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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.

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THE PROBLEM

Most chemical contaminants exist in aquatic systems in a variety of chemical forms. Only some of those forms are "available" to adversely affect aquatic life; the other forms are unavailable/non-toxic. The key to the use of chemical concentration-based criteria and standards for reliable and cost-effective water quality protection, therefore, is distinguishing between available and unavailable forms for organisms of concern in the aquatic environment of concern. Because of the limitations of chemical analytical techniques and because of the environmental variables that control the impact of chemical contaminants on aquatic life, this distinction cannot be made for most chemicals by chemical analysis.

Because of the variety of chemical forms in which heavy metals exist, for example, it has long been recognized that the total concentration ("total recoverable concentration") of a heavy metal in a water or sediment is an unreliable indicator of the impact of that contaminant on aquatic life in that system. For many heavy metals, the concentration of "dissolved" forms more closely approximates the concentration of available forms, but still includes some forms that are not available. In recognition of that situation, the US EPA has recently recommended the use of concentrations of dissolved metals rather than of total recoverable metals for implementation of its chemical concentration-based criteria (US EPA, 1993). However, the Agency has still not addressed the problem of over-regulation of other heavy metals and a wide variety of nonmetallic contaminants that are still being regulated based on total contaminant concentrations.

The US EPA also tried to give states an opportunity to compensate for the overly protective nature of its water quality criteria by prescribing a water-effects-ratio adjustment for the implementation of the criteria into site-specific criteria/standards. However, even the recent revision of its guidance for the development of site-specific water quality criteria/standards through water-effects-ratio adjustments (US EPA, 1994) does not address some of the most important deficiencies in that approach which results in many contaminants in point and non-point sources being highly over-regulated. The adjustment approach presumes that the particulate forms of contaminants rapidly equilibrate with the dissolved ("available") forms, and on that basis, available forms of contaminants are used in the testing procedure and applied to unavailable forms. However, many particulate forms do not equilibrate with dissolved/available forms in a timeframe applicable to the evaluation or to the receiving water situation.

Recognition of significant problems with the use of chemical-specific concentration criteria and standards is not new. The National Academies of Sciences and Engineering committees (NAS/NAE, 1973) concluded that heavy metals could not be reliably regulated based on chemical concentration measurements without significant waste of public and private funds. Those committees recommended that toxicity testing be used to assess the toxicity/availability of metals. While the US EPA adopted that technically valid approach in its "Red Book" of water quality criteria in 1976, in the early 1980's it unfortunately abandoned it for a technically unreliable approach (Lee and Jones-Lee, 1995a).

While the technical short-comings and limitations of the use of chemical concentrations has been long-recognized in the technical community, and biological effects-based assessment approaches are available and have been used effectively, the analysis of a list of chemical contaminants with the comparison of the concentrations to a list of delimiting values to determine the need for regulation, remains a fact of regulatory expedience. Some try to rationalize the use of that approach by claiming it is used only for "screening". While as discussed below, chemical concentration-based criteria can have a role in screening for potential problems, they are not reliable as the first line of screening or without substantiating biological effects-based evaluation. Further, it must be recognized that "screening" is the first step in the decision-making and regulatory process.

Over-Regulation of Copper in San Francisco Bay

An unfortunate, but very good and current example of the gross over-regulation of heavy metals is the regulation of copper in San Francisco Bay (Lee, 1994a). Concentrations of total recoverable and dissolved copper in San Francisco Bay frequently exceed the US EPA water quality criterion for copper, and the site-specific water quality standard (objective) for copper developed by the San Francisco Bay Regional Water Quality Control Board based on and with concurrence of the US EPA guidance. If those criteria were adequately but not overly protective, their frequent exceedance in Bay waters should be causing toxicity to aquatic life. However, comprehensive toxicity testing conducted in 1993 by independent laboratories using the same type and forms of aquatic organisms used to establish the original water quality criterion for copper, showed no evidence of toxicity to aquatic life (Thompson et al., 1994). That finding is not unexpected based on the nature of the criteria and standards, and the aqueous environmental chemistry and toxicology of copper.

Notwithstanding the results of the comprehensive toxicity evaluation, the US EPA's Independent Applicability Policy holds that the numeric chemical concentration criteria are to be applied independently; the exceedance of a numeric criterion/standard is, itself, considered an "impact". Thus as a result of the Independent Applicability Policy, the point and non-point source dischargers, including the agencies responsible for stormwater runoff quality management, have been forced into an arbitrarily developed wasteload allocation and TMDL's (total maximum daily loads), controls that are projected to ultimately result in expenditures in excess of one billion US dollars, all without evidence of adverse impact of copper on beneficial uses of the Bay. Almost as disconcerting is the fact that implementation of those restrictions and the expenditure of those funds will not result in the achievement of the US EPA copper criterion or the site-specific objective for total or dissolved copper in San Francisco Bay waters. Under the current Policy, any exceedance of the criterion for more than one hour once in three years is considered to be a water quality violation. Even if all copper inputs to the Bay from external sources were stopped, the copper derived from wind-induced stirring of sediments into the watercolumn would cause such water quality violations under the current Policy.

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Under-Regulation of Diazinon

The problems with chemical concentration-based criteria and standards are not limited to the over-regulation or unreliable regulation of contaminants. Reliance on those criteria can also result in inadequate regulation of pollutants. In the US, massive amounts of money are being spent to regulate, or often over-regulate, the comparatively few contaminants for which numeric criteria exist. While a few hundred contaminants are covered by such criteria, there exist on the order of 65,000 largely unregulated chemicals; about 1,000 new chemicals are developed each year. Without a numeric criterion/standard, chemical concentration-based approaches cannot be applied. Consequences of this aspect of the reliance on chemical-specific approaches can be illustrated by the situation with diazinon in California (Lee, 1994b). Recently reported studies have demonstrated that diazinon is a significant cause of toxicity to aquatic life in the watercolumn of the Sacramento/San Joaquin River Delta in California. However, according to representatives of the State Water Resources Control Board, the input of that chemical to that system cannot be regulated because the State has not developed a chemical-specific water quality criterion for diazinon. Thus, a chemical known to be causing toxicity to ambient water organisms goes unregulated, while copper that has been found to not be causing toxicity is being severely regulated.

Toxic Hot Spot Identification and Management

Chemical concentrations have been, and continue to be, used as a bureaucratically expedient method for the identification of "hot spots" of contamination that warrant further investigation or management. While approaches used for screening areas for further investigation can be more conservative (protective) than necessary to protect beneficial uses of aquatic systems, they can not be less reliable. As discussed above, the chemical-specific approach is often over-protective, but can also be under-protective. Further, the identification of a chemical concentration "hot spot" can be misleading to the lay public and those not adequately versed in aqueous environmental chemistry and toxicology. It is easy to presume that the higher the concentration, the worse the situation, but the fact remains that there is typically no reliable relationship between the total concentration of a contaminant and degree of impact of that contaminant, owing to the control over the impact exerted by the aqueous environmental chemistry and toxicology of the contaminant in the particular system. Focusing on situations in which the concentration exceeds a particular level not only wastes funds on sites at which there is no real water quality problem, but also overlooks or relegates to low priority sites at which there may be real problems.

APPROPRIATE USE OF CHEMICAL-SPECIFIC WATER QUALITY CRITERIA

The authors, as well as other professionals, have maintained for many years that chemical-specific water quality criteria of the type available today, and standards based on those criteria, can be used as indicators of *potential* water quality problems, but that they should not be used as independently applicable values that cannot be exceeded at the edge of a mixing zone for point or non-point-source discharges as is being required today (Lee, 1973; Lee and Jones, 1979, 1981, 1983, 1995b; Lee et al., 1982). If an exceedance of a chemical-specific numeric criterion or standard occurs, those responsible should be provided the opportunity to conduct appropriate studies to determine whether that exceedance is causing an impairment of the designated beneficial uses of those waters. If the entity responsible chooses not to conduct such studies, the worst-case numeric values may be applied for regulating that discharge.

For example, if the chemical of concern is mercury and a publicly owned treatment works (POTW) finds that it has excessive mercury in its discharge compared with that which would be allowed based on a chemical-specific criterion, the POTW should be afforded the opportunity to determine if that "excessive" concentration of mercury is leading to excessive levels of mercury in edible tissue of aquatic organisms downstream of the discharge. If there are no problems with excessive bioaccumulation of mercury, there should be no need for additional control of the mercury in the discharge from the POTW beyond the current controls.

A similar approach should be taken in a situation such as that described for San Francisco Bay. If, as has been found, there is no watercolumn toxicity being caused by current copper discharges, there should be no need for the POTW's, industrial dischargers, stormwater dischargers or others to reduce their copper inputs from the current levels. There may be some who attempt to argue that while there may be no toxicity due to copper in the watercolumn, there could be toxicity problems in the organisms associated with the sediments. The water quality criteria and standards were developed to address watercolumn issues; they cannot be presumed to be applicable to assessing issues of benthic organisms. Sediment quality - benthic organism - concerns should be addressed through an appropriate evaluation of the impact of sediment-associated copper on aquatic life (Lee and Jones-Lee, 1993). This cannot be done by application of chemical-specific watercolumn-based water quality criteria or standards for aquatic life.

The use of chemical-specific/chemical concentration criteria and standards to flag potential problems as prescribed above does not address the problem of chemical contaminants that are causing water quality problems but that go unregulated because for a lack of numeric concentration criteria. Receiving waters should be screened for indications of aquatic life-related beneficial use impairment

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(water quality problems) using appropriate biological effects-based approaches to screen for toxicity, organism wholesomeness, and numbers and types of organisms. Where water quality (beneficial use) impairment is found, careful evaluation of discharges and selective measurement of chemical contaminants in a Toxicity Identification Evaluation (hazard assessment) framework can elucidate the cause/source of the impairment. However, for the reasons discussed above, the fact that a particular measured contaminant is present in elevated concentrations cannot be presumed to be tantamount to a problem or to be the cause of a problem.

The use of such biological-effects-based evaluation would render largely unnecessary the measurement of lists of chemical contaminants. It would allow the focus to be on identification of water quality problems (rather than identification of administrative exceedances of criteria), judicious use of chemical analytical techniques, and correction of problems where they are found.

CONCLUSION

It is the authors' position that, rather than throwing money at non-problems identified by an exceedance of an overly protective national or site-specific water quality criterion or standard, it is far more responsible, both environmentally and fiscally, to use the limited funds available to address the control of contaminants that are causing real, readily discernible, significant adverse impacts on designated beneficial uses of waterbodies. When "administrative exceedances" of chemical-specific criteria occur, those responsible for the exceedances should be given the opportunity to provide sufficient funding to enable credible studies to be conducted to ascertain whether those exceedances are of significance in adversely impacting the designated beneficial uses of the waterbody.

Abandonment of the US EPA's Independent Applicability Policy for chemical-specific criteria and adoption of an approach that uses biological effects-based criteria as the predominant evaluation and management tool and chemical-specific criteria and standards as one trigger to allow site-specific evaluation of potential adverse impacts of the discharge, would provide a much more technically valid and cost-effective approach for regulating chemical contaminants in the Nation's waters.

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