Chemical Constituents vs. Water Quality

G. FRED LEE, Ph.D., P.E., D.E.E.
and
ANNE JONES-LEE, Ph.D.

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

Part One of this article discusses the problems with current stormwater runoff water quality monitoring programs and suggests the values of alternative monitoring approaches. Part Two will continue the discussion with specific examples from San Francisco Bay and Santa Monica Bay.

FEDERAL, state, and local regulatory agencies, counties, municipalities, other political jurisdictions, and industry, etc., are required to monitor stormwater runoff as part of NPDES stormwater runoff permits. The monitoring approach typically used today is to take a few grab samples of runoff from certain storms over the year and analyze certain chemical constituents in these samples. These data are then submitted periodically to the agency that administers the NPDES stormwater runoff permit. There is, however, growing realization that this type of monitoring program provides little, if any, useful information to the entity responsible for managing the stormwater runoff, the regulatory agency, or others on the impact of the stormwater runoff associated constituents on water quality.

The Engineering Foundation held a conference in August 1994 devoted to stormwater NPDES related monitoring needs[1]. Several of the papers [2] in the conference proceedings discuss the significant deficiencies in current stormwater runoff monitoring relative to providing reliable information that can evaluate the impact of chemical constituents and pathogenic organism indicators on the beneficial uses of the receiving waters for the runoff, that serve as a reliable basis for developing stormwater runoff water quality management BMPs, and that can determine the adequacy of a BMP in addressing real water quality issues associated with stormwater runoff. Presented herein is a discussion of the problems with current stormwater runoff water quality monitoring programs and suggestions for alternative monitoring approaches that will provide appropriate data upon which to evaluate the water quality impacts of stormwater runoff-associated constituents and to develop and evaluate the efficacy of BMPs to manage water quality problems associated with stormwater runoff.

It has been known since the 1960s that urban stormwater runoff typically contains elevated concentrations of various chemical constituents relative to federal and state water quality criteria and standards.[3] It has also been known since the 1960s that substantial parts of many of these constituents are in non-toxic, non-available forms; yet stormwater runoff monitoring programs typically measure total concentrations of certain constituents. While these programs (or expanded versions of them where more frequent monitoring takes place for a greater number of parameters at locations other than just the discharge point) are called water quality monitoring programs, a critical review of the data collected in such programs shows that they are chemical constituent monitoring programs with limited applicability to defining water quality issues.

The basic problem is that the current so-called water quality monitoring programs are an outgrowth of NPDES domestic and industrial wastewater compliance monitoring requirements, which have as their objective, determining whether the concentrations of a constituent in the wastewater discharge comply with NPDES discharge limits. An understanding of how these discharge limits are established shows that typically they tend to be highly over-restrictive compared to the allowable discharges that could take place without adversely impacting the designated beneficial uses of the receiving waters for the discharge. Compliance monitoring is a well known, highly unreliable approach for evaluating the water quality impact of chemical constituents in treated wastewaters and stormwater runoff.

Reliability of Monitoring

Chemical constituent monitoring as it is typically practiced, where certain chemical parameters are monitored in the discharge-runoff periodically for a period of time and the concentrations found are compared to water quality criteria or standards, does not provide reliable information about the water quality impacts/use impairments of the chemical constituents in the stormwater runoff in the receiving waters for the runoff. The approach adopted in stormwater runoff monitoring is patterned after the typical regulatory approach used in compliance monitoring for NPDES permits from point sources, such as municipal and industrial wastewaters. About all that can be said from such monitoring is that if the concentrations of chemical constituents in the discharge are less than the EPA water quality criteria and state standards equal to these criteria, then it is fairly certain that the constituents monitored are not responsible for water quality problems in the receiving waters for the discharge provided that they do not add sufficient quantities of the monitored parameters to the receiving waters which, combined with existing concentrations of chemical constituents in these waters, cause water quality impacts.

Typically today, POTWs and industrial wastewater dischargers are required to sufficiently treat the discharge so that exceedances of water quality standards at the edge of a mixing zone for the discharge do not occur. While this approach is protective, it frequently represents gross over-regulation of the discharge in which public and private funds are spent unnecessarily for chemical constituent control for constituents that are not adversely impacting the designated beneficial uses of the receiving waters for the discharge.

From a regulatory perspective, NPDES permitted discharges of municipal and industrial wastewaters should include an end-of-the-pipe monitoring compliance component. It is important however, not to confuse the need for compliance monitoring for NPDES permitted wastewater discharges with the monitoring requirements for urban area and highway stormwater runoff. The EPA's[4] urban and highway stormwater management program does not establish numeric limits for chemical constituents in stormwater runoff. Instead, the EPA has established a requirement of controlling pollutants in urban area and highway stormwater runoff to the maximum extent practicable using best management practices (BMPs). Pollutants are defined as those constituents that impair the designated beneficial uses of the receiving waters for the stormwater runoff. The domestic and industrial wastewater compliance monitoring approach is obviously not a reliable approach for determining compliance with EPA requirements for managing the water pollution caused by chemical constituents and pathogenic organisms in stormwater runoff.

The authors[5,6] have reviewed the basic chemical and toxicological characteristics of stormwater runoff that should be considered in evaluating its impact on receiving water quality. As they discuss, stormwater runoff from residential areas, commercial areas, and highways, as well as most other land uses, contains

various chemical constituents at concentrations above water quality standards. Many of these constituents, however, are present in particulate, non-toxic, non-available forms. This, coupled with the knowledge that the duration of exposure of organisms in receiving waters for urban stormwater runoff is usually short compared to those that are adverse to aquatic life, leads to the conclusion that true water quality monitoring of stormwater runoff must involve examining the impact of the runoff-associated constituents on the receiving waters' designated beneficial uses. Therefore, meaningful stormwater quality monitoring must have, as an important basic component, stormwater runoff receiving water water quality evaluation, and should more appropriately be called stormwater runoff water quality evaluation monitoring. Rather than calling stormwater runoff monitoring simply "monitoring," in this discussion the word "evaluation" is added to emphasize the need for information on evaluating the impacts of stormwater runoff.

Approaches for Monitoring

Stormwater runoff quality monitoring can take two significantly different approaches: discharge characterization with estimation of impact or direct measurement of impact (evaluation monitoring).

Discharge Characterization. In discharge characterization monitoring, samples are obtained from end-of-the-pipe discharge sampling of stormwater runoff for a set of chemical constituents, such as heavy metals, selected organics, nutrients, etc., that are either indicators or direct constituents of concern in traditional water pollution control programs. The focus of this discharge characterization is, primarily, chemical constituents. This type of monitoring is now frequently being expanded to include some biological response characteristics of the discharge such as toxicity testing. While this approach is characterized as a water quality discharge characterization approach, in fact, it falls far short of characterizing the discharge with respect to determining the impact or even potential impact of the stormwater runoff-associated chemical constituents in causing pollution/use impairment of the receiving waters.

Pollution is defined by federal and state statutes and regulations as the impairment of the designated beneficial uses of the receiving waters for the stormwater runoff discharge. Therefore, for a chemical constituent in stormwater runoff to be a pollutant and require control according to state and federal regulations, the constituent and, for that matter, toxicity must adversely impact the designated beneficial uses of receiving waters for the stormwater runoff. It is the authors' experience that it will indeed be rare that that situation occurs.

This traditional chemical constituent monitoring basically only provides more data of the type that have been generated since the 1960s and then in the 1970s and 1980s by the EPA as part of the National Urban Runoff Program (NURP), which show that urban stormwater runoff from residential and commercial areas contains a wide variety of chemical constituents that are in the discharge above water quality criteria and standards. The EPA NURP studies however, failed to provide the information needed to determine whether the elevated concentrations of chemical constituents found in urban stormwater runoff are causing real water quality use impairments in the receiving waters for the runoff.[7] Fundamentally, the NURP studies failed to address real water quality issues upon which to develop a national program for stormwater runoff water quality management.

Further, the NURP approach has led to the EPA's and the states' now unreliably reporting to Congress the magnitude of the urban stormwater-caused water quality impairment of the nation's waters.[8] It is important to clearly distinguish between "chemical constituent" and "pollutant" through the appropriate use of aquatic chemistry and aquatic toxicology that is developed on a site-specific basis for stormwater runoff impact on water quality assessment. The unreliable reporting by the EPA of the current status of national water quality and the causes for impairment has led Congress to believe that urban stormwater runoff is a much greater cause of water quality impairment in the nation's waters than is actually occurring.

With the addition of toxicity testing to the stormwater runoff discharge testing, the discharge characterization that is being done shows that many stormwater discharges have aquatic life toxicity in the discharge, as measured by standard testing procedures. This toxicity is of potential concern. The toxicity being found in urban stormwater runoff in many areas is related to the use of diazinon on home and commercial properties for insect control and from its use by agricultural interests as a dormant spray in orchards and for other purposes. Connor[9] has found that part of the applied diazinon becomes airborne and is incorporated in precipitation, causing wide-spread aquatic life toxicity in runoff waters at considerable distances from where the diazinon was applied. Similar problems are being found with other organophosphorus pesticides, such as chlorpyrifos.

Finding the concentration of a potentially toxic constituent in urban stormwater runoff above the EPA water quality criterion only indicates that there is a potential for aquatic life toxicity near the point where the stormwater runoff enters the receiving waters. No information is provided, however, in the toxicity test results on whether the potentially toxic chemical constituent is, in fact, toxic in the receiving waters to a sufficient extent and degree to significantly adversely impact aquatic life-related beneficial uses of these waters.

Similarly, finding aquatic life toxicity in stormwater runoff should not be interpreted to mean that this toxicity will persist for a sufficient extent and duration to be significantly adverse to aquatic life in the receiving waters for the stormwater runoff. About all that can be said with respect to the potential significance of the stormwater runoff is that the stormwater runoff is toxic at the point of measurement in accord with the test conditions used. This should not be used to infer that significant impairment of the beneficial uses of the receiving waters are occurring because of the toxicity.

For both the chemical measurement and the toxicity measurement approaches, site-specific receiving water analysis studies have to be conducted to determine whether the potential toxicity for chemical measurements or measured toxicity for toxicity measurements are, in fact, adverse to the receiving waters for the stormwater runoff. This will require site-specific evaluation.

The studies of Kuivila and Foe[10] on the fate and persistence of diazinon-caused aquatic life toxicity show that shortly after diazinon was applied as a dormant spray to orchards in Northern California, major pulses of aquatic life toxicity that ranged over many miles occurred in the Sacramento/San Joaquin River Delta lasting for several weeks. These toxicity pulses, which matched the pulses of diazinon found in the same water, were acutely toxic to some forms of aquatic life that are important components of larval fish food. In this case, there is no question that the stormwater runoff derived diazinon caused highly significant aquatic life toxicity in the receiving waters for the runoff.

Evaluation Monitoring. The other approach to stormwater runoff water quality monitoring is water quality problem definition oriented. In the water quality problem evaluation monitoring approach, rather than focusing on a routine monitoring of a suite of chemical constituents in the discharge and then trying to estimate toxicity or other adverse impacts in the receiving waters for the stormwater runoff-associated constituents, the focal point of the evaluation monitoring program is the receiving waters for the discharge. Sometimes, a shotgun approach for stormwater monitoring of the receiving waters is used in which various chemical and biological parameters are measured in the receiving wate for the stormwater discharge for a fixe period of time, usually one or two years. At the end of the data collection period, an attempt is made to draw water quality inference about the stormwater discharge impacts on the receiving waters.

Such programs are easy to administer and execute by individuals with limited understanding of water quality issues and their proper definition.

The shotgun receiving water monitoring approach is often expensive and frequently leads to the generation of data that do not provide definitive answers on the water quality impacts of the stormwater runoff. A number of point source discharge receiving water water quality monitoring programs have been conducted in which hundreds of thousands to millions of dollars have been spent, yet have provided little in the way of useful data to define the impact of the point source discharges on the receiving water quality. This experience causes those responsible for stormwater quality management programs to be reluctant to become involved in receiving water evaluation monitoring for stormwater impacts. One area of great concern to stormwater quality managers in conducting such a program is how to distinguish impacts from other non-point and point source discharges from those of the urban stormwater discharge. This issue must be reliably addressed in any receiving water monitoring program.

An approach that has been successful in evaluating water quality impacts of point source discharges with direct applicability to technically valid, cost-effective evaluation of the water quality impacts of urban and highway stormwater runoff discharges is the highly directed, "intelligent" water quality problem oriented "evaluation monitoring." As discussed by Lee and Jones-Lee[11], this monitoring focuses on particular discharge events in which the initial phase of the monitoring is devoted to defining whether there is a real water quality problem use impairment in the receiving waters associated with the discharge, irrespective of the source of the chemical constituent responsible for causing the problem.

For example, are the receiving waters for the stormwater discharge toxic for a sufficient extent and duration to be adverse to desirable forms of aquatic life in the receiving waters? Obviously, if no toxicity is found in the receiving waters within a short distance of the stormwater discharge using appropriately sensitive aquatic organisms and appropriate durations for conducting the toxicity test, then it is possible to conclude that the stormwater discharge associated constituents that are of concern because of their potential toxicity are not pollutants, i.e., do not impair the uses of the receiving waters for the discharge and therefore, do not require control under the current EPA stormwater runoff water quality management program.

As mentioned above, it is important in these programs to not assume that because toxicity is present in a stormwater runoff discharge that this toxicity manifests itself as a use impairment in the receiving waters. The toxicity tests that are typically used today to evaluate toxicity greatly exaggerate the real toxicity that will occur in receiving waters from stormwater discharge. As discussed by the authors[3,12], the duration of exposure of aquatic organisms in the toxicity test often greatly exceeds the duration of exposure that an organism in the ambient waters can receive from a stormwater discharge.

Similarly, it is important not to assume that because the concentrations of a chemical constituent in a discharge exceed water quality standards, this represents an impairment of the designated beneficial uses of the receiving waters. From a technical perspective, such exceedances should only be used as triggers of potential problems that need further evaluation before initiating programs for chemical constituent control. The issue of the technically appropriate approach to use in evaluating the water quality significance of an exceedance of an EPA water quality criterion or state standard has been reviewed[3,13]. As the authors discuss, the EPA's current Independent Applicability Policy, which requires the control of potentially toxic chemicals even if they are found to be non-toxic in a receiving water, is technically invalid and wasteful of public and private funds that could be more appropriately used to control real water quality problems.[14]

In the problem definition evaluation monitoring approach a suite of sensitive organisms are used to measure ambient water toxicity at various locations in the receiving waters within and outside the plume associated with the stormwater discharge. In waterbodies in which the stormwaters do not completely mix within a short time within the waterbody it is necessary to define the plume of toxicity within the receiving water. Usually, it is simple to find where stormwater runoff has been mixed with the receiving waters through measurements of temperature, specific conductance, or other easily measured parameters. Further, it is possible to define, based on ambient water measurements of conservative (non-reactive) parameters, such as sodium, chloride, etc., the degree of dilution that has occurred within the receiving waters for the discharge at various locations within the plume.

By first focusing the monitoring program on the receiving waters and asking whether there is a potential toxic effect in the receiving waters associated with the stormwater discharge, it is then possible to screen for an integrated impact of all regulated and unregulated potentially toxic constituents in the discharge without the large-scale expenditures associated with the typical stormwater monitoring approach.

If there is toxicity in the receiving waters associated with the stormwater discharge that could be adverse to aquatic life-related beneficial uses, i.e. impact the numbers, types, and characteristics of the desirable forms of organisms in the receiving waters, due to a measured toxicity in the receiving waters that persists sufficiently to exhibit real toxicity to aquatic life, then the monitoring program shifts to focusing on the cause of this toxicity in a toxicity investigation evaluation (TIE). TIE investigative techniques have been developed sufficiently well today so that it is usually relatively simple to screen out whether a toxicity is due to heavy metals, certain types of organics, etc.

Once the cause of significant toxicity in the receiving waters has been defined, it is then possible to develop a BMP that will, in fact, control the use impairment that results from the stormwater discharge. This BMP will almost certainly be significantly different than any of the structural BMPs which are being developed today based primarily on hydraulic considerations that fail to consider that constituents removed in these detention basins, many grassy swales, etc. are nontoxic, non-available. The authors[15] have recently discussed the use of detention basins for control of constituents in stormwater runoff. They point out that detention basins are not effective in controlling chemical constituents in stormwater runoff that are potentially toxic to aquatic life. The EPA[16], as part of the implementation of the National Toxics Rule, has determined that the dissolved forms of most heavy metals are the forms that should be regulated. Since dissolved forms of heavy metals are not removed in a typical detention basin, such basins are not, in fact, a BMP for heavy metals in stormwater runoff.

Obviously, the BMP that should be considered first in urban and highway stormwater runoff is constituent control at the source. For example, if diazinon is found to be a cause of real use impairment in receiving waters, the appropriate BMP is restriction of its use on lawns, yards, or other places where wash-off from the treated area leads to adverse impacts in receiving waters. With respect to diazinon use as a dormant spray in orchards where the airborne transport and runoff from such areas causes widespread toxicity to aquatic life, restrictions should be placed on its use to prevent this toxicity.

The authors[11,17] have provided general guidance on how the evaluation monitoring program can be used to address the potential water quality problems caused by chemical constituents in urban and highway stormwater runoff. These include aquatic life toxicity to water column organisms, impairment of domestic water supply water quality, excessive bioaccumulation of hazardous chemicals, sediment toxicity, eutrophication-excessive fertilization, sanitary quality that impairs contact recreation and shellfish harvesting, oil and grease accu-

mulation, dissolved oxygen depletion, litter accumulation, and sediment accumulation. For example, if measurements of aquatic organism tissue levels of bioaccumulated chemicals show that the organisms potentially influenced by the stormwater discharge do not have excessive concentrations of bioaccumulatable chemicals compared to those not influenced by the discharge, then it is possible to rule out the stormwater discharge being a significant contributor to bioaccumulation in the receiving waters.

The evaluation monitoring program does not involve massive, routine monitoring of stormwater runoff or receiving waters. Instead, through a careful consideration of aquatic toxicology, aquatic chemistry, and the hydraulic characteristics of the discharge and the receiving waters, it is possible to define with a high degree of reliability and with limited expenditures whether the stormwater discharge is having a potentially significant impact on receiving water quality.

While some characterize this type of a monitoring program as a research project, this is inappropriate. Basically, to those who understand water quality, aquatic chemistry, aquatic biology, and the transport and fate of chemical constituents in receiving waters from any source, this is a simple, common-sense approach to defining whether there is a real water quality problem in the receiving waters associated with the stormwater discharge.

It is important to note that this approach focuses on near-field (near the point of discharge) impacts, which in most cases is the area of greatest concern. There are far-field waterbody-wide impacts that have to be considered as well where the stormwater discharge could significantly contribute to adverse impacts. Often these types of problems are more difficult to define and best addressed through carefully coordinated studies conducted by all potential contributors to the problem, i.e. point and non-point source dischargers to a particular waterbody in a watershed-based approach. □□□

References

1. Torno, H. C., *Stormwater NPDES Related Monitoring Needs*, Proceedings, Engineering Foundation Conference, American Society of Civil Engineers, New York, NY (1994).

2. Lee, G. F., and Jones-Lee, A., "Deficiencies in Stormwater Quality Monitoring," IN: Proc. of an Engineering Foundation Conference, American Society of Civil Engineers, New York, NY pp 651-662 (1994).

3. Lee, G. F. and Jones, R. A., "Suggested Approach for Assessing Water Quality Impacts of Urban Stormwater Drainage," In: Symposium Proceedings on Urban Hydrology, American Water Resources Association Symposium, November 1990, AWRA Technical Publication Series TPS-91-4, AWRA, Bethesda, MD, 139-151 (1991).

4. US EPA, "National Pollutant Discharge Elimination System Permit Application Regulations for Stormwater Discharges; Final Rule," 40 CFR Parts 122, 123, and 124, *Federal Register* 55(222):47990-48091, November (1990).

5. Lee, G. F., and Jones-Lee, A., "Stormwater Runoff Management: Are Real Water Quality Problems Being Addressed by Current Structural Best Management Practices? Part 1," Public Works, 125:53-57,70-72 (1994).

6. Lee, G. F. and Jones-Lee, A., "Appropriate Use of Numeric Chemical Water Quality Criteria," Health and Ecological Risk Assessment, 1:5-11 (1995).

7. Lee, G. F. and Jones, R. A., "Will EPA's Nationwide Urban Runoff Study Achieve Useful Results?" Civil Engineering 51:86-87 (1981).

8. Lee, G. F., and Jones-Lee, A., "Unreliable Reporting of Water Quality Impairment by the US EPA's National Water Quality Inventory," Submitted to the Journal of Water Environment and Technology, Water Environment Federation, February (1996).

9. Connor, V., "Diazinon as a Cause of Stormwater Runoff Toxicity," Presentation to the California Stormwater Quality Task Force, Burbank, CA, Central Valley Regional Water Quality Control Board, Sacramento, CA, May (1995).

10. Kuivila, K.M., and Foe, C.G., "Concentrations, Transport and Biological Effects of Dormant Spray Pesticides in the San Francisco Estuary, California," Environmental Toxicology and Chemistry 14(7): 1141-1150, (1995).

11. Lee, G. F. and Jones-Lee, A., "Assessing Water Quality Impacts of Stormwater Runoff," Proc. ASCE North American Water and Environment Congress, Anaheim, CA June (1996).

12. Lee, G. F. and Jones-Lee, A., "Water Quality Impacts of Stormwater-Associated Contaminants: Focus on Real Problems - Condensed Version," Proc. Specialized Conference on Diffuse Pollution: Sources. Prevention, Impact and Abatement, International Water Quality Association, London, England, pp. 231-240, September (1993).

13. Lee, G. F., and Jones-Lee, A., "Stormwater Runoff Management: Are Real Water Quality Problems Being Addressed by Current Structural Best Management Practices? Part 2," Public Works, 126:54-56 (1995).

14. Lee, G. F. and Jones-Lee, A., "Independent Applicability of Chemical and Biological Criteria/Standards and Effluent Toxicity Testing," The National Environmental Journal, 5(1):6063, (1995), Part II, "An Alternative Approach," 5(2): 66-67 (1995).

15. Lee, G. F. and Jones-Lee, A., "Evaluation of the Water Quality Significance of Eroded Suspended Sediment-Associated Constituents," Land and Water, 40:19-23 (1996).

16. US EPA, "Stay of Federal Water Quality Criteria for Metals; Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance—Revision of Metals Criteria; Final Rules," *Federal Register*, Vol. 60., No. 86, pp. 22228-22237, May 4 (1995).

17. Lee, G. F. and Jones-Lee, A., "Evaluation Monitoring for Stormwater Runoff Monitoring and BMP Development," Report of G. Fred Lee & Associates, El Macero, CA (1996).