Chemical Constituents vs. Water Quality

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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 waters for the stormwater discharge for a fixed 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 non-toxic, 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 accumulation, 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. □□□

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

THE copper situation in San Francisco Bay provides an excellent example of the relative merits of the highly directed evaluation monitoring program designed to identify real problems vs. the traditional monitoring program focusing on chemical constituents. A number of the stormwater dischargers to San Francisco Bay have conducted one- to several-year studies of the various discharges to the Bay, which cost many tens of thousands to $100,000 or more. In these studies, the traditional approach of monitoring a suite of parameters in the discharge waters and some of the source waters to the discharge were conducted. While large amounts of data on the chemical characteristics of the stormwater discharge waters were generated by this approach, such an approach provides no useful information on water quality impacts that were not available before the study was conducted.

It was known before the studies were conducted that runoff from urban areas and highways in the San Francisco Bay region have a variety of chemical constituent concentrations above water quality standards. Whether these exceedances of the standards, however, represent a real use impairment that affects the numbers, types, and characteristics of aquatic organisms in the Bay has not been determined by these types of studies. Further, while as discussed previously these are often called stormwater runoff discharge characterization studies, they fall far short of properly characterizing the discharge, since the purpose of discharge characterization is to find pollutants. These studies define chemical constituent concentrations and do not define pollutants, i.e. those constituents that do, in fact, impair the designated beneficial uses of the receiving waters for a particular discharge on a site-specific basis.

It is totally inappropriate to use the approach that is often done by those not knowledgeable in aquatic chemistry, aquatic toxicology, and water quality of assuming that because copper from some source, such as a plating waste, is toxic to aquatic life in some waterbody and is therefore adverse to the beneficial uses of that waterbody, then all copper from all sources is adverse to the designated beneficial uses of all waterbodies. Such an approach is similar to characterizing all people with red hair as having certain personality traits. It is obviously technically invalid.

Another example of the relative merits of the evaluation monitoring approach for monitoring stormwater impacts is provided by San Francisco Bay. As noted above, the large-scale studies conducted by a number of stormwater dischargers on the characteristics of the stormwater discharges to San Francisco Bay, while determining to some extent the amounts of copper and other constituents entering the Bay, provided no information on the impact of these constituents on the beneficial uses of the Bay waters.

By focusing on defining Bay water quality problems, first through the use of toxicity measurements on ambient waters, it has been shown that there is no toxicity in San Francisco Bay waters due to all constituents derived from stormwater runoff and other sources. Therefore, copper and all other constituents are not causing a toxicity problem in San Francisco Bay, and there is no technically valid need based on current information to control copper inputs from urban stormwater runoff as well as other sources to the Bay because of the exceedances of the water quality objectives for copper in the Bay waters.

Some recent data generated on the northern part of San Francisco Bay show that there may, in fact, be a toxicity problem due to pesticide runoff. This is an area where the evaluation monitoring approach could help determine whether this is a potentially significant problem. If significant, the specific cause of the problem and the source responsible for contributing the toxicants can be identified. At that point, specific source controls can be initiated to prevent this problem from occurring in the Bay and its tributaries.

It would have been far more technically valid and cost-effective to screen San Francisco Bay waters for toxicity problems first and then, if found, identify the cause of the problems, than the approach that has been followed and is going on today to collect in routine monitoring programs large amounts of data on stormwater discharge characteristics that focus on chemical constituents rather than water quality issues.

Santa Monica Bay Studies

The deficiencies of the mechanical, unintelligent, traditional monitoring approach can also be demonstrated by the situation that has developed in the Santa Monica Bay Restoration Project where in September 1994 the management of that project, which included local, regional, and state agencies and the EPA, committed the public to spending $40 million over the next five years to implement structural BMPs for control of chemical constituents, principally heavy metals, in stormwater runoff from the Santa Monica Bay watershed.

A review of the technical base for this so-called restoration program shows that the traditional monitoring approach was used where the total concentrations of chemical constituents and the stormwater flows from the Santa Monica Bay watershed were used to develop a mass load of heavy metals and a few other constituents of potential concern into the Bay.1 Since the heavy metals are conservative and are largely associated with particulates, these metals settle in the Bay waters and become part of the sediments, resulting in elevated concentrations of heavy metals in the sediments compared to areas that are not impacted by runoff from the Santa Monica Bay watershed.

It was assumed, based on fundamentally flawed principles, that because elevated concentrations of certain heavy metals that are present in stormwater runoff from streets and highways accumulated in the sediments of Santa Monica Bay, this must represent a significant adverse impact on Santa Monica Bay's designated beneficial uses through these heavy metals being toxic to aquatic life. However, no toxicity measurements were made before committing the public to the $40-million restoration program to verify that toxicity was even present in the sediments, and if present that it was due to heavy metals, and if due to heavy metals that these heavy metals were derived from current urban stormwater inputs to the Bay.

Rather than spending large amounts of money, as was done in the Santa Monica Bay Restoration Project, on defining the amounts of the mass loads of heavy metals and a few other constituents

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entering Santa Monica Bay, the focal point of an intelligent monitoring program would have been to determine whether there is a real water quality problem in Santa Monica Bay due to current inputs of constituents from all sources. Is there toxicity in the Bay water column and/or is there toxicity in the Bay sediments? These are the questions that should have been asked first. If toxicity is found in either the water column or sediments, is this toxicity of significance to the beneficial uses of the Bay? If it is found to be of significance to beneficial uses of the Bay, what is the cause of the toxicity? If it is due to heavy metals, are these heavy metals derived from current urban stormwater runoff to the Bay? If it is found that current heavy metal inputs from stormwater runoff are causing toxicity in the receiving water sediments, then what is the specific source of the toxic heavy metals that have ultimately accumulated in the sediments?

It is totally inappropriate to assume that all sources of copper result in the same toxicity in sediments independent of the source. Copper from Mercedes brakepads that will accumulate in Santa Monica Bay sediments will likely have significantly different toxicity to aquatic life than copper derived from its use in a sewer to control excessive root growth within the sewer which tends to plug up the sewer. Both will be contributed to Santa Monica Bay—one through the wastewater discharges, the other through stormwater runoff.

The approach used in the Santa Monica Bay Restoration Project for developing the basis for defining a stormwater runoff-associated water quality problem is rapidly becoming recognized as a highly technically invalid approach that has a high probability of resulting in massive waste of public and private funds in developing structural BMPs to achieve an ill-conceived mass load emission strategy for heavy metals from the Santa Monica Bay watershed. This ill-conceived approach arose out of failing to conduct a reliable stormwater runoff water quality evaluation monitoring program.

Mechanical vs. Intelligent

Basically, the development of a monitoring program for stormwater runoff that focuses on water quality through periodic measurement of chemical constituents comes down to choosing between a mechanically implemented approach, which is the approach typically followed today, vs. an intelligent monitoring program, which focuses on first defining a real water quality problem independent of the source and then when found, using the limited monitoring resources available to focus on finding the role that stormwater dischargers of constituents play in causing the problem. This is followed by focusing the monitoring program on defining and controlling the cause of the problem.

While some will correctly claim that the approach advocated does not define all possible problems, especially the very subtle problems associated with yet unidentified, unregulated chemical constituents that are not manifested in toxicity to the sensitive forms of aquatic life used to establish the water quality criteria exceedances in the stormwater discharges of concern, this approach does focus resources on defining the most important causes of the use impairment, and can, if properly carried out, provide the biggest bang for the buck in terms of solving real use impairments in the receiving waters for the discharge. By allocating small amounts of funds for ongoing studies to identify more subtle problems associated with any major discharge, it is possible through these ongoing water quality problem definition studies to refine the initial studies to include some more subtle effects associated with stormwater discharges. The more subtle effects may be due to unrecognized problems that may be found but not yet identified, or due to the introduction of new chemicals into the urban environment, such as a new pesticide or herbicide used on lawns, a new additive to gasoline, a new material incorporated into brakepads that would replace copper that somebody considered was adverse to receiving water quality because it was simply copper without considering its speciation and whether it was toxic-available or not, etc.

As proposed, the evaluation monitoring program should define and rank the significance of all potential water quality use impairments of a waterbody that receives stormwater runoff from a particular source. This should be a cooperative program between the stormwater dischargers, the water quality regulatory agencies, the public, and others interested in water quality in a particular waterbody. It should be repeated for each of the types of water quality use impairments at least once each NPDES permit period (five years).

The problem definition evaluation monitoring studies should be conducted in a tiered hazard assessment approach in which through an integrated use of aquatic chemistry, which includes transport-fate and aquatic toxicology information, it is possible to define to various degrees of each tier whether a potentially significant water quality problem exists or not, associated with a stormwater discharge. Many problems can be eliminated from further consideration at the early tiers and thereby greatly reduce the cost to the public of conducting the monitoring program. It is important to emphasize that the focus of these efforts is to define the most significant impacts of stormwater discharges first and control these while continuing to provide funds to try to find more subtle impacts which, if they are found, can then be addressed in a similar manner. This approach is a far more technically valid, cost-effective approach for the use of public and private funds in developing stormwater quality programs than those typically being followed today.

Funding Evaluation Monitoring

There is increasing recognition that funds currently being used for end-of-the-pipe pavement, property monitoring of stormwater runoff should be shifted at least in part, if not totally, to evaluating the impact of the stormwater runoff on receiving water quality. It is recommended that stormwater quality managers and regulatory agencies work together in funding the evaluation of the impact of stormwater runoff-associated constituents on the receiving waters' beneficial uses. In situations where there are multiple NPDES stormwater-permitted dischargers to a particular storm sewer system, including industrial and commercial sources, each of the permitted dischargers should work with the regulatory agencies and the public in pooling the financial resources available to define, on a site-specific basis, the significant water quality problems caused by a stormwater runoff. This approach will lead to a far more technically valid, cost-effective control of real water quality problems caused by urban area and highway stormwater runoff than is being achieved today.

There is also need to expand the regulated stormwater community to include smaller communities and especially agricultural and forest interests. All entities contributing stormwater runoff should be responsible for defining the water quality impacts of the constituents in the runoff on the beneficial uses of the waters in a particular watershed. The evaluation monitoring approach is particularly useful for implementing a technically valid, cost-effective watershed management approach for water pollution control.

Active vs. Passive

The authors[2] have discussed the relative merits of what they call active vs. passive water quality monitoring. The traditional approach of water quality monitoring involves the periodic sampling of the discharge and/or receiving waters where each sample is analyzed for a suite of parameters for a fixed period of time. At the end of this period an attempt is made to develop inference about water quality issues from the data set. This approach is the passive approach which often proves to yield information of non-definitive and sometimes highly questionable quality. In the Lee and Jones active water quality monitoring program, the data are examined as they are collected to evaluate their reliability and to ascertain to the extent possible the real

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water quality information available in the data.

In the active approach, the water quality evaluation monitoring program is an evolving program that is adjusted to match the characteristics of the system being studied. As discussed by the authors[3], the characteristics of the system being monitored should be sufficiently well understood so that the monitoring program is specifically tailored to investigate those parameters likely to cause water quality impairment. While a periodic monitoring program that is either time or event driven can serve as a backbone for the active monitoring program, often special-purpose, highly specific, short-term studies are key components of the active program to further investigate within a short period after a data collection event shows a potential impact that needs to be further defined. The active water quality monitoring program is in accord with the recommendations of the National Research Council review panel devoted to developing guidance on assessing water quality problems.[4]

The authors[2,3] recommend that an active monitoring program be used where the overall program design is formulated to match the variability and characteristics of the system being studied. Further, the data are analyzed as they are being collected for consistency, reliability, and information on water quality issues. The sampling program is adjusted to take into account the new information that is gathered through the studies.

Source Identification

One component of stormwater runoff water quality evaluation monitoring that needs attention is the identification of pollutant sources. The typical approach today in such monitoring is the shotgun approach, in which a wide variety of chemical constituents are measured at various locations in a stormwater runoff discharge watershed to attempt to determine what specific activities or entities within the watershed are responsible for the pollutants found in the discharge. While not addressed by this type of monitoring, obviously the first step in a technically valid pollutant identification monitoring program is identifying the real pollutants that are adversely impacting the designated beneficial uses of the receiving waters for the stormwater runoff.

The shotgun approach for pollutant source identification is usually highly wasteful of public and private funds and often not reliable. About all that can be said of such programs is that a constituent of concern, such as copper, is derived from various sources to certain degrees. However, no information is provided as to whether copper is, in fact, a real pollutant and most importantly, what source is responsible for that part of the copper that causes the pollution-use impairment in the receiving waters for the stormwater runoff. It is certainly highly inappropriate to assume, as is often done, that all copper from all sources is equally adverse to the designated beneficial uses of a waterbody. Such an approach ignores the aquatic chemistry and toxicology of copper that are important in determining the extent that copper impacts the designated beneficial use of the waterbodies.

In the evaluation monitoring approach, once a specific water quality problem has been identified it is then possible through combining selected chemical, toxicological, and other measurements, such as aquatic life toxicity for potentially toxic chemicals, to use a forensic study program to specifically identify the source(s) of the chemicals causing the water quality use impairment. Based on this identification, site-specific BMPs can be developed to control the constituents of concern at the source in the most technically valid, cost-effective manner. This issue is discussed further in the reviews by Lee and Jones-Lee.[5]

Monitoring Hazardous Waste

Stormwater quality management agencies are finding that they must consider the management of stormwater runoff-associated residues, particularly sediment solids that accumulate within the stormwater treatment or runoff conveyance system. Environmental activist groups such as NRDC are asking the courts to force stormwater management agencies, such as highway departments, to undertake highly expensive removal of particulates that accumulate in stormwater inlet structures because these particulates are classified as "hazardous waste." There is a general lack of understanding of the basis for such classification and the relationship between classification of a settled solid associated with highway and street runoff as a hazardous waste and the impact of that solid on water quality in the receiving waters for the runoff. The classification of a solid material as a hazardous waste may not, and frequently does not, mean that the chemicals associated with the solid are hazardous to aquatic life.

The chemicals associated with solids-particulates are generally recognized as being nonhazardous to aquatic life. To be hazardous to aquatic life it is necessary that the chemical constituents associated with the solids are released from the solid, i.e. dissolved. A key factor controlling the dissolution of chemical constituents from solids is pH. More acidic conditions tend to promote greater dissolution. The hazardous waste definitions used at the federal and state levels are designed to mimic the acid conditions that occur in municipal landfills and use testing procedures that involve far more acidic conditions than the solids in the stormwater runoff will normally encounter in the receiving waters for the runoff. This is especially true for stormwater discharges to marine waters. Therefore, even if stormwater-associated particulates are classified as a hazardous waste based on municipal solid waste-based leaching tests, this does not mean that the chemical constituents will be adverse to aquatic life in receiving waters for the stormwater runoff.

California, under Title 22, is one of the few states that in addition to classifying hazardous waste based on its expected behavior in a municipal solid waste landfill through the use of an acidic leaching test, also classifies hazardous waste based on the total content of constituents. This approach is of highly questionable validity since it does not properly consider the environmental chemistry and toxicology of the constituents associated with the solid material. This could lead to highly arbitrary, very expensive management approaches for stormwater-associated contaminants that accumulate in detention basins, stormwater conveyance structures, etc.

The best defense for a stormwater management entity to follow in protecting itself and those it represents against inappropriate actions that assert that solid associated contaminants are a hazardous waste and therefore must be hazardous to aquatic life in the receiving waters for the stormwater runoff is to conduct problem definition focused stormwater runoff evaluation monitoring. By demonstrating that there are no real water quality problems associated with the particulates in the stormwater runoff in the receiving waters for the runoff, it would be possible to avoid the waste of public and private funds in unnecessary management of stormwater runoff-associated particulate constituents that accumulate in the stormwater conveyance system. Site-specific studies can be highly cost-effective in assisting the stormwater management entity in focusing its limited resources in developing control programs that address real water quality problems rather than those that arise out of the inappropriate use of hazardous waste definitions.

Effectiveness of BMPs

Stormwater management entities are being required to develop monitoring programs to evaluate the effectiveness of the BMPs that are implemented to control stormwater pollution. The typical approaches used today in this area focus on chemical constituent monitoring and are frequently expensive since a wide variety of chemical constituents are measured periodically. This is more of the shotgun approach that ignores how chemical constituents in stormwater runoff impact the designated beneficial uses for the runoff. As discussed by the authors[5,6], the development of a best management practice to control stormwater-caused pollution of a waterbody requires, as the first step, defining the pollutant(s) in the stormwater runoff. It is certainly inappropriate to assume that a stormwater detention basin, grassy swale, etc. is, in fact, removing pollutants. Such "BMPs" remove chemical constituents that in most situations are not pollutants.

It is evident that the development of a technically valid, cost-effective monitoring program for BMP efficacy must be based on a proper definition of pollutants and focus on how the BMP influences the beneficial uses of the receiving waters for the stormwater runoff. Without a reliable definition of pollutants, the monitoring program will likely be a waste of public and private funds and serve only the purpose of developing file cabinet fodder that meets the regulatory requirements for some type of monitoring program, but has little or no relevance to real issues of concern in evaluating the efficacy of the BMP.

Recommended Approach

The most cost-effective, technically valid approach for defining water quality impacts of potentially toxic chemical constituents in stormwater runoff is to focus on defining a problem in the receiving waters that could in some way be attributable to stormwater runoff-associated constituents. There are basically two types of problems of concern. One is toxicity to aquatic life, which adversely affects the numbers, types, and characteristics of the desirable aquatic organisms in the receiving waters for the stormwater runoff, and the other is excessive bioaccumulation of chemicals that are potentially toxic to higher trophic levels that use aquatic organisms that have accumulated constituents from the water as a source of food. A higher-level-trophic organism can be man, where the concern is carcinogens such as from chlorinated hydrocarbon pesticides, PCBs, dioxins, PAHs, etc.

While the EPA and others somewhat arbitrarily attempt to distinguish between monitoring for assessment of impact and characterization of stormwater discharge, such a distinction is inappropriate. There is no point in chemically characterizing a stormwater discharge from urban area and highway runoff, as is typically done today. The chemical characteristics of these discharges are well known. A proper discharge characterization must include impact evaluation since the purpose of discharge characterization is the definition of pollutants, i.e. those constituents that on a site-specific basis impair the designated beneficial uses of the receiving waters for the discharge.

One issue that frequently develops with departments of public works or other stormwater management entities who now are responsible for stormwater quality management, is the appropriateness of such departments funding stormwater impact studies. Some public works directors take the attitude that this must be done by the regulatory agencies or others. Such an approach is short-sighted and contrary to the best interests of the stormwater management agencies and the public they represent. If the stormwater management agency does not define impacts, then no one else will. Or if they are defined by others, they will likely attribute a far greater impact than actually occurs because of the number of chemical constituents that exceed water quality standards in urban and highway stormwater discharges.

It is the authors' experience that normally regulatory agencies adopt a somewhat overprotective approach in regulating point and non-point source discharges under conditions where reliable data are not available to show that a more technically valid, cost-effective management approach is possible. While this situation has existed for many years, with Clean Water Act citizen suits against regulatory agencies and/or dischargers becoming commonplace, such as the NRDC suits against Caltrans, Los Angeles County, City of Los Angeles, etc. for failing to adequately implement the NPDES stormwater discharge permit, it is in the best interest of stormwater dis-

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chargers to conduct the necessary studies to define what, if any, real water quality problems are occurring because of the chemical constituents in the stormwater discharge. By defining real water quality problems it is possible to focus available resources on their control rather than taking a technically invalid approach of trying to control every potential problem that could arise because stormwater runoff contains total concentrations of a variety of chemical constituents that from some sources other than stormwater runoff are adverse in some waterbody to the beneficial use of that waterbody.

Basically, today's mechanical approach toward monitoring chemical constituents in stormwater runoff is largely a waste of public and private funds since it does not define the impacts of the discharge-associated constituents on the designated beneficial uses of the receiving waters. Evaluation monitoring focusing on problem definition, while not traditional, is without question far more technically valid and cost-effective in developing the information needed by regulatory agencies, stormwater management entities, etc. in defining the approach that should be used to manage water quality impacts of stormwater discharges where real, significant adverse impacts are identified. ☐☐☐

The authors have developed a number of papers and reports that provide additional information on the evaluation monitoring approach for stormwater runoff and its implementation. These publications contain numerous references to the literature that discuss the need for and the characteristics of the approaches that should be used in evaluation monitoring. Copies of the authors' papers and reports, some of which are listed below in the references, are available upon request. Please contact: Dr. G. Fred Lee, 916/753-9630, FAX: 916/753-9956, e-mail: gfredlee@aol.com. The authors have established a web page (http://members.aol.com/gfredlee/gfl.htm) which lists many of their stormwater runoff quality related papers. A number of these papers are directly downloadable from this page.

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