Start at the SOURCE

Maintaining the quality of bodies that receive storm water has become increasingly difficult, and municipal permits that require storm-water managers to meet increasingly stringent requirements offer limited benefits at best. The solution? Tighter controls on the chemical compounds that are available commercially and create polluted runoff in the first place. By Scott Taylor, P.E., M.ASCE

The number of chemical compounds used in society continues to expand, and the effect that these compounds have on surface water resources is, in most cases, poorly understood. As of March 2004, nearly 23 million organic and inorganic substances had been indexed by the American Chemical Society's Chemical Abstracts Service, and roughly 7 million of those substances are available commercially, according to Christian Gaaei Daughton, Ph.D. ("Non-Regulated Water Contaminants: Emerging Research," *Environmental Impact Assessment Review* 24, numbers 7–8 [2004]: 711-732), who works for the U.S. Environmental Protection Agency (EPA) in Las Vegas as chief of the environmental chemistry branch, part of the agency's Environmental Sciences Division. Certainly not all of these compounds have an active pathway to the environment or would be harmful if they did, but when the number of commercially available substances is contrasted with the number of compounds that are sampled in a typical municipal storm-water program (about 150 to 300), it becomes clear that there is a significant potential for surface water pollution of unknown origin. Viewed strictly from a human health perspective, about 120 diseases have been linked to pollution, with still others deemed to be potentially linked, according to research conducted by the University of California and the Boston Medical Center and summarized in an article by Geoffrey Lean ("U.S. Study Links More Than 200 Diseases to Pollution") that appeared in the November 14, 2004, issue of the *Independent,* a British newspaper.

The U.S. government has attempted to address this issue in a number of ways; the primary body of regulations dealing with surface water quality comprises the 1972 Clean Water Act (CWA) and an amendment to that act passed in 1987 prohibiting pollutant emissions from point sources unless the discharger secures a National Pollutant Discharge Elimination System (NPDES) permit. The 1987 amendment acknowledged the difficulty of regulating the quality of storm water and thus required "controls to reduce the discharge of pollutants to the maximum extent practicable (MEP)." This MEP standard was, of course, open to interpretation.

Under these regulations, states are required to develop water quality standards that must be met to maintain "the desired condition of a waterway." The water quality standard established by the state is based on the designated "beneficial uses" of the water body, for example, as a source of drinking water, for contact recreation (swimming), or for such other recreational purposes as fishing. The water quality objective will vary depending on the designated use.

For storm water, the NPDES was implemented in two phases, the first covering municipalities with a population of 100,000 or more (based on the 1990 census) and the second covering municipalities with populations of 10,000 to 100,000. The permits for the first phase were first issued in the early 1990s. The program is now in its fourth round of permitting, and with each round the permissible levels of certain contaminants are ratcheted down, the goal being to reduce storm-water pollution ever further and to achieve particular levels of receiving water quality. Although each state is officially operating under the EPA's 1996 document "Interim Permitting Approach for Water Quality-Based Effluent Limitations," the NPDES permit language in some states is more exacting than the national standards. California, for example, often does not allow discharges to "cause or contribute to the exceedance of a receiving water standard."

Further, the implementation of total maximum daily loads (TMDLS)—the sum of the loads of a single pollutant from all contributing point and nonpoint sources that can be discharged into a body of water under the CWA—has altered the permitting process. Many NPDES permits now include load allocations for particular constituents in storm-water runoff. Some programs, such as the one operated by Wisconsin's Department of Natural Resources, have begun placing numeric limits on selected storm-water constituents. Unfortunately, the sophistication of many storm-water pollution control measures—commonly called BMPS (for best management practices)—has failed to keep pace with these increased regulatory demands. Several studies have been completed of typical municipal discharges showing that these strict water quality standards cannot be achieved through the implementation of even the most comprehensive source control and storm-water treatment program.

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The current storm-water permitting process has emphasized the concept of presumptive compliance; that is, it is assumed that water quality standards will be achieved if the controls that are used meet the MEP test. Unfortunately, that is not always the case; in fact, third parties have sued permitting authorities for excluding particular, numeric "end-of-pipe" limits in their permits. The current system encourages the diversion of substantial resources to litigation regarding these issues, while discouraging innovation in prevention and treatment.

The current problem facing most permittees is that there are few viable methods that they can use as the permits impose requirements that are ever more stringent. Source control options have been explored in some depth within current legislative boundaries, and treatment controls have consistently been shown to provide a modest level of performance that generally does not meet the receiving water standards. The fundamental problem lies in the volume of storm water to be treated. A typical publicly owned treatment works may treat 1 mgd (3.8 million L/d) of domestic sewage for each square mile (2.6 km^2) within an urban area, but the same urban area will discharge roughly 12 times that volume during a normal rainfall event. Couple the relatively large runoff volume with the short, episodic nature of the discharge, and engineered solutions quickly prove to

Constituents Exceeding Objectives for Surface Water in California

Constituent category	Common examples
Metals	Aluminum, barium, beryllium, cadmium, chromium, mercury, nickel, iron, lead
Pesticides	Legacy pesticides as well as organophosphates and carbamate
Organic compounds and polycyclic aromatic hydrocarbons	Phthalates, chrysene, benzopyrene, benzapyrene
Nutrients	Nitrate, nitrite, phosphorus
Conventional constituents	Total suspended solids (TSS), total dissolved solids (TDS)
Sanitary	*E. coli,* fecal coliform, total coliform

be few and costly. The ultimate solution for surface water regulation is revised legislation developed expressly for wet-weather events. Any effective legislative solution would include receiving water standards and discharge standards.

In the absence of a regulatory method to quantitatively compare discharge compliance with receiving water standards, municipal operators will instead compare the results of their characterization monitoring—that is, monitoring of the chemical constituents within a sample at the end of the pipe—with state-established standards and objectives. A review of these data provides one of the few proxies for assessing our progress toward attaining the standards set for the receiving water.

I have reviewed characterization data from several municipal storm-water programs in the northern and southern parts of California to generally assess storm-water runoff discharge compliance in relation to receiving water standards. The table above provides an overview of the constituents that were found to generally exceed the receiving water objectives in storm-water discharges across the state.

It is clear from the number of potential constituents that can cause surface water pollution and from the results of current constituent monitoring programs that chemically based analysis programs are inefficient and ineffective. G. Fred Lee, Ph.D., and Anne Jones-Lee, Ph.D.—the founders of G. Fred Lee & Associates, an engineering consulting firm in El Macero, California, that focuses on water quality, water and wastewater treatment, and pollution control—have written extensively on this topic. They offer the following comprehensive list of beneficial use impairments that should be further investigated:

- Aquatic toxicity;
- Sediment toxicity;
- Excessive bioaccumulation of hazardous chemicals;
- Dissolved oxygen depletion;
- Domestic water supply quality;
- Groundwater recharge;
- Eutrophication (from excessive fertilization);
- Sanitary quality impairment (as it relates to contact recreation activities and shellfish harvesting);
- Suspended sediment impacts and accumulation;
- Oil and grease accumulation;
- Litter accumulation.

Steps can be taken to achieve water quality standards and address the potential impairments to receiving waters that are of most interest to the public, namely, toxicity, bioaccumulation, dissolved oxygen depletion, eutrophication, sanitary quality, sedimentation, and oil and grease accumulation. Passive and active treatment technologies—combined with a more aggressive form of source control—can achieve water quality standards in receiving waters in some cases. But for other impairments, wet-weather standards must be created to recognize the extremely difficult technical issues associated with source control and treatment. It is imperative that planning for more advanced storm-water programs begin now to avoid the extremely costly mistakes that will come with a piecemeal and reactionary approach to meeting NPDES requirements.

Sampling receiving waters for beneficial use impairment offers a far more efficient approach to achieving surface water objectives. Recognizing this, some storm-water programs have begun to shift resources from characterization monitoring to the monitoring of receiving waters. However, even if storm-water managers determine the constituents of concern, they still lack many of the tools needed to effectively mitigate them.

Chemical constituents that can become pollutants are deposited in the air and on the land through three sources: government activity, commercial and industrial activity, and consumer activity.

Government activity can be highly regulated to eliminate or reduce reliance on chemicals of concern. For example, a municipality can choose to eliminate the use of fertilizers and herbicides in public parks. The Department of Defense can prohibit construction near stream corridors and require that its projects retain runoff onsite. Many governmental bodies already do this. The second source, commercial and industrial activity, is already highly regulated. Industrial activities are covered through a separate type of NPDES permit that includes construction activities. The requirements of the industrial permit have become more stringent with each round of permits. Current permits require managers to compare monitoring data with benchmarks or water quality standards, and future permits are likely to contain numeric limits on effluents. Hence, the industrial discharger may soon be required to demonstrate quantitatively that the

The BMP Database

In compliance with the Clean Water Act, the U.S. Environmental Protection Agency (EPA) in the early 1990s established a national database of storm-water management approaches known as best management practices (BMPS). The database was intended to assist communities in determining the types of BMPS appropriate for them and in monitoring the performance of the techniques selected.

In 2004 the development and management of what had become known as the International Stormwater BMP Database Project was turned over to a coalition of partners, including the Water Environment Research Foundation (WERF), ASCE and its Environmental and Water Resources Institute, the Federal Highway Administration, and the American Public Works Association, in addition to the EPA. Two consulting engineering firms—Wright Water Engineers, Inc., based in Denver, and GeoSyntec Consultants, based in Boca Raton, Florida—maintain and operate the database. The overall project is managed by Jeff Moeller, P.E., M.ASCE, the research program director for WERF, with the support of an expert advisory committee.

In 2005 the management team began actively pursuing new BMP data for inclusion in the database while it continued to conduct statistical analyses of current and new BMP data. The team is also in the process of developing a framework for expanding the database to include what are called low-impact development (LID) methods, that is, techniques that can be implemented with little or no effect on the surrounding environment. (See "High-Impact Innovation," by Jay Landers, *Civil Engineering,* February 2004, pages 50–57.)

The project maintains a Web site, and it is here that engineers may find the protocols for submitting BMP monitoring studies for inclusion in the database; guidance for monitoring storm-water BMPS to meet these protocols; data entry software that will make it possible to store and report BMP monitoring study data; performance summaries for individual BMPS via an online, searchable database containing more than 200 BMPS; statistical summaries of the overall BMP database; statistical summaries of performance broken down by BMP type; technical reports describing the statistical techniques recommended for analyzing BMP performance and the results of performance evaluations; published papers from conference proceedings and journals regarding the BMP database; and other useful information.

As of press time, some 247 BMPS had been entered into the database, including 219 structural methods and 28 nonstructural methods. Biofilters is the topic covered by the largest number (59), whereas 38 relate to media filters, 37 to retention ponds, and 26 to detention basins. Such a database will only become more useful as more BMPS and evaluations are entered. The project management team is seeking new entries for the database—traditional and LID methods—to help the project remain effective and useful. Engineers wishing to enter their storm-water BMPS may access the resource at www.bmpdatabase.org.

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site for which the permit has been issued is not causing or contributing to a violation of a receiving water standard. The industrial discharger has the authority to modify its site operations to meet permit requirements and standards set by the permit.

By contrast, consumer activity is much more modestly regulated. Municipalities can rely on ordinances enacted by the city or county to help them meet the requirements set forth in their NPDES permits, but these municipal NPDES permits usually acknowledge the diverse and diffuse nature of runoff by incorporating flexibility. Runoff from private property not covered by the industrial permit process remains relatively unregulated at the source level. Consumer education and enforcement are difficult tasks for municipalities that may not have the manpower or the right to enter and inspect property. Some municipal programs tend to focus on requiring new development and redevelopment plans to incorporate stricter controls, and this provides some limited progress. Retrofit of treatment devices also is being considered in areas already covered by municipal permits, but the few studies that have been completed on this subject indicate that retrofitting treatment controls provides a relatively poor return on investment, that is, cost versus progress toward achieving water quality standards.

Treatment controls simply cannot achieve water quality standards for many constituents for several fundamental reasons. First, as previously noted, treatment devices must be able to handle a volume of storm water that is relatively large, and they must be able to accept the volume at a high rate of flow (or store it for later treatment). Second, treatment systems must generally be designed to operate passively; it is impractical to have systems requiring operators for relatively infrequent rain events. Third, owing to the sheer number of systems required to serve diffuse urban drainage systems, treatment systems must have relatively modest maintenance requirements. Centralized treatment can be impractical in many areas.

Contemporary combined sewer outfalls (CSOs) may confer an advantage in the area of effluent quality during storms that do not exceed their storage capacities because they are able to take advantage of actively managed and relatively sophisticated treatment works. But when overflows occur, pollution results.

If current municipal permitting strategies are taken to their apparent logical conclusion—requiring the retrofit of treatment controls in existing urbanized areas while maintaining current strategies for controlling sources—a substantial gap will still remain between effluent quality and receiving water standards. The situation is analogous to controlling water quality from a construction site where only treatment controls (such as sediment basins and silt fences) may be used. Without effective source controls, municipal programs will be severely limited in the level of runoff water quality that they can achieve.

To reach the next level in urban runoff water quality, new BMPs for source control must be implemented. The current focus of pursuing ever more sophisticated treatment controls to meet receiving water quality standards is tactically and strategically ineffective. Municipal storm-water program managers must have more authority to control consumer activity based on the findings of their receiving water monitoring programs. The municipal storm-water model must move toward the industrial model if significant progress is to be expected within the current regulatory framework. Changes that should be implemented to the municipal program include the following:

- Greater focus on receiving water monitoring for beneficial use impairments and less focus on mass emission monitoring;
- Giving the permitting authority, through current processes, the power to establish local ordinances to ban the sale and use of consumer products that are shown to be contributing to the exceedance of receiving water standards;
- Giving the permitting authority the power to restrict or otherwise control commercial and agricultural applications of products that are shown to be contributing to the exceedance of receiving water standards.

The factors affecting water quality are numerous and cross jurisdictional, regulatory, social, and economic boundaries. Government must therefore play a larger role if surface water quality efforts are to be successful. However, conflicts exist even within the current regulatory framework. In 2003 the EPA noted that the application of a pesticide to waters of the United States, if consistent with the Federal Insecticide, Fungicide, and Rodenticide Act, did not constitute a discharge of a pollutant under the CWA. Yet the presence of such a compound would violate receiving water standards for toxicity.

On a broader scale, the EPA has responsibility under section 5 of the Toxic Substances Control Act to evaluate new commercial substances for threats to human health or the environment. However, it does not appear that this assessment is conducted in sufficient detail to evaluate or prohibit effects regulated under the CWA. The agency is charged with weighing the "risks versus the social and economic benefits" of a substance to determine if it should be approved for use. The possibility of pollution occurring from "approved" compounds is apparently anticipated by the CWA in section 403(a), which directs the EPA to set water quality criteria for pollutants. But the promulgation of standards under section 403(a) can be an exceptionally slow process. For example, in 2003 the EPA published a draft of criteria that would apply to nonylphenol, but it does not appear to have made any progress since. The 2003 document was years in the making, and nonylphenol has been known to cause surface water quality problems for some time. A regulatory process that sets water quality criteria after a compound is in use and only after it has been found to impair beneficial uses in receiving waters cannot possibly keep pace with the realities of water quality management.

The EPA should change its internal approach to promulgating regulations and rethink the requirements it places on manufacturers prior to approval of a compound for commercial use. Basic evaluations of the effects of new substances on water quality could be required of the manufacturer using established protocols. Methods of controlling the substance in the environment—and the costs to do so—could be predetermined so that a more informed cost-benefit analysis could be completed. Moreover, because the burning of fossil fuels has a substantial effect on water quality, it would be appropriate to regulate air and water quality together, setting standards that are protective of both resources.

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The promulgation of wet-weather standards is of cardinal importance for certain pollutants, particularly pathogens. Sanitary standards are difficult to achieve under storm flow, and the options for either source control or treatment control during periods of high flow and volume are limited.

The current system of water quality regulation diverts far too many resources toward litigation, treatment controls, and characterization monitoring. The method for approving new chemical compounds for commercial use fails to safeguard the quality of surface water.

The framework for detecting existing compounds that impair the quality of surface water is slow and underfunded. Unless basic changes are made to the regulatory system and the approach used to prevent pollution, we will be frustrated by only incremental water quality improvement, by complex regulatory "solutions" such as TMDLs, and by frequent litigation. ■

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