to eliminate the exceedances of the water quality criteria or standards, or change the standards. It was reported to be EPA's position under the policy of independent applicability to require that site-specific water quality criteria or standards be developed in order to justify not complying with EPA's water quality criteria, or more properly, state standards equivalent to those criteria.

It is appropriate to question the appropriateness of requiring dischargers and state regulatory agencies to develop site-specific water quality standards in response to that scenario (i.e., a situation in which it had been shown that there was no aquatic life toxicity in the receiving waters for the discharge/runoff and the populations of aquatic life in the region of expected impact were what would be expected based on habitat characteristics). There have been few attempts to develop site-specific water quality standards as outlined in EPA's Water Quality Criteria Handbook. As a consequence of the state of California Water Resources Control Board's adoption of EPA criteria as state water quality objectives (standards) in April 1991, a number of studies have been undertaken in California in an effort to develop site-specific objectives. More than $300,000 were spent in such effort in the San Francisco Bay area; more than $1.1 million were spent in efforts to develop site-specific criteria/standards for the Santa Ana River in southern California. However, as discussed below, the funds spent in trying to develop site-specific water quality objectives for copper in San

Watershed Approach for Managing San Francisco Bay Copper
A Watershed Approach Gone Awry

Exceedance of National Copper Water Quality Standard - 2.9 μg/L

Developed Site-Specific Standard Based on Water Effect Ratio Approach - 4.9 μg/L

Find 10 to 15 μg/L Soluble Copper in San Francisco Bay Waters

Because of Independent Applicability Must Develop Waste Load Allocation and Total Maximum Daily Loads (TMDLs)

"Phased Approach" Adopted Because of a Lack of Understanding of the Relationship Between Copper Loads and Copper Concentrations in Bay Waters

Phase I - All Dischargers Reduce Total Copper Loads by 20%

Copper Sources For South San Francisco Bay: Treated Wastewaters 15%, Auto Brakepads 35%, Other Runoff Sources - Urban and Highway Stormwater and Mine Waste 50%

Each Source of Copper Must Reduce Copper Input to Achieve TMDLs

All Sources of Copper Considered Equally Harmful

Ignored the Role of Bay Sediments as a Source of Copper to the Water Column During Storms

If All Copper Inputs From the Watershed Terminated, the Soluble Copper Concentrations in the Bay Will Be Exceeded for More Than Once in Three Years, i.e., Will Still Have Exceedance of Water Quality Standards

Phased Approach Technically Invalid Must Have an Understanding of the Relationship Between Copper Loads and the Resultant Concentrations Also Must Consider Sediments in Evaluating Exceedance of Water Quality Standards

All Sources of Copper Are Not of Equally Toxicity

Cu - Metal - Some Auto Breakpads
Cu^{2+}, $Cu(H_2O)_6^{2+}$
$CuOH^+$, $Cu(OH)_2$, $CuCO_3$
CuO, $CuCO_3$,
Cu organic, Cu-humates, Cu-EDTA, Etc.

Models - MINTEQ Not Reliable to Predict Toxic Forms

Soluble Copper - Some Non-Toxic

Must Use Toxicity Measurements and TIEs To Determine If Copper In a Water Sample Is Toxic

Watershed Approach for Managing San Francisco Bay Copper
Where Is The Problem?

Extensive Toxicity Measurements of San Francisco Bay Waters Over Three Years Have Shown No Toxicity Due to Copper or Other Constituents to Several Highly Sensitive Aquatic Organisms

Used the Same Organism and Test as Was Used to Establish the Water Quality Criterion - No Toxicity Found

Exceedance of the Water Quality Standard is an Administrative Exceedance Due to Overly Protective Standard (Worst-Case) and Inappropriate Regulatory Approach (Independent Applicability)

Could Cause Stormwater Dischargers (Municipalities) to Spend Over One Billion Dollars Treating Urban Area and Highway Stormwater Runoff to Achieve Copper Water Quality Standard in Bay Waters

No Beneficial Uses of the Bay are Expected to Result From Such Expenditures

Example of Inappropriate Watershed Approach That Fails to Properly Incorporate Aquatic Chemistry and Toxicology

Santa Monica Bay Stormwater Runoff

- Santa Monica Bay Restoration Project Adopted the Watershed Approach for Managing 22 Chemicals That are Transported into Santa Monica Bay in Stormwater Runoff

  Heavy Metals Focal Point of Attention

  Mass Load Emission Strategy Adopted

  All Stormwater Runoff Sources of Metals Considered Toxic and Available - No Measurements Made to Verify Assumptions

Heavy Metals Accumulate in Near-Shore Sediments of Santa Monica Bay - Assumed That Elevated Concentrations of Heavy Metals in Sediments Represents Significant Adverse Impacts to Beneficial Uses of Santa Monica Bay Due to Aquatic Life Toxicity

No Toxicity Measurements Made

Require Expenditure of $42 Million Over Five Years to Control Heavy Metal and Other Constituent Inputs to Santa Monica Bay From Watershed (Including City of Los Angeles and Surrounding Communities)

Implementation of Stormwater "BMPs"

Assume That Any Approach That Removes Heavy Metals in Stormwater Runoff is a BMP for Protection of Santa Monica Bay

Technically Invalid Approach

A BMP for Stormwater Runoff is Valid if it Improved Beneficial Uses of Receiving Waters

Heavy Metals in Stormwater Runoff from Urban Areas and Highways Are in Non-Toxic, Non-Available Forms Also Rarely Will Heavy Metals From These Areas Be Adverse to Aquatic Life When They Accumulate in Receiving Water Sediments

Pollutant Trading

Under TMDL Situations, Dischargers Are Required to Control a "Pollutant" to a Specified Load

Some Sources Can Control the Pollutant at Less Cost Per Unit Mass of Pollutant Removed Than Others

The Discharger Which Can Most Cost-Effectively Remove Pollutants Do So and Thereby Allow Another Discharger to Remove Less of Their Pollutant Load

In a True Pollutant Trading Situation Must Trade Pollutants That Impact Water Quality Not Chemical Constituents Irrespective of Their Impact

Consider Near-Field and Far-Field Effects

Evaluate Toxic-Available Forms

Pollutant Trading For Control of Toxicity

Metals and Some Organics Are Of Concern Because of Potential Toxicity or Bioaccumulation

Should Trade Toxic Units Not Total Metals or Even Dissolved Metals

Should Trade Bioaccumulatable Forms Not Total Concentrations

Technically Valid Pollutant Trading Will Require Site-Specific Evaluation of Each Major Source of Constituents of Concern To Determine the Pollutant Content

Management of Eutrophication

Eutrophication - Excessive Fertilization One of the Most Important Causes of Water Quality - Use Impairment in the US

Excessive Growth of Algae and Other Aquatic Plants

Most Freshwater Waterbodies Algal Growth Controlled by Phosphorus

Nitrogen Important For Most Estuarine and Marine Systems and Some Freshwater Systems Especially on the West Coast

Watershed Approach to Eutrophication Management Focusing on Controlling Limiting Nutrient Input Often Technically Invalid

Ignores the Aqueous Environmental Chemistry of Phosphorus

The Total Phosphorus Load From Some Sources is a Poor Predictor of Algal Available Phosphorus

Only About 20% of the Particulate Phosphorus in Urban Area and Rural Runoff Available to Grow Algae

Pollutant Trading For Eutrophication Control

Phosphate From Non-Point and Point Sources Are Not Pollutants To the Same Degree

POTW Residual Phosphorus May or May Not Be Available to Support Algal Growth

Aluminum and Iron Treatment For Phosphate Removal Produces Particulate Iron or Aluminum Phosphates

Filter Effluent to Further Remove Particulates

Removing Non-Algal Available Phosphorus

Non-Point Sources - 80% of the Particulate Phosphorus Non-Available to Support Algal Growth

Must Trade Algal Available Phosphorus Not Total Phosphorus

Water Quality Issues in Pollutant Trading[1]

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Abstract

As part of implementing the watershed approach for water pollution control, interest is being focused on pollutant trading. The pollutant trading programs that have been developed thus far are based on total chemical constituent concentrations and fail to properly consider that for many chemical constituent sources and types of chemical constituents the total chemical constituent concentration in a source or within the waterbody is a poor measure of potential water quality impacts. Pollutant trading should be based on trading chemical constituents that are adversely impacting the designated beneficial uses of a waterbody, i.e. cause pollution, rather than the total chemical constituent concentrations within the various sources for which trades are being considered.
(KEY TERMS: pollutant trading; point/nonpoint source; water quality criteria/standards; water quality.)

Introduction

Malik *et al.* (1994) have discussed economic aspects of pollutant trading as part of their discussion of economic issues of the watershed approach for water quality management. This discussion, however, fails to consider important often overriding water quality issues that should be addressed in any pollutant trading activity. A fundamental deficiency in most pollutant trading programs that have been proposed is the failure of those involved to recognize the difference between pollutants and chemical constituents. Basically, Malik *et al.* have discussed chemical constituent trading. It is important in any water quality management program to clearly distinguish between those forms of chemical constituents that are present in a waterbody or its inputs which give rise to a total concentration in the waterbody and those that are present in chemical-specific forms that adversely impact the designated beneficial uses of the waterbody.

Chemical Constituents vs. Pollutants

Chemical constituents exist in aquatic systems in a variety of chemical forms, only some of which are toxic-available (see Lee *et al.*, 1982). For the purposes of this discussion and in accord with traditional approaches, "chemical constituents" are defined as those chemicals which are present in a waterbody or input irrespective of whether they are in chemical forms that adversely impact the designated beneficial uses of the waterbody. "Pollutants," on the other hand, are those chemical constituents that are present in sufficient concentrations of available-

[1] Submitted for publication in Water Resources Bulletin, February (1996).

Purpose of Water Quality Monitoring

- Define Water Quality Impacts of Stormwater Runoff
- Serve as a Basis for BMP Selection
- Establish Basis for Pollution Source Control
- "Compliance" with NPDES Discharge Limits

egulatory Requirements

Purpose - To Control Stormwater Runoff Caused Pollution - Use Impairment to MEP Using BMPs

US EPA Proposed Policy - Must "Achieve" Water Quality Standards in the Receiving Waters. However, Exceedance of these Standards Does Not Constitute an NPDES Permit Violation
No Need for Traditional End-of-the-Pipe Compliance Monitoring

Need for Alternative Approach

Urbanos and Torno in the overview summary of the Stormwater NPDES Related Monitoring Needs, Engineering Foundation Conference, August 1994,

> *"If we are to acquire this understanding, we must stop wasting monitoring resources on the 'laundry list' type of monitoring encouraged or required by our current regulations. We must instead move towards well-designed and adequately funded national and regional scientific study programs and research efforts."*

Davies in Proceedings Engineering Foundation Conference "Stormwater Runoff and Receiving Systems: Impact, Monitoring and Assessment," 1995

> *"It is generally agreed that NPS* [nonpoint source] *problems are unique and complex, and they will not be resolved as easily as the relatively simple treatment and standard compliance approaches used in the PS* [point source] *program. NPS programs will require development and application of innovative and imaginative control strategies, and the program will cost much more than the PS program."*

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US EPA May 3 Draft Interim Stormwater Runoff Permitting Approach

- *"In order to gather necessary information about storm water discharges, storm water permits should include coordinated and cost-effective monitoring programs, such as ambient monitoring, receiving water assessment, discharge monitoring (as needed), or a combination of monitoring procedures designed to gather necessary information."*

  "The amount and types of monitoring necessary will vary depending on the individual circumstances of each storm water discharger. EPA encourages dischargers and permitting authorities to carefully evaluate monitoring needs and storm water program objectives so as to select useful and cost-effective monitoring approaches. For most dischargers, storm water monitoring can be conducted for two basic reasons: 1) to identify if storm water problems are present, either in the receiving water or in the discharge, and to characterize the cause of those problems; and 2) to assess the effectiveness of storm water controls to reduce contaminants and make improvements in water quality."

Focus of Recommended Monitoring Programs on Receiving Water Characterization Using:

"Techniques that assess receiving waters will help to identify if storm water problems are present, where these are not known. Techniques that assess storm water discharge characteristics will help to identify potential causes of any identified water quality problems."

"Although municipal NPDES storm water permit applications emphasized end-of-pipe chemical-specific storm water monitoring, this type of monitoring does not need to be repeated during the term of the permit if it is not identified as the best monitoring tool to support the purpose of the municipality's storm water management program."

Evaluation Monitoring For Implementation of a Watershed Based Water Quality Management Program

Current Water Quality Monitoring Programs are Largely End-of-the-Pipe Edge-of-the-Pavement/Property "Compliance" Monitoring

Provide Little to No Useful Information on the Real Water Quality Use Impairments That Are Occurring in the Receiving Waters For the Discharge - Runoff

Evaluation Monitoring Developed to Use Monitoring Funds More Appropriately to Define Real Water Quality Use Impairments in the Receiving Waters For the Discharge - Runoff

Shift Monitoring Emphasis From Discharge - Runoff to Receiving Waters

All Dischargers, Regulatory Agencies and the Public Work Together to Use Monitoring Funds Available to Find Real Water Quality Use Impairments in a Waterbody

Where Such Use Impairments Are Found, Assess and Prioritize Their Significance

Potential Water Quality Problems That Should Be Considered in a Watershed Based Water Quality Management Program

Aquatic Life Toxicity - Water Column and/or Sediments

Excessive Bioaccumulation of Hazardous Chemicals

Domestic Water Supply for Surface and Groundwaters

Sanitary Quality - Contact Recreation and Shellfish Harvesting

Eutrophication - Excessive Fertilization

Petroleum Hydrocarbons - Oil and Grease

Aquatic Life Carcinogens

Oxygen Demand

Sediment Accumulation - Siltation, Turbidity, Navagation, Habitat

Litter and Debris

Evaluation Monitoring Approach (continued)

Problem Definition and Control

Determine the Cause and the Source of Constituents Responsible for the Use Impairment

Develop Site-Specific Programs That Will Control the Use Impairment to the Maximum Extent Practicable

Repeat Evaluation Monitoring Program Evaluation of Each Potential Water Quality Use Impairment Every Five Years to Detect Changes in Activities Within the Watershed That Are or Could Be Adverse to the Waterbodies Water Quality

Also to Detect New or Increased Use of Constituents That Impair the Beneficial Uses of a Waterbody Introduced Into the Watershed

Overall, Evaluation Monitoring Focuses on Finding a Real Water Quality Problem in a Waterbody, Determining Its Cause and Significance and Developing Control Programs For Controlling the Input of Pollutants at the Source

Assessing Water Quality Impacts of Stormwater Runoff[1]

G. Fred Lee, PhD, PE, DEE (Member)[2]
Anne Jones-Lee, PhD (Member)

Abstract

Current "water quality" monitoring of non-point source runoff typically involves periodically measuring a laundry list of chemicals in the runoff waters. This approach, while satisfying regulatory requirements, provides little to no useful information on the impact of the chemicals in the runoff on the real water quality - designated beneficial uses of the receiving waters for the runoff. There is need to focus water quality monitoring on investigating the receiving waters in order to assess whether the chemicals in the runoff are adversely affecting beneficial uses. This paper presents an evaluation monitoring approach for monitoring receiving waters that determines whether the runoff is a significant cause of water quality - use impairments. For each type of use impairment, such as aquatic life toxicity, excessive bioaccumulation of hazardous chemicals, excessive fertilization, etc., highly focused site-specific studies are conducted to determine the use impairment that is likely occurring due to a stormwater runoff event(s) and the specific cause of this impairment.

Key words: stormwater, water quality, monitoring, highway

Introduction

There is growing recognition that domestic and industrial wastewater and stormwater runoff "water quality" monitoring involving the measurement of a suite of chemical "pollutant" parameters in discharge/runoff waters is largely a waste of money. For stormwater runoff, such programs generate more data of the type that have been available since the 1960's on the chemical characteristics of urban area, highway and street runoff. It has been known since that time that runoff from these areas contains a variety of regulated chemical constituents and waterborne pathogenic organism indicators that exceed water quality standards at the point of runoff discharge to the receiving waters. However, discharge monitoring provides little to no useful information on the impacts of the apparently excessive regulated chemicals and unregulated chemicals in the discharge on receiving water water quality - designated use impairment. As discussed by Lee and Jones (1991) and Lee and Jones-Lee (1994a, 1995a,b), many of the chemical constituents in urban stormwater runoff are in particulate, non-toxic, non-available forms. Further, the short-term episodic nature of

[1]Invited paper to be presented at the American Society of Civil Engineers North American Water and Environment Congress '96 to be held in Anaheim, CA, June 1996.

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Evaluation Monitoring for Stormwater Runoff Monitoring and BMP Development

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February 1996

Abstract

This report covers the development and application of evaluation monitoring to highway, urban area and street stormwater runoff water quality management. A discussion is presented on the need for an alternative approach to the conventional approach of evaluating the water quality impacts of highway and urban area stormwater runoff on receiving water quality. Information is presented on the background to the development and application of site-specific studies (evaluation monitoring) that are conducted on the receiving waters for stormwater runoff that identify real water quality use impairments in these waters that are caused by chemical constituents and/or pathogenic organism indicators in the stormwater runoff.

The evaluation monitoring program is designed to replace the conventional "water quality" monitoring programs that are used for measuring the chemical constituents in highway, urban area and street stormwater runoff. It is widely recognized that conventional runoff water quality monitoring provides little in the way of useful information that can be used to evaluate the impact of stormwater runoff on the beneficial uses of the receiving waters for the runoff. Evaluation monitoring serves as a technically valid, cost-effective basis for BMP development that replaces the conventional approach that is used to develop stormwater runoff water quality BMPs. The conventional BMP development approach assumes that detention basins, grassy swales, various types of filters, etc. are effective BMPs in controlling real water quality use impairments due to heavy metals, organics and other constituents in highway and urban area stormwater runoff. However, it is now well-known that particulate forms of heavy metals and other constituents that are removed in conventional stormwater runoff BMPs do not adversely impact the beneficial uses of the receiving waters for the runoff. The particulate forms of heavy metals and other constituents are in non-toxic, non-available forms. Therefore, their removal in a detention basin will not be of benefit to the beneficial uses of the receiving waters for the stormwater runoff.

Basically, the evaluation monitoring program shifts the funds that are used for end-of-the-pipe runoff monitoring to site-specific, highly directed studies designed to find real water quality use impairments of the receiving waters for the stormwater runoff. When such use impairments are found that are due to highway, urban area or street runoff, then BMPs are developed that control the input of the pollutants, i.e. those constituents that cause impairment of the beneficial uses of the receiving waters for the stormwater runoff to the maximum extent practicable. The

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Chemical Constituent vs. Pollutant

Must Clearly Distinguish Between Those Chemical Constituents Which Are Important in Adversely Affecting the Beneficial Uses of a Waterbody
Must Be Evaluated on a Site-Specific Basis

Selection of BMP's

Objectives: Control Impairment of Waterbody Uses of Concern to the Public in a Technically Valid, Cost Effective Manner
Err Slightly on the Side of Protection
Protect and Enhance without Wasting Large Amounts of Public and Private Funds

Evaluation of the Efficacy of BMP's

Current Approach
Across Structural BMP or Before and After Chemical Input Control
Not Technically Valid Focuses on Chemical Constituents Not Pollutants

Valid Approach

Must Focus BMP Efficacy Evaluation on Receiving Waters Changes in Beneficial Uses
Not the Same as Chemical Constituent Changes

Development of Technically Valid Watershed Approach for Water Quality Management

- Organize All Stakeholders (Dischargers, Water Users, Interested Parties, Regulatory Agencies, Etc.) to Develop Watershed Based Water Quality Management Approach

- Appoint a Stakeholders Technical Advisory Committee That Includes Several Individuals Knowledgeable in Aquatic Chemistry, Aquatic Toxicology and Water Quality

- For Each Potential Type of Water Quality Use Impairment Within the Waterbody of Concern, Assess What is Known About Its Magnitude and Significance Within the Waterbody and Downstream Thereof

- Develop a Data-Information Gathering Program to Fill Data Gaps on Current Water Quality Problems Within the Waterbody

Is There Aquatic Life Toxicity in the Ambient Waters?

Do Fish and Other Aquatic Life Have Excessive Concentrations of Bioaccumulatable Chemicals?

Is There an Impairment of Contact Recreation or Shellfish Harvesting Due to Excessive Concentrations of Fecal Indicator Organisms?

Is The Use of Water For Domestic Water Supply Purposes Impaired? - Consider Both Surface and Groundwater

Is There Excessive Growth of Algae and Other Aquatic Plants?

Are the Sediments Toxic to Aquatic Life?

Do the Sediments Serve as a Source of Bioaccumulatable Chemicals That Impair the Beneficial Uses of the Waterbody?

Do Low Dissolved Oxygen Conditions Exist in the Waterbody?

Is There Excessive Trash and Other Debris, Oil and Grease, Etc.?

(continues)

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Development of Technically Valid Watershed Approach for Water Quality Management (continued)

- The Stakeholders - the Public Should Prioritize the Water Quality Use Impairments Within the Waterbody In Terms of Their Importance to the Public Considering Any Legal or Other Constraints That Exist on Water Quality Management Approaches Within the Watershed

  The Proper Prioritization of Both Near-Field and Far-Field Water Quality Impacts Within a Watershed May Require Acquisition of Additional Information That May Not Be Available

  The Prioritization Should Be Reexamined Every Few Years, i.e., Five Years to Incorporate New Information That Has Been Developed and Changes in Use of the Waters Within a Watershed

Development of Technically Valid Watershed Approach for Water Quality Management (continued)

- Assess the Current Information on the Causes of Water Quality Use Impairments Within the Waterbody

  If There is Aquatic Life Toxicity, What Constituent(s) is Responsible For It?

    Do Not Assume That Exceedance of Water Quality Criteria - Standards For Potentially Toxic Chemicals Represents a Real Water Quality Use Impairment - Use Toxicity Tests and TIEs

- Through Forensic Analysis, Determine the Specific Sources of the Pollutants That Cause Water Quality Use Impairments Within the Watershed That Are of Sufficient Magnitude to Require Control

- Develop and Implement Site-Specific Control Programs For Each of the Sources of Pollutants That Significantly Impairs the Near-Field or Far-Field Uses of the Waterbody

  Focus Control Programs on Sources Rather Than Trying to Treat Stormwater Runoff From Urban Areas, Highways and Rural Areas

Development of Technically Valid Watershed Approach for Water Quality Management (continued)

- Implement Pollution Prevention Program Designed to Detect Potentially Emerging Problems

  Focus Pollution Prevention on Control of Pollutants Not Chemical Constituents Irrespective of Whether They Are Potentially Adverse to Water Quality

- Repeat the Evaluation Monitoring Approach for Each Potentially Significant Water Quality Problem Every Five Years

Overall, Approach Is Technically Valid and Cost-Effective

  Utilizes Current Understanding of Factors Influencing the Water Quality Significance of Chemical Constituents in Aquatic Systems

Overall Approach to Implementation of Evaluation Monitoring

- Work with Dischargers, Regulatory Agencies and Others in Defining Existing and Potential Water Quality Problems of the Receiving Waters for ETC Runoff, Prioritize the Significance of these Problems, Define How the Available Funds Will Be Used to Address these Problems
  - Define Real Water Quality Use Impairment(s)
  - Determine Cause of Water Quality Problems
  - Determine Source of Constituents that Cause Problems
  - Work with Regulatory Agencies and Others in Development of BMP's to Control Input of Constituents Responsible for the Water Quality Impacts to the Maximum Extent Practicable
  - Cycle Through the Potential Impacts Every Five-Year NPDES Permit Period

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Summary Biographical Information

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

Dr. G. Fred Lee is president and Dr. Anne Jones-Lee is vice president of G. Fred Lee & Associates, an environmental consulting firm located in El Macero, California.

For 30 years, Dr. G. Fred Lee held university graduate level teaching and research positions at several major US universities, including a Distinguished Professorship of Civil and Environmental Engineering at the New Jersey Institute of Technology. Dr. Anne Jones-Lee taught graduate level environmental engineering and environmental sciences courses and conducted research for 11 years. She held an associate professorship in civil and environmental engineering at the New Jersey Institute of Technology. In 1989, Dr. G. Fred Lee and Dr. Jones-Lee assumed full-time consulting activities through G. Fred Lee & Associates.

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