Regulating Water Quality Impacts of Urban and Highway Stormwater Runoff

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In early March 2008 the Los Angeles *Times* and the Santa Monica *Daily Press* carried articles on law suits that have been filed by the National Resources Defense Council (NRDC) and other environmental groups against Los Angeles County and the city of Malibu (Weiss, 2008; Daily Press Staff, 2008). According to those reports, concentrations of fecal bacteria, heavy metals, and other pollutants associated with stormwater runoff from Los Angeles and Santa Monica exceed water quality criteria/standards. It appears that the law suit is designed to compel Los Angeles County and the city of Malibu to manage urban stormwater runoff to prevent violations of water quality standards in coastal waters that receive the runoff.

While not involved in that litigation, the authors have been involved in the investigation, assessment, and management of, and in publishing on, water quality impacts of stormwater runoff for more than 40 years. The senior author has spent much of his five-decades-long professional career involved in various aspects of the development, peer-review, application, and site-specific adjustment of water quality criteria and standards both nationally and in numerous states, for the protection of water quality/beneficial uses. This report highlights key technical aspects of regulating water quality impacts from stormwater runoff from urban areas and highways, with particular reference to compliance with water quality standards. It also has applicability to nonpoint source runoff/discharges, such as those from irrigated agriculture. These issues, and recommended approaches for developing appropriate water quality standards for urban and highway stormwater runoff are discussed in greater depth by Lee and Jones-Lee (2000a, 2004, 2005), as well as in numerous other publications, reports, and presentations posted on their website (www.gfredlee.com) in the "Surface Water Quality" section, "Urban Stormwater Runoff" subsection (http://gfredlee.com/pswqual2.htm#runoff). For the past decade the authors have also published an approximately monthly, email-based, "Stormwater Runoff Water Quality Newsletter" that addresses current topics related to the sources, significance, fate, and control of contaminants in urban, rural, and agricultural stormwater runoff. Past issues of those newsletters are archived on their website at http://www.gfredlee.com/newsindex.htm; issues are identified by topics covered at http://www.gfredlee.com/swnews_indexa.pdf.

Water Quality Criteria/Standards for Stormwater Runoff

One of the problems faced by stormwater quality managers and regulatory agenices is the application of numeric worst-case-based water quality criteria and standards to situations beyond those for which they have technically reliable applicability. In 1972, the US Congress mandated that the US EPA develop national water quality criteria that would be protective of the beneficial uses of the Nation's waters. That requirement led to worst-case-based water quality criteria that presume that the all forms of a contaminant to which organisms are exposed are toxic or available to adversely affect beneficial uses of the water, and that organisms receive chronic (long-term or critical life-stage) exposure to the available forms of the contaminants. The use of enforceable standards equivalent to those criteria ignores the fact that most chemicals that are potential pollutants exist in aquatic systems in a variety of chemical forms, only some of which are toxic/available to adversely impact water quality. Further, they do not give adequate consideration to the fact that organisms do not necessarily receive long-term or critical life-stage exposures to contaminants in ambient waters.

US EPA water quality criteria and numeric standards based on them were not developed for the conditions typically encountered with urban and highway stormwater runoff. Those criteria and standards were developed for aquatic life protection under conditions more typical of a continuous discharge of largely available/toxic forms of contaminants (such as from a domestic wastewater treatment facility (POTW)) and that result in longer term (chronic) exposure scenarios for aquatic organisms. Chemical contaminants in urban and highway runoff, by contrast, are typically in largely unavailable, nontoxic forms; organisms in receiving waters generally receive short-term, episodic exposure to those discharges.

Nevertheless, since the late 1980s, the US EPA has incorporated into NPDES permits for discharges to surface waters (including larger (MS-4) stormwater runoff discharges), the prohibition from violating water quality standards at the point of discharge or at the edge of a defined mixing zone. That requirement, however, has not been enforced for permitted stormwater runoff by the federal and state regulatory agencies. Past court rulings have, in general, concluded that the US EPA has discretion regarding requiring NPDES-permitted stormwater runoff dischargers to manage urban stormwater runoff to prevent violations of water quality standards. The management approach that has typically been followed has been the development of BMPs (Best Management Practices) to work toward compliance with water quality standards, and the reporting of violations of water quality standards by dischargers. The recently filed NRDC lawsuit attempts to eliminate the current exemptions to meeting water quality standards that are being allowed by regulatory agencies.

One of the foremost reasons that the US EPA and state regulatory agencies have not required compliance with water quality standards applied to stormwater runoff is the very high cost of compliance to attain no more than one exceedance by any magnitude in three years, i.e., the conventional NPDES requirements for wastewater discharges. It is estimated that the costs of property acquisition, construct of a collection system, storage facilities, and treatment works, and the operation of the treatment works would translate to several dollars per person per day for the population served by the treatment works. The bulk of the cost is associated with the acquisition of property and the up-sizing of the collection and treatment works to manage the very high stormwater flows that can occur during major stormwater runoff events.

The evaluation and management of urban and highway stormwater runoff to meet US EPA water quality criteria or worst-case numeric standards based on them is, therefore, not technically appropriate and leads to over-regulation of chemical constituents in runoff waters, and establishment of ineffective or unnecessary BMPs. It can also result in the failure to identify real causes of water quality problems and in the overlooking of contaminants that are, in fact, causing water quality problems. (Jones-Lee and Lee (2008) discussed issues that need to be considered in regulating water quality impacts of stormwater runoff; a copy of that paper is appended to these comments.)

The US EPA has developed a procedure, the "water effects ratio," to adjust the national water quality criteria for site-specific conditions in an effort to correct, to some extent, the overregulation of the application of worst-case-based water quality criteria to many waterbodies. Unfortunately, the water effects ratio only partially corrects the overregulation; potential pollutants in some sources such as urban and highway stormwater runoff are in chemical forms that behave differently than the 100%-available forms used in the US EPA water-effects-ratio adjustment. This can cause the adjusted value to also substantially over-regulate contaminants in these types of discharges. Lee and Jones-Lee have developed several reviews on the deficiencies in the monitoring approaches that are typically used by stormwater runoff water quality managers but often required by regulatory agencies (including Lee and Jones, 1991, and Lee, 2002).

"Evaluation Monitoring" for Stormwater Runoff

In the mid-1990s, Lee and Jones-Lee worked with S. Taylor of RBF Consulting in Irvine, CA to evaluate the need for, and appropriateness of, incorporation of conventional BMPs for stormwater management in the development of a proposed toll road in the Upper Newport Bay area of Orange County, California. The primary concern was that the stormwater runoff contained several heavy metals in concentrations above their worst-case-based national water quality criteria. Such violations indicated the potential that the heavy metals could be causing aquatic life toxicity in receiving waters; conventional BMPs would have removed particulates, which contained heavy metals.

Rather than following the conventional monitoring approach of collecting grab samples of stormwater runoff and analyzing them for a suite of potential pollutants such as heavy metals, they obtained permission from the regulatory agencies to shift the emphasis to what they call the "evaluation monitoring" approach described by Jones-Lee and Lee (1998) and Lee and Jones-Lee (1999). The evaluation monitoring employed measurement of toxicity in the runoff instead of the conventional approach of measuring heavy metal concentrations in the runoff and then trying to infer toxicity. This approach evaluates whether the heavy metals, in combination with all other potentially toxic chemicals in the runoff, are present in toxic amounts. It was found that the stormwater runoff was toxic to *Ceriodaphnia*. However, as discussed by Lee and Taylor (2001), contrary to what would have been surmised through conventional chemical analysis, that toxicity was not due to heavy metals. Rather, further investigation revealed that it was caused by pesticides used in urban and agricultural areas of the Upper Newport Bay watershed, but that were not at that time routinely measured in stormwater runoff.

The conventional evaluation approaches would likely have measured total heavy metals, found them to be "excessive" and in need of control, and triggered construction of conventional BMPs such as detention basins or filters to remove particulate heavy metals. This would not have identified or addressed the real problem. The BMPs that were adopted in response to the evaluation monitoring that was conducted included source control on the use of pesticides that become part of the stormwater runoff. Not only did this provide more appropriate pollutant control, it was also more cost-effective. The success of the evaluation monitoring approach in the Upper Newport Bay watershed has caused Lee and Jones-Lee to recommend that stormwater runoff water quality managers and regulatory agencies shift from the conventional monitoring of stormwater runoff to a site-specific, focused effort to define the real, significant water quality impacts of urban area and highway stormwater runoff. This approach could serve as the basis for developing water quality criteria/standards that are appropriate for stormwater runoff.

Further discussion of the inappropriateness of regulating urban area and highway stormwater runoff through application of the US EPA national water quality criteria is provided by Lee and Jones-Lee (1998, 2000b) and Lee (1998). There is need to develop stormwater runoff water quality criteria that will protect the designated beneficial uses of waterbodies without significant overregulation of chemical constituents in the runoff. While the US EPA has proposed to develop wet-weather water quality criteria to address this need, the agency has not devoted needed resources to this work in part due to opposition to this approach by environmental groups.

Recommendation

There is need to develop wet-weather criteria/standards that properly reflect the coupling between critical concentrations of available forms of potential pollutants and duration of organism exposure that is characteristic of stormwater runoff into receiving waters. To provide the technical foundation for such criteria/standards, stormwater runoff water quality managers and the regulatory agencies need to fund representative, comprehensive, evaluation monitoring studies to define the real, significant impacts of runoff-associated chemical constituents in receiving waters.

Until this approach is formulated and implemented, there will continue to be attempts by some environmental groups to try to get regulatory agencies and/or the courts to force public and private interests to fund stormwater runoff water quality management programs to achieve worst-case-based national water quality criteria/standards. Forcing such compliance will be counterproductive to providing environmental quality protection as it will result in the waste of funds for unnecessary and/or ineffective treatment leaving fewer funds to address real water quality problems. It would far more effective for environmental groups to work with the technical community, stormwater runoff water quality managers, and the public to develop a regulatory approach that will protect the designated beneficial uses of the receiving waters for runoff without significant unnecessary expenditures for chemical constituent control. This should be undertaken under the leadership of an expert panel knowledgeable and experienced in the technical aspects of the nature and behavior of chemical contaminants in urban and highway runoff as it enters receiving waters.

Other Sources of Information

Discussions of Previous Court Rulings. Stormwater Runoff Water Quality Newsletter issues 9-6, 8-4, 5-3, 2-2, 1-5 (designations refer to Volume-Number of the issues found at http://www.gfredlee.com/newsindex.htm) provided background information on discharges of stormwater associated with municipal, industrial, and construction activities, and to some of the past litigation regarding compliance of urban stormwater runoff with water quality standards. Newsletter Volume 2 Number 2, October 16, 1999 summarized the Ninth Circuit Court Ruling on Compliance with Water Quality Standards. Newsletter Volume 5 Number 3, March 5, 2002 summarized the US EPA Appeals Board Decision, Washington, DC, February 2002 Order regarding the need of the District of Columbia's municipal storm sewer system to comply with water quality standards for urban stormwater runoff.

Newsletter Volume 1, Number 5, January 30, 1999, discussed issues affecting the meeting of water quality standards in urban stormwater runoff. Newsletter Volume 9, Number 6, June 27, 2006 reviewed issues that need to be considered in developing water quality criteria/standards for urban area and highway stormwater runoff to control adverse impacts on water quality, and the efficacy of conventional "best management practices" to meet water quality standards. It also provided information on an expert panel report to the California State Water Resources Control Board (SWRCB) entitled, "The Feasibility of Numeric Effluent Limits Applicable to Discharges of Storm Water Associated with Municipal, Industrial and Construction Activities." Several other Lee and Jones-Lee Stormwater Runoff Water Quality Newsletters have included information on the application of water quality criteria/standards to urban stormwater runoff, including Newsletter Volume 8, Number 4, August 12, 2005 that discussed the Clean Water Act, water quality criteria/standards, TMDLs, and weight-of-evidence approaches for regulating water quality.

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CENews.com Feature Article | Posted: Tuesday, January 29, 2008

Modeling Water Quality Impacts of Stormwater Runoff –
Why Hydrologic Models Aren't Sufficient

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It is a common practice in assessing water quality impacts of stormwater runoff to use hydrology-based "water quality" models to estimate total concentrations of chemical contaminants at a particular location in the runoff and receiving waters. Those estimates are then compared with U.S. Environmental Protection Agency (EPA) worst-case-based water quality criteria and state water quality standards to render judgments about water quality impacts. However, the results of stormwater hydrology-runoff models do not, in fact, properly assess water quality impacts.

Chemical composition versus water quality

A fundamental error made in the water quality management field is the consideration of chemical concentrations (as typically measured by EPA or "Standard Methods" analytical procedures) as being synonymous with water quality. By Clean Water Act requirements, water quality is assessed relative to the designated beneficial uses of a water body. Since it is not possible to directly translate total concentration of a chemical in either a discharge or within a water body to an impairment of beneficial uses, it is not appropriate to characterize a set of chemical concentration data as an assessment of water quality. While such data describe certain water characteristics, it is only when those characteristics are appropriately integrated with other information, such as chemical bioavailability and behavior, duration of organism exposure, organisms of interest, habitat characteristics, desired use of the water body, et cetera, that they can provide insight into the role of those chemical contaminants in water quality—their impact on beneficial uses of the waterbody.

Additionally, chemical constituent or contaminant is not synonymous with chemical pollutant. Chemical contaminants or constituents are only pollutants when they adversely impact the beneficial use of a particular water body (for example, cause toxicity that affects organisms of concern, cause bioaccumulation of chemicals in edible organisms to render them unsuitable for use as food, change organism assemblages, adversely affect the character of the water for domestic water supply, et cetera, depending on the water body). This nomenclature distinction recognizes the paramount role of site-specific aquatic chemistry and toxicology/biology in water quality evaluation and more properly focuses the public and private funds available on cost-effective water quality protection and management. Focusing on chemical impacts rather than on concentrations of regulated chemicals also enables better focus on assessment of the impact of unregulated constituents—those without numeric water quality criteria/standards—that may be causing water quality impairment.

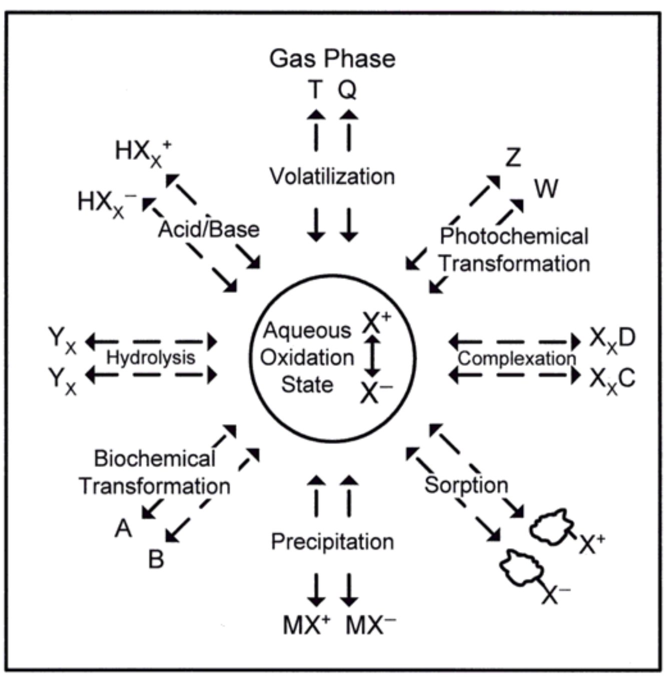
The current approach of finding an exceedance of a numeric water quality criterion/standard and then developing treatment works/control programs, without properly evaluating whether or not the exceedance is, in fact, adversely affecting beneficial uses of the water body, can waste public and private funds and at the same time fail to address significant water quality problems in the water body. This is especially true in the evaluation and management of water quality problems associated with stormwater runoff from urban and rural/agricultural areas, and in water quality modeling.

Aquatic chemistry

There is a general lack of consideration of the importance of aquatic chemistry in water quality evaluation and management. Aquatic chemistry can be complex and not easily modeled; its proper incorporation requires a more in-depth understanding than many in the field possess. It can also be more challenging to explain why removal of particular "chemicals" in a situation is not warranted for water quality protection than it is to cause the development of a treatment works. That notwithstanding, it has been well-known since the late 1960s that the total concentrations of potentially toxic constituents in the water column or sediment is an unreliable basis for estimating the water quality impacts on the Clean Water Act-designated beneficial uses of a water body.

The reason that total concentrations of a selected chemical(s) are unreliable in assessing water quality/use-impairment is that many chemical constituents in aquatic systems exist in a variety of chemical forms, only some of which are toxic or otherwise available to affect water quality adversely. This is shown conceptually in the aquatic chemistry "wheel" presented in Figure 1.

Figure 1: Aquatic chemistry of chemical constituents



Different forms of a chemical can have vastly different degrees of impact on the beneficial uses of a water body (such as aquatic life propagation or wholesomeness of aquatic life used as food). The forms in which chemicals exist in a particular aquatic system depend on the nature and levels of detoxification materials in the water and sediments. Those materials, such as organic carbon, sulfides, carbonates, hydrous oxides, clay minerals, et cetera, react with potentially toxic forms of chemicals, yielding chemical forms that are non-toxic, less toxic, or otherwise less available to aquatic life.

The reactions that take place and the toxicity/availability of the various forms of chemicals that are created through these reactions depend on the nature of the particular contaminant, as well as the characteristics of the aqueous environment being considered.
In an attempt to better represent aquatic chemistry in water quality assessment, the EPA developed the MINTEQA2 exposure assessment model. (Information on that model and its use is available at www.epa.gov/ceampubl/mmedia/minteq/index.htm.) MINTEQA2 can be used to some extent to describe the position of equilibrium for the potential reactions that a chemical may undergo in an aqueous environmental system. However, it does not account for the kinetics of those reactions—the rates at which equilibrium is attained—and hence the actual concentrations of the various forms expected in a particular system. Thus, while the MINTEQA2 model is useful in describing the aquatic chemistry of a constituent, it must be used in conjunction with site-specific investigations of the location to which it is being applied. The purpose of those site-specific investigations is not the quantitative speciation of a chemical, but rather evaluation of the availability of the forms that are present through effects-based assessments.

Duration of exposure
In addition to considering the bioavailability of the chemical species present in a given aquatic system, it is necessary to consider the duration of exposure that aquatic life of concern can receive as the runoff waters mix into the receiving waters. Figure 2 illustrates the general relationship among the concentration of available chemical forms, duration of organism exposure, and laboratory toxicity measurement (impact).

As shown, comparatively high concentrations of available forms of a toxic chemical can be tolerated by aquatic organisms without impact as long as the duration of exposure is sufficiently short. As the duration of exposure is increased, the concentration of available forms that can be tolerated without impact lessens until, for many chemicals, a concentration is reached to which an organism can be exposed for a lifetime or over critical life stages without adverse impact. How this relationship is manifested in an aquatic environment can be influenced by the characteristics of the organisms of concern, the nature of the discharge being considered, as well as the hydrodynamics of the receiving water.

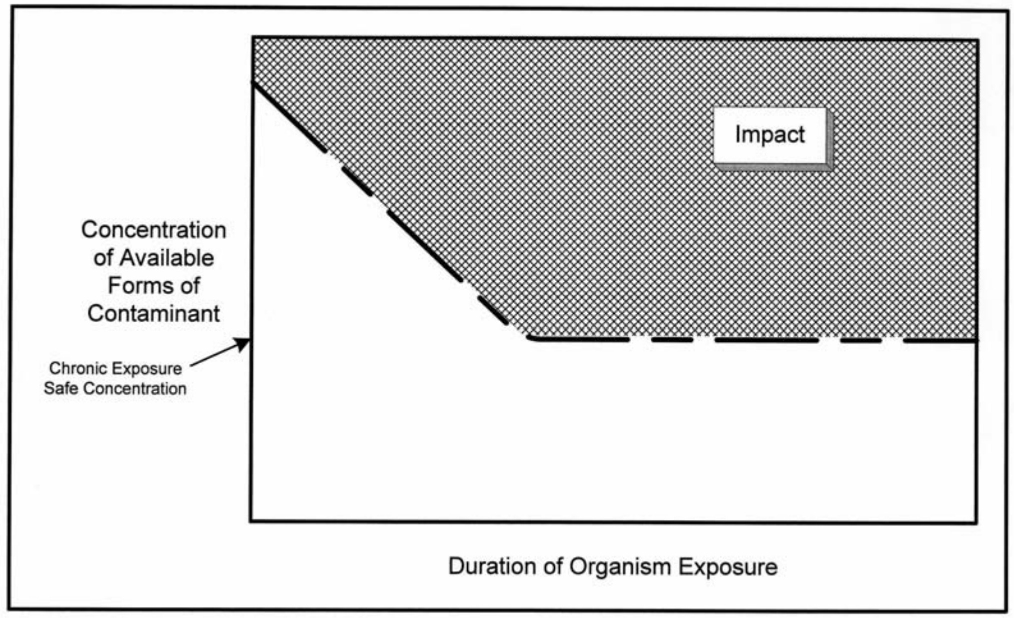


Figure 2: Critical concentration/duration of exposure relationship

Some discharges, such as stormwater runoff, are short-term and episodic in nature; organisms would be unlikely to be exposed to the discharge for a substantial duration. Mobile organisms such as fish may move in and out of an effluent/receiving water mixing area, altering the exposure it receives to contaminants in the discharge. There can be characteristics of a discharge, such as its temperature, that attract fish to it; other characteristics may repel fish. Some discharges contain some aspects that attract fish as well as others that repel them. These discharge characteristics, thus, affect the exposure a mobile organism may receive. There may also be zones of passage in a receiving water such that a mobile organism may avoid exposure altogether. To reliably model potential water quality impacts of stormwater runoff it is necessary to conduct site-specific studies of the mixing of the runoff waters with the receiving waters.

Since the concentrations of potential pollutants in runoff are typically the greatest at the point at which the runoff enters the receiving water, there is concern about whether there can be toxicity to aquatic life at or near the point of runoff entry. There is also concern about toxicity in areas outside of the mixing zone of runoff with the receiving water. The concentrations of runoff-associated contaminants in those areas are typically substantially more dilute than those in the runoff water itself. Potential impacts within the mixing zone, as well as out of the mixing zone, need to be addressed. One of the difficulties with the application of some states' regulations to stormwater runoff is that they do not allow a mixing zone for runoff-associated constituents in the receiving waters. Such a regulatory approach presumes that the concentrations in the discharge persist in the receiving water, which is rarely the case.

Recommended approach

Evaluation of the impact of chemical contaminants in a discharge on water quality should begin with the reliable definition of the water quality/use-impairment that is of concern. The water pollution control programs need to be shifted from comparing concentrations of chemicals to worst-case-based standards/guidelines to reliably assessing impacts on beneficial uses of a water body. If the beneficial uses of a water are being adversely impacted, a toxicity identification evaluation (TIE) approach needs to be followed to determine the cause/source of the problem. This is in contrast to, for example, measuring copper, lead, zinc, and cadmium that typically occur in street and highway stormwater runoff, finding they exceed EPA worst-case-based numeric water quality criteria/state water quality standards, and declaring that an impact has occurred.

We described an Evaluation Monitoring approach (see discussion at www.gfredlee.com/wqchar_man.html) to focus monitoring on chemical impacts rather than on chemical concentrations. If toxicity is found in laboratory tests of an effluent or receiving water, an assessment should be made as to whether such toxicity is manifested in the water of concern and whether that toxicity significantly adversely affects the water body's beneficial uses. It should not be assumed that toxicity measured in a standard laboratory toxicity test necessarily translates to toxicity that is significantly altering the numbers, types, or characteristics of desirable forms of aquatic life in a water body. This is especially true for situations such as urban-area and highway stormwater runoff, where there can be short-term pulses of contaminants associated with runoff events that are not of sufficient magnitude and duration to exceed the critical magnitude—duration of exposure needed to be adverse to important forms of aquatic life in a water body.

For example, in the mid-1990s, G. Fred Lee, Ph.D., P.E., DEE, and Scott Taylor, P.E., initiated Evaluation Monitoring studies on the toxicity and water quality impacts of heavy metals in urban-area street and highway stormwater runoff in the Upper Newport Bay watershed in Orange County, Calif. It had previously been found, as is typical in urban-area and highway runoff, that several heavy metals, including copper, lead, and zinc, were present in runoff from those areas in concentrations above EPA worst-case-based water quality criteria. That finding indicated that there was a potential for those heavy metals to cause aquatic life toxicity in the waters receiving the runoff.

In the Evaluation Monitoring studies conducted, samples of stormwater runoff were collected from 10 watersheds covering urban, highway, and agricultural areas. The studies showed that stormwater runoff from urban areas and highways frequently contained heavy metals in concentrations above EPA water quality criteria. They also showed that that runoff was toxic to the zooplankton, Ceriodaphnia, with as much as 10 TUa of acute aquatic life toxicity. TIEs involving the addition of ethylene diamine tetra acetic acid (EDTA) to the toxicity tests to complex (render non-toxic) copper and other heavy metals, however, revealed that the toxicity was not due to heavy metals. Rather, it was found that the toxicity was due to organophosphate-based pesticides, including diazinon and chlorpyrifos, and likely as well to pyrethroid-based pesticides used in the watersheds studied.

The Lee and Taylor studies demonstrated the appropriateness of using the Evaluation Monitoring approach to evaluate the potential water quality impacts of stormwater runoff-associated potential pollutants. The overall report covering those studies is available for download at
http://www.members.aol.com/apple27298/Heavy-metals-319h.pdf and
http://www.members.aol.com/apple27298/295-319-tox-paper.pdf

Conclusion

To reliably model the water quality/beneficial-use impacts of a chemical constituent in stormwater runoff or wastewater discharges, detailed information on aquatic chemistry, thermodynamics and kinetics, and mixing and transport/mixing processes that occur on a site-specific basis, as well as the water quality significance of the forms of contaminants, need to be properly incorporated into the modeling effort. It is rare that this type of information is available or can be developed without extensive, site-specific investigations. It is far more reliable to follow the Evaluation Monitoring approach to evaluate the water quality impacts of pollutants in runoff/discharges. This includes directed, site-specific investigation and evaluation of the water quality impairments such as aquatic life toxicity, excessive bioaccumulation of hazardous chemicals, et cetera. Where impairment is found, follow-on studies are needed to determine the cause of the impairment and the sources of constituents causing the impairment, and to develop control programs to eliminate the impairment of the water quality/beneficial uses of the water body of concern.

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www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf.

Drs. G. Fred Lee and Anne Jones-Lee

Expertise and Experience in Water Quality Standards and NPDES Permits Development and Implementation into NPDES and other Permitted Discharges

Dr. G. Fred Lee has over 40 years of experience in developing water quality criteria, state water quality standards and their implementation into NPDES permitted and other discharge limits. In the 30 years that he held university professorial teaching and research positions from 1960-1989, he was highly involved in conducting research for the purpose of determining the impact of chemical constituents on aquatic life and public health. Since the mid-1970's he and Dr. Jones-Lee have worked together as a team in these areas. Her expertise in aquatic biology and aquatic toxicology coupled with his expertise in aquatic chemistry, public health and environmental engineering enable them to undertake work on complex issues associated with evaluating the significance of chemical constituents on the designated beneficial uses of waterbodies and in developing cost effective control programs for those situations where excessive concentrations of constituents are present that impair the designated beneficial uses of the waterbody.

Drs. G. F. Lee and A. Jones-Lee have published extensively on water quality criteria and standards development and their implementation into discharge limits. These publications have included invited review articles on the chemical aspects of bioassay procedures and the translation of laboratory toxicity testing results to field situations. A summary of their experience in these various topic areas is presented below.

Water Quality Research

Beginning in the early 1960's Dr. Lee initiated some of the first work ever done on evaluating the available - toxic forms of chemical constituents in aquatic systems. He pioneered in the combined integrated use of aquatic chemistry and aquatic toxicology in evaluating the water quality significance of chemical constituents. Work of this type is leading to more technically valid criteria and standards which focus on controlling toxic - available forms of contaminants.

Regulatory Experience

During the mid to late 1960's he served as an advisor to the state of Wisconsin on developing water quality standards that would protect aquatic life without unnecessary expenditures for contaminant control. While teaching at the University of Wisconsin-Madison where he developed and then directed the Water Chemistry graduate degree program, Dr. Lee conducted some of the first work ever done on fate and persistence of a variety of chemical constituents in various types of aquatic systems, including inland lakes, reservoirs, rivers, streams, the Great Lakes and coastal marine waters. During that time, through the mid-1970's he served as an advisor to the International Joint Commission for the US-Canadian Great Lakes in developing water quality objectives for the Great Lakes and their implementation. He was also an advisor to a number of industries, municipalities and various governmental agencies at the federal, state and local levels on water quality criteria and standards development and implementation. His pioneering work on PCB's in the 1960's led to his being selected to head the US Public Health Service committee on developing drinking water standards for PCB's.

Pesticide Experience
While teaching at the University of Wisconsin-Madison h**e** conducted extensive research on the fate and effects of pesticides. He was appointed secretary for the Technical Committee of the Pesticide Review Board for the state of Wisconsin. That committee was responsible for developing pesticide use regulations in the state which included the banning of the use of DDT. Wisconsin was the first state to pass such a ban. Drs. Lee and Jones-Lee have developed a comprehensive report for the State of California Water Resources Control Board on the occurrence of legacy pesticides such as DDT, chlordane, toxaphene etc that are accumulating in edible fish tissue to sufficient amounts to be hazardous to those who consume fish taken from California Central Valley waterbodies.

Consulting Experience with Large Chemical Companies
Beginning in the late 1970's he served as an advisor to a number of chemical companies such as Procter and Gamble Company, Monsanto and FMC in helping them evaluate procedures for determining the potential environmental impact of new or expanded-use chemicals on public health and the environment. This activity led to his serving as an advisor to the President's Council on Environmental Quality which formulated the initial version of the Toxic Substances Control Act.

Development of Water Quality Criteria
In the early 1970's he was selected as a peer reviewer for the National Academies of Science and Engineering "Blue Book" of Water Quality Criteria. He was asked in the mid-1970's to critique the US EPA's proposed adoption of the "Red Book" national water quality criteria. In the late 1970's he was appointed a member of the American Fisheries Society Water Quality Committee review panel that conducted an in-depth review of the July 1976 US EPA "Red Book" of Water Quality Criteria.

In the early 1980s he was selected as US EPA water quality criteria ("Gold Book") development approach and for several criterion (ammonia, copper) documents.

During the 1970's he continued to be active in assisting industry, municipalities and governmental agencies to review the impact of their point and non-point source discharges on domestic water supply and aquatic life-related water quality in specific waterbodies. At that time he held a position as a Professor of Engineering at the University of Texas-Dallas and was the Director of the Institute for Environmental Studies at UTD.

Development of Water Quality Hazard Assessment Approach
In the late 1970's as part of the work that he did while holding a Professorship in Civil and Environmental Engineering at Colorado State University he and Dr. Jones-Lee, in connection with work that they were doing for several Colorado Front Range cities (Fort Collins, Loveland, Colorado Springs and Pueblo), developed the hazard assessment approach for determining the hazard that a particular POTW (domestic wastewater) discharge containing certain chemical constituents represented to the designated beneficial uses of the receiving waters for that discharge. This hazard assessment work was the first time that such an approach had been applied to complex effluents and was

instrumental in causing the state and federal agencies to determine that their proposed discharge limits for several constituents in the POTW permits were excessively restrictive compared to what was needed to protect the designated beneficial uses of the receiving waters for the discharge.

The hazard assessment approach that was developed by Drs. Fred Lee, Anne Jones-Lee and their graduate students has evolved into what is now called ecological risk assessment. It is an integrated, tiered evaluation of the aquatic toxicology and aquatic chemistry for a group of constituents in a wastewater discharge as they may impact the designated beneficial uses of a waterbody. While initially both the Department of Health which regulated water quality in the state of Colorado and the US EPA indicated that they would not approve this approach, eventually when the technical validity and cost-effectiveness of the hazard assessment approach was realized by the state of Colorado, Drs. Lee and Jones-Lee were asked to work with the state in developing this approach as an approach that could be used to develop appropriate discharge limits for all NPDES permit holders in the state. A paper presenting the results of the initial work on aquatic life hazard assessment approaches which focused on the city of Pueblo's POTW discharge was presented in the proceedings of the ASTM Aquatic Toxicology symposium where it tied for first place as the best paper presented at the symposium.

Contaminated Sediment Issues

During the 1970's Dr. G. F. Lee conducted over $1 million in research for the US Army Corps of Engineers in developing dredged sediment disposal criteria. Since the late 1970's Drs. G. F. Lee and A. Jones-Lee have been highly active in developing sediment quality criteria and their implementation into programs designed to evaluate the water quality significance of chemical constituents associated with sediments and in developing technically valid, cost-effective approaches for remediation of sediments that contain excessive concentrations of available - toxic forms of chemical constituents. Recently they have been active in reviewing the approach that the state of California Water Resources Control Board has adopted to evaluate the impact of chemicals in aquatic sediments on the beneficial uses of waterbodies. The adopted approach can readily misevaluate the role of chemicals in aquatic sediments on water quality and lead to inappropriate limits of NPDES permitted discharges. Several reports on these issues is available on their website.

Full-Time Consulting

In 1989 Drs. G. F. Lee and A. Jones-Lee terminated their university teaching positions and began to expand the part-time private consulting that they had been doing while they were university professors into a full-time activity. At that time Dr. G. F. Lee held a Distinguished Professorship in Civil and Environmental Engineering at the New Jersey Institute of Technology. Dr. Anne Jones-Lee held the position of Associate Professor of Civil and Environmental Engineering at NJIT. Their consulting activities caused them to move to the Sacramento, CA area in 1989. Shortly after returning to California, they became involved in what ultimately became the April 1991 water quality objectives adopted by the State Board. They submitted extensive comments on the highly significant technical problems and inappropriate approaches that the State Board staff had proposed at that time for developing water quality objectives, including commenting on the lack of consideration of economic issues in developing these objectives. A copy of the comments provided to the State Board on these problems is available upon request. Many of the issues raised by Drs. G. F. Lee and A. Jones-Lee in 1990 and 1991 are still pertinent to developing technically valid approaches for formulating water quality objectives in the state.

National Toxics Rule

In November 1990 Drs. G. F. Lee and A. Jones-Lee provided extensive comments on the inappropriate approaches being proposed by the US EPA as part of developing the National Toxics Rule. As part of these comments they reviewed the evolution of national water quality criteria and their implementation into state standards. A copy of their comments on the US EPA's proposed National Toxics Rule is available upon request.

Mining Wastes

Dr. Lee has worked on evaluating the water quality impact of mining wastes and their management since the late 1960's. Extensive work has been done on mine waste tailings including acid production from sulfide-containing ores. He and Dr. Jones-Lee worked for the Port of San Diego in conducting a water quality and public health risk assessment for a copper ore concentrate spill in San Diego Bay. They demonstrated that the copper ore concentrate was inert in San Diego Bay sediments. They served a the US EPA Technical Assistance Grant advisor to the public on the adequacy of the US EPA investigation and remediation of the Lava Cap mine Superfund site located near Nevada, CA. Additional information on Drs. Lee and Jones-Lee's experience in environmental aspects of mining and mineral processing is available.

Stormwater Quality Runoff Water Quality Management

Dr. G. Fred Lee conducted one of the first studies on water quality impacts of urban stormwater runoff as part of the work that he did at the University of Wisconsin-Madison in the 1960's in the International Biological Program. In that Program he and his graduate students found that urban stormwater runoff contained high concentrations of a variety of constituents which have the potential to adversely impact designated beneficial uses of waters. However, substantial parts of these constituents were in forms that were non-toxic, non-available.

As part of the National Urban Runoff Program (NURP) studies conducted by the US EPA in the early 1980's, Drs. G. F. Lee and A. Jones-Lee conducted a number of studies on behalf of Fort Collins, Colorado and the City and County of Denver, Colorado in evaluating the impact of urban stormwater runoff on water quality in specific waterbodies of interest to them. It was at that time that Drs. Lee and Jones-Lee suggested that these cities should be conducting instream bioassays to determine what, if any, toxicity was associated with urban stormwater runoff derived from the Denver, Colorado area. The US EPA, Washington, D.C. managers of NURP however determined that it was inappropriate for cities to use funds derived from NURP in evaluating the impact of the urban stormwater-associated contaminants on receiving water quality. This eventually led to Drs. Lee and Jones-Lee publishing a paper in Civil Engineering questioning whether NURP would provide the information needed by water quality managers to determine how best to proceed to address real water quality problems associated with stormwater runoff. That discussion of these issues has proven to be correct in that NURP failed to provide the kind of information needed to evaluate the water quality significance of chemical constituents in urban stormwater runoff.

Over the past several years, Drs. Lee and Jones-Lee have published extensively on the problems with the way in which federal and state regulatory agencies are developing programs for evaluating the water quality impacts of urban stormwater-associated contaminants. Copies of their papers on these topics are available. Although the focus of this work is on urban stormwater runoff, they have direct applicability to industrial stormwater runoff as well as agricultural and rural non-point source runoff. They have developed papers on the inadequate approach that is used to monitor land manage stormwater runoff from municipal landfills. A listing of their papers and reports pertinent to evaluating non-point source-associated contaminant impacts is available upon request.

Drs. Lee and Jones-Lee are have assisted several clients in the Midwest on water quality issues, including a city in Indiana which was being sued by the US EPA for combined sewer overflow stormwater and wastewater discharges. They pointed out that the proposed approach for remediation of river to remove contaminated sediments will not be effective in improving the rivers water quality until the combined sewer overflows are controlled.

Beginning in the mid 1990s Drs. G. F. Lee and Anne J. Lee initiated an email based Stormwater Runoff Water Quality Newsletter that is distributed at about monthly intervals at no cost to over 9600 individuals. Past Newsletters are available on their website.

Heavy Metal Criteria and Standards

Drs. Lee and Jones-Lee have worked on the fate and effects of a variety of heavy metals in fresh and marine waters. Their work in this topic area resulted in his being an invited participant in the January 1993 heavy metal criteria workshop. It was this workshop that established the approach for establishing dissolved metals as the basis for regulating heavy metals in ambient waters. They have discussed the need to develop site specific water quality criteria for copper in New York Harbor and San Francisco Bay in order to properly regulate copper discharges from wastewater and urban and highway runoff. Subsequently studies have shown that the copper water quality criterion can be adjusted to more reliable reflect the toxicity of copper in these waters.

Groundwater Quality Protection and Management

Drs. G. F. Lee and A. Jones-Lee have many years of experience in evaluating the potential hazard that municipal solid waste and hazardous waste landfills represent to groundwater quality. They have presented over 15 short courses on this topic through several University of California Extensions, the American Society of Civil Engineers and the American Water Resources Association. They have developed a comprehensive report on the inadequate regulation of land surface activities such as disposal on land of municipal and industrial wastewaters, irrigated agriculture etc by State of California and its Regional Water Quality Boards that will lead to groundwater pollution.

Contaminated Soils

Drs. Lee and Jones-Lee have extensive experience in Superfund site investigation and remediation. This work includes evaluation of the public health hazard that chemical constitutes represent in soil to human health and to aquatic life. Particular emphasis has been devoted to the significance of lead residues in soils as they may impact the blood lead concentrations in children who play in the soil.

Regulating Irrigated Agriculture Stormwater Runoff/Discharges Water Quality Impacts

Drs. G. F. Lee and Anne J. Lee have been activity in providing guidance the approach that should be followed in regulating evaluating the potential water quality impacts of stormwater runoff and tail water discharges from irrigated agriculture as part of the State of California Irrigated Lands Agricultural Waiver water quality monitoring and management. An area of particular attentions is the management of aquatic plant nutrients that are derived from urban and agricultural sources the lead to excessive fertilization of waterbodies. Through the California Water and Environmental Modeling Forum they organized a day long workshop on excessive fertilization the Sacramento San Joaquin Delta.

Short-Courses, Presentations and Lectures

While Drs. G. F. Lee and A. Jones-Lee are no longer active in teaching in university graduate programs in environmental engineering and environmental science, they continue to be active in professional education activities through presenting short-courses in various areas in which they have expertise. They have developed short-courses in water quality criteria and standards development and implementation, urban stormwater impacts and their management, and sediment quality evaluation and sediment quality criteria development and implementation. These short-courses are made available at any location where a local sponsor will make arrangements for them.

Dr. Lee has been a frequent invited lecturer on water quality and solid and hazardous waste evaluation and management issues. For the 20 years he has been an American Chemical Society tour speaker in which he lectures on water quality issues to local ACS sections at various locations.

Drs. Lee and Jones-Lee are highly active in developing professional publications that are designed to inform other professionals on the approaches that should be used to develop water quality criteria, state water quality standards, NPDES discharge limits, waste load allocations, total maximum daily loads, watershed approach and pollutant trading. Condensed lists of recent publications in various topic areas is available from this site. A complete list of their papers and reports is available from Dr. Lee upon request.

Overall Approaches and Further Information

Drs. Anne Jones-Lee and G. Fred Lee are interested in establishing technically valid, cost-effective approaches for evaluating and managing chemical contaminants in aquatic systems. They are available to assist anyone in answering questions or providing guidance on how a particular issue should be addressed. A list of their past and current clients is available. If it is felt that they can be of assistance in addressing a particular problem, please contact Dr. Lee.

Dr. G. Fred Lee

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