Water Quality Monitoring of Stormwater Runoff: Chemical Constituent vs. Pollutant Monitoring

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The state of California Stormwater Quality Task Force appointed a committee to provide guidance to the State Water Resources Control Board on the revisions of the General Permit covering stormwater quality management from industrial and commercial facilities that are subject to NPDES permitting. One of the major issues of concern to this committee is the approach that should be followed in monitoring stormwater runoff from industrial/commercial properties. The author introduced to the committee the concept of focusing at least part, if not a substantial part, of the funds that have traditionally in the past been used for stormwater runoff "water quality" monitoring to a pool of funds that could be used to determine what, if any, real water quality use impairments, i.e. pollution, of the receiving waters for the stormwater runoff from a particular area are occurring due to the chemical constituents in the runoff.

As discussed herein, there is wide-spread recognition among municipal stormwater dischargers that traditional end-of-the-pipe monitoring that is being practiced under the current permit is of little or no value in defining the adverse impacts of the constituents in the stormwater discharge on the receiving water quality. The current municipal stormwater runoff monitoring is confirming what is already well known from pre-NURP and the extensive NURP studies that urban stormwater runoff contains elevated concentrations of a variety of constituents that have the potential to be adverse to receiving water quality. However, there is increasing evidence that the periodic nature of the stormwater discharges, coupled with the chemical forms of constituents in the discharge, results in a situation where exceedance of US EPA worst-case based water quality criteria in the stormwater discharge does not mean that a water quality use impairment is occurring in the receiving waters for the discharge. Encouraging industrial/commercial stormwater dischargers to work with municipal dischargers and regulatory agencies in developing a watershed management approach for evaluating and managing the adverse impacts of stormwater discharges, would significantly strengthen the cost effectiveness and the reliability of the monitoring conducted by both municipal and industrial/commercial stormwater dischargers.

As suggested, both municipal and industrial/commercial stormwater dischargers could develop a pool of funds that would enable site-specific investigations to be conducted on whether the combined stormwater discharges from a particular area are causing significant toxicity, excessive bioaccumulation, impairing domestic water supply water quality, causing excessive fertility - algal and weed growth and other water quality use impairments of concern to the public. The use of these funds could be administered through an advisory panel of stormwater dischargers, regulatory agencies and members of the public. Justification for shifting funds from mechanical edge-of-the-property - end-of-the-pipe monitoring stems from the fact that such monitoring provides essentially no useful information on whether a chemical constituent measured in such monitoring is, in fact, a pollutant in

the receiving waters for the stormwater runoff.

Significant additional justification is provided by the need for stormwater dischargers to become active participants in the watershed management approach being developed nationally by the US EPA, at the state level by the Water Resources Control Board and locally by the regional boards. Focusing on finding water quality use impairments of receiving waters and then defining the cause of any adverse impacts that are found and developing control programs for those responsible for the water quality use impairments is a key component of a watershed management approach. Presented below is a discussion of these issues.

Chemical Constituent vs. Pollutant Monitoring

Many individuals tend to use the word "pollutant" in their discussions of water quality monitoring as a catch-all term for various types of chemical constituents that are present in stormwater runoff. "Pollution," while not formally defined in the federal regulations is formally defined in the state of California Porter-Cologne as an impairment of the designated beneficial uses of a waterbody. At the federal level, this same definition is applicable based on the approach that is used in the Clean Water Act of designating the beneficial uses of waterbodies and then developing programs designed to protect and where degraded, enhance these uses.

It is important to make a clear distinction between chemical constituents which are present in receiving waters and their tributaries, including stormwater runoff, and pollutants, i.e. those constituents which impair the designated beneficial uses of the waterbody of concern to the public.

The overall purpose of the Clean Water Act is the protection and, where degraded, the enhancement of the designated beneficial uses of the nation's waters. With respect to protecting fish and aquatic life-related resources, the concern focuses on the control of those chemical constituents that adversely impact the numbers, types and characteristics of desirable forms of aquatic life. This impact is manifested through aquatic life toxicity or sufficient accumulation of chemicals within the aquatic organism tissue to be a threat to higher trophic level organisms such as fish eating birds, and also man, who uses the aquatic organisms as a source of food. The excessive bioaccumulation of chemicals typically leads to a health advisory in which restrictions are placed on the use of aquatic organisms as a source of food because of the potential adverse impacts of the bioaccumulated chemicals on those who use the organisms as food.

As discussed by Lee and Jones-Lee in their papers entitled, "Suggested Approach for Assessing Water Quality Impacts of Urban Stormwater Drainage," (Lee and Jones, 1991); "Water Quality Impacts of Stormwater-Associated Contaminants: Focus on Real Problems," (Lee and Jones-Lee, 1993); "Deficiencies in Stormwater Quality Monitoring," (Lee and Jones-Lee, 1994); "Stormwater Runoff Management: The Need for a Different Approach," (Lee and Jones-Lee, 1995) and "Unreliable Reporting of Water Quality Impairment by the US EPA's National Water Quality Inventory," (Lee and Jones-Lee, 1996) and in Urbanos and Torno (1994) in an editorial overview of the proceedings of the conference, Stormwater NPDES Related Monitoring Needs; Davies (1995) "Factors in Controlling Nonpoint Source Impacts," and several authors in the proceedings of the conferences, Stormwater Runoff and Receiving Water Systems: Impact, Monitoring and Assessment (Herricks, 1995) and Stormwater NPDES Related Monitoring Needs (Urbanos and Torno, 1994), the current end-of-the-pipe - edge-of-the-property stormwater runoff monitoring is proving to be largely a waste of money.

As discussed in detail in these papers and conference proceedings as well as summarized herein, the traditional monitoring does not determine whether chemical constituents in the runoff that occur in the runoff waters above water quality criteria - standards are pollutants in the receiving waters. Nor does this monitoring approach address the large number of chemical constituents in stormwater runoff from municipal and industrial/commercial properties that are not now regulated and therefore are not measured in the traditional, mechanical end-of-the-pipe and runoff water monitoring programs.

The so-called stormwater runoff water quality monitoring of the four indicator parameters that has been done under the current General Permit was ornamental and had little to no possibility of being of value other than mechanically complying with the regulatory requirement. If that type of monitoring continues in the general stormwater permit, the permittees will continue to waste funds mechanically fulfilling a requirement that has no meaning in terms of water quality evaluation and management. There is general agreement by those knowledgeable in the topic area that there is need to shift from edge-of-the-property - end-of-the-pipe monitoring to a focus on receiving waters. The current General Permit mechanical monitoring approach leads to the highly inappropriate mass emission type control strategy such as has been adopted for the Santa Monica Bay Restoration Project where control of chemical constituents is being advocated, irrespective of whether they cause any water quality problems in the receiving waters for the stormwater runoff (Lee, 1995). That approach may have been appropriate in the early to mid-1960's when little was known about the toxic - available forms of constituents in stormwater runoff. The public is entitled to a more enlightened approach than the mechanical end-of-the-pipe monitoring approach today where extensive information is available to show that mass emission strategies are inappropriate approaches for controlling real water quality problems associated with stormwater runoff in a technically valid, cost-effective manner.

It is well-known through the aquatic chemistry and aquatic toxicology literature (see listed references) that chemicals exist in aquatic systems in a variety of chemical forms, only some of which are toxic. This is especially true for many of the chemicals of greatest concern in stormwater runoff, such as heavy metals. In the stormwater runoff work that Dr. G. Fred Lee and his graduate students conducted in the 1960's on the impact of stormwater runoff on receiving water quality, at the University of Wisconsin - Madison, they found that even though the concentrations of a number of heavy metals, such as lead, in the stormwater runoff were greatly elevated, the lead was in a non-toxic, non-available form and therefore from the perspective of an aquatic organism, was inert. This situation has been confirmed a number of times by many investigators since then and by many of those conducting the urban stormwater runoff monitoring programs for lead and the other heavy metals as part of the current national stormwater runoff management program.

It has been found in many parts of the country that the heavy metals in urban and highway stormwater runoff are not pollutants in that they do not adversely impact aquatic life either through toxicity or bioaccumulation. A similar situation occurs for many of the high molecular weight organics that are present in urban and highway stormwater runoff in that they are in chemical forms that are non-toxic and do not bioaccumulate.

It is important to understand, however, that there is toxicity associated with urban stormwater runoff in many areas. Much of this toxicity has been found to be due to organophosphorus pesticides such as diazinon. Diazinon is a non-regulated chemical with respect to water pollution impacts. There are no water quality criteria for it, yet it is present in stormwater runoff in some areas to a

sufficient extent, in toxic available forms, to be adverse to aquatic life. There is no doubt that diazinon and other similar chemicals are real pollutants in many situations associated with stormwater runoff from urban areas, highways and agricultural areas. The diazinon present in highway runoff is believed to be largely from airborne transport of agriculturally used diazinon. In urban areas, diazinon is from both airborne transport of agriculturally applied diazinon and by urban dwellers' use in and around homes, commercial buildings, etc. The aqueous environmental chemistry of diazinon is such that it does not become associated with particulate matter and therefore would not be removed in the conventional stormwater BMP's such as a detention basin.

There is now widespread agreement among those responsible for conducting stormwater runoff water quality monitoring programs that the approaches that have been adopted in the past of mechanically assuming that all chemical constituents, such as heavy metals and various organics, present in stormwater runoff in elevated concentrations are adverse to aquatic life in the receiving waters for the stormwater runoff is technically invalid, ignores what is well-known in aquatic chemistry and aquatic toxicology and can lead to a massive waste of public and private funds in controlling chemical constituents that are non-toxic, non-available in the runoff and receiving waters. The traditional approaches of constructing detention basins which are designed to remove particulate forms of heavy metals and organics for the control of chemical constituents in urban and highway stormwater runoff is now known to be technically invalid and wasteful of public and private funds. Lee and Jones-Lee (1996b) in "Significance of Eroded Suspended Sediment-Associated Constituents" have recently reviewed the water quality significance of particulate constituents in stormwater runoff. They point out that while there may be justification to construct detention basins to remove particulates because of adverse impacts of the particulates due to turbidity, shoaling and altering aquatic life habitat, there is no justification for constructing detention basins to remove particulate heavy metals and other particulate constituents because of their potential toxicity to aquatic life.

The US EPA (1995), through the National Toxics Rule, formally implemented regulatory approaches for many heavy metals based only on dissolved forms. The Agency does not require that particulate forms of many heavy metals, including copper, zinc, cadmium, lead and nickel be controlled in ambient waters. This regulatory approach formally recognizes what has been known for well over 20 years (see the National Academies of Science and Engineering Bluebook of Water Quality Criteria) (NAS/NAE, 1973), that particulate forms of these heavy metals are non-toxic and non-available.

The March 1996 Society for Environmental Toxicology and Chemistry News reported on the results of a special workshop that was organized by SETAC to review the regulatory approaches that should be used for regulating heavy metals in aquatic systems. There was consensus that dissolved forms of heavy metals should be the forms that are regulated and that even the dissolved forms may over-regulate heavy metals due to the fact that in some waters dissolved heavy metals are in non-toxic, non-available forms.

Because of the very high cost associated with the control of real pollutants in stormwater runoff, i.e, those constituents which are adverse to the designated beneficial uses of the receiving water for the runoff, it is important that those working in a stormwater quality evaluation field focus their efforts on controlling those constituents in stormwater runoff that adversely impact the beneficial uses of receiving waters, such as the numbers, types and characteristics of desirable aquatic life in these waters. This means that those working in this field should clearly distinguish between

chemical constituents and **pollutants**. The term "pollutant" should not be used as a generic term for chemical constituents as is done today by those who do not reliably consider the basic principles of aquatic chemistry and aquatic toxicology in stormwater runoff water quality evaluation. "Pollutants" should only be used to describe those chemical constituents which have been found to be adverse to the beneficial uses of a waterbody in which they are present. This requires a site-specific receiving water evaluation of whether heavy metals, organics, etc. in stormwater runoff from industrial/commercial properties as well as from urban areas, highways, etc. are present in toxic, available forms at sufficient concentrations and for a sufficient duration to be adverse to the designated beneficial uses of the receiving waters for the runoff.

There are some members of the stormwater water quality community who persist with advocating the mechanical monitoring of stormwater runoff from properties as an appropriate requirement. Such an approach has no technical validity and misdirects the resources available to largely unimportant issues, thereby precluding the use of these resources to address real water quality problems associated with unmeasured toxicants such as diazinon in stormwater runoff. Every winter in the Northern California Central Valley, all industrial/commercial properties as well as other properties in the valley, have sufficient diazinon in their runoff waters to be hazardous to aquatic life. The end-of-the-pipe - edge-of-the-property stormwater runoff monitoring programs do not address this issue.

Evaluation Monitoring

In order to provide guidance on how the receiving water monitoring can be conducted in a technically valid, cost-effective manner, the authors (Lee and Jones-Lee) have developed a report (Lee and Jones-Lee, 1996c) and a paper (Lee and Jones-Lee, 1996d) on this approach. This approach, which they call "evaluation monitoring," can be readily implemented through relatively simple measurements of aquatic toxicity and bioaccumulation. If the stormwater runoff waters that enter a waterbody are, in fact, toxic in the waterbody, and this toxicity is judged to be of significance to the beneficial uses of the waterbody, then it is possible through forensic analysis and toxicity investigation evaluations (TIE's) to determine the cause of the toxicity and its origin. It is through this approach that diazinon was discovered to be a widespread problem in stormwater runoff. It is also through this approach that it has been found that the heavy metals from urban and highway runoff rarely cause water quality problems.

Basically, the evaluation monitoring approach recognizes that heavy metals and other constituents occur in stormwater runoff in a variety of chemical forms, many of which are non-toxic and non-available. Rather than wasting resources measuring heavy metals and then trying to estimate toxicity or bioaccumulation in the receiving waters which cannot be done reliably, the evaluation monitoring approach measures toxicity using highly sensitive aquatic organisms of the same type as were used to develop the water quality criteria - standards to determine whether the heavy metals as well as other regulated and unregulated constituents are, in fact, toxic in the receiving waters for a sufficient duration to be adverse to the beneficial uses of these waters.

Further, for those heavy metals and other constituents which are of concern because of their potential to bioaccumulate within aquatic organism tissue to a sufficient extent to cause a health advisory associated with the consumption of the tissue, the evaluation monitoring approach determines whether there is excessive bioaccumulation in aquatic organism tissue from all sources of

constituents that are of concern because of this type of problem. If excessive accumulation is found, then studies are conducted to determine the source of those constituents that lead to the excessive accumulation.

The evaluation monitoring approach is a highly focused problem definition approach that utilizes the resources available to find real water quality use impairments in the receiving waters for the runoff waters, to identify the cause of the use impairments and to specifically identify the source of the constituents that cause the water quality use impairment. It incorporates the current state of knowledge of aquatic chemistry and aquatic toxicology as well as water quality assessment in defining water quality problems. Further, this approach specifically addresses the widely recognized problem of the unreliability of the mechanical end-of-the-pipe - edge-of-the-property so-called water quality monitoring associated with coverage under NPDES stormwater General Permits as well as municipal permitees.

The adoption of this approach is predicated on the fact that an industry covered under the General Permit will practice good housekeeping and prohibit illegal connections and illicit discharges of pollutants to the storm sewer system. It should be noted that the conventional monitoring approach will not detect these types of problems since a discharger that practices such approaches will obviously be able to monitor in such a way as to not reveal their illegal activities. However, the receiving water monitoring focusing on real water quality use impairments could possibly detect significant problems associated with inappropriate discharges to the storm sewer system.

Monitoring for BMP Efficacy

Some of those who advocate mechanical end-of-the-pipe - edge-of-the-property monitoring assert that such monitoring is needed to evaluate the reliability of the BMP's. Such an assertion is totally inappropriate. The purpose of BMP's is not to control chemical constituents; it is to control pollution to the maximum extent practicable (US EPA 1990). Pollution control as discussed above is not simply the control of chemical constituents independent of whether they have an adverse impact. It is devoted to controlling constituents that have adverse impacts on the receiving waters. The only way to reliably assess whether a BMP is, in fact, a real BMP and not simply an approach that functions in name only, is to determine what real impact the implementation of the BMP had on the beneficial uses of the receiving waters for the stormwater runoff. It is the receiving waters that should be the focus of BMP development, implementation and efficacy evaluation, not what happens in the storm sewer next to the property.

Pollution Prevention

There are some who advocate the mechanical stormwater monitoring programs as part of a "pollution prevention" program. Pollution prevention as applied to water quality management should focus on preventing those chemical constituents from entering a receiving water via stormwater runoff which will cause real water pollution in the receiving waters for the stormwater runoff. The control of particulate forms of heavy metals in stormwater runoff from an area is not pollution prevention. The control of agriculturally applied diazinon that causes rainfall and fog-fall in an area to be a source of toxicity in stormwater runoff from industrial/commercial and urban areas and highways is pollution prevention.

The shotgun approach of controlling all chemical constituents in stormwater runoff under the

guise of a so-called pollution prevention program is technically invalid and wasteful of resources. The Water Environment Federation has recently released a policy statement on "Pollution Reduction and Elimination Principles," (WEF, 1995). This statement focuses pollution prevention efforts on preventing pollution - impairment of uses of the receiving waters. This is the approach that should be adopted in pollution prevention programs for stormwater runoff from industrial/commercial properties as well as other areas.

Addressing Unreliable Monitoring Approaches

Since there are still individuals who persist with advocating continued mechanical end-of-the-pipe - edge-of-the-property stormwater runoff monitoring, it is suggested that those who wish to implement a more technically valid, enlightened approach should require that those who advocate perpetuating mechanical end-of-the-pipe - edge-of-the-property monitoring provide technical justification for this approach that can be peer reviewed by knowledgeable individuals. Such a review will show that continued use of monitoring resources for the traditional mechanical monitoring of runoff waters of the type that has been practiced in the past and is still being advocated today by some is based on an inadequate - unreliable understanding of the basic issues of water quality management as well as the principles of aquatic toxicology and chemistry as applied to water quality evaluation and management and is largely a waste of public and private resources.

Water Quality Monitoring Expertise

For 30 years Dr. G. Fred Lee taught university graduate-level environmental engineering and environmental science courses and conducted research at several major universities. He retired from university teaching and research in 1989 where he held a Distinguished Professorship in Civil and Environmental Engineering. Dr. Anne Jones-Lee taught in the same topic areas for 11 years and held a tenured associate professorship in Civil and Environmental Engineering. During his university career, Dr. Lee conducted over $5 million in research and published over 500 professional papers and reports on this work. One of their primary areas of work was aquatic chemistry and analytical chemistry as it applies to water, wastes and water pollution control.

Drs. G. Fred Lee and Anne Jones-Lee pioneered in the use of an integrated aquatic chemistry - aquatic toxicology approach in an engineering-based hazard assessment for evaluating and managing chemical constituents that are, in fact, pollutants in a particular waterbody. A key aspect of this approach is that it leads to the control of chemical constituents without significant unnecessary expenditures for chemical constituent control.

Dr. G. Fred Lee has served as an advisor for a number of governmental agencies, including the International Joint Commission for the Great Lakes, NOAA, the US EPA, industry and others on how to establish technically valid monitoring programs for water quality. This work included developing a major report on this topic for the US EPA devoted to establishing a monitoring program for toxic chemicals in the Great Lakes. Upon returning to California in 1989, this report, "Guidance for Conducting Water Quality Studies for Developing Control Programs for Toxic Contaminants in Wastewaters and Stormwater Runoff," (Lee and Jones-Lee, 1992) was updated and broadened in scope to include lakes, rivers, estuaries, nearshore marine waters, etc. and specifically addressed stormwater runoff water quality monitoring.

Additional Information

Those interested in further information on the deficiencies of the current monitoring approaches should consult the proceedings of the two stormwater monitoring conferences (Urbanos and Torno, 1994 and Herricks, 1995) as well as the papers of Drs. G. Fred Lee and Anne Jones-Lee. Copies of these papers and reports on these and related issues are available upon request.

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