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Street Dirt

A better way of measuring BMP effectiveness

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Phase I jurisdictions have spent, and will, in the near future, spend millions of dollars characterizing discharges from stormwater outfalls. Yet many presentations, articles, and reports over the past several years indicate the complexity of outfall sampling and biases and limitations of the sampling methods and laboratory analytical procedures.

A common objective stated for the sampling of stormwater discharges is to measure the effectiveness and progress of the implementation of various best management practices (BMPs), such as homeowner education on pesticide and fertilizer use, cleaning of public and private drain inlet sumps, street sweeping, use of brake drums with less copper, and pickup of dog feces.

Yet, given the variability of the quality of stormwater from storm to storm and from outfall to outfall, it is reasonable to question the validity of outfall monitoring as a means to measure progress. It is problematic that modest reductions—less than 50%—cannot be discerned statistically with outfall sampling. Furthermore, sampling protocols and analytical procedures will continue to change over time, bringing into doubt the validity of older data with which trend analysis is attempted. The high cost of sampling results in only a few outfalls being sampled, raising the question as to whether the few sampled outfalls are representative of the community. And how does the regulator or citizen discern which BMPs are having which effect if two or more BMPs are expected to affect the same pollutant?

In this article, we explore a radically different means to measure effect and progress: the chemistry of street dirt. If our BMPs are having an effect, it should be reflected in the chemistry of street dirt. Street dirt, rather than stormwater, becomes the integrator of community behavior. For example, if the use of pesticides is being reduced over time, it will be apparent in the chemistry of the street dirt. Collecting and evaluating street dirt has many advantages over collecting water at outfalls. It is cheaper per sampling station, and it requires a lower level of technical expertise, a simpler menu of equipment, and lesser constraints on sampling procedures and analytical holding times. There is no issue of detection limits, and it is arguably safer. The information can also be used to directly evaluate the cost and cost-effectiveness of the particular BMPs themselves, such as sump cleaning and street sweeping. Street dirt sampling can be complemented with dry and wet fall sampling as practiced by air-quality regulators. A particular BMP can be tied directly to the information that is collected.

Shortcomings of Outfall Discharge Monitoring

Many reasons are given for the monitoring of stormwater discharges. After 30 years of discharge monitoring, it is reasonable to question whether the incremental increase in knowledge is worth the cost. In an extensive examination of the state of urban stormwater management, the National Research Council (2008) stated, “Because of a ten-year effort to collect and analyze monitoring data from MS4s nationwide, the quality of stormwater from urbanized areas is well characterized.” The reference is to National Pollutant Discharge Elimination System (NPDES) Phase I permit monitoring programs.

With the passage of time, the complexities and, in turn, the cost of discharge monitoring have increased significantly as biases, shortfalls, and complexities have become known. Among these:

The highly variable range of concentrations observed from storm to storm requires many storms to be sampled to meet statistical requirements.
The number of storms required increases significantly if one is to discern only a modest change in community behavior.
The concentrations of many contaminants of interest are within a factor of 10 of their respective detection limits, making problematic the validity of any statistical statement regarding significance.
It is difficult to meet holding time requirements less than the length of storm.
Changes in analytical procedures over time make problematic the validity of comparing current results to past data.
The potential exists for contamination of samples.
It is questionable whether the true event mean concentration (EMC) is being measured.
The relevance of EMC is in question with respect to short-term toxic impact and exceedances of standards for toxic substances such as metals and pesticides.
There is potential bias associated with splitting collected stormwater into sample analysis bottles.
Automatic samplers have limitations with respect to the capture of larger sediments.
There is a need for highly skilled and experienced personnel.
The necessity of being active during inclement weather presents a concern for the safety of personnel.
Equipment is sometimes vandalized.
Monitoring is constrained to a particular time of the year.
Outfalls are selected on the basis of physical accessibility and concerns about safety and vandalism, rather than whether they are representative of the community.
Sampling a few discharges in a community—a limit imposed by the high cost of monitoring per discharge—might not properly represent the community. (For example, the city of Seattle has about 950 outfalls and will be sampling three to comply with its NPDES permit.)
The efficacy of translating observed changes at a few discharge outfalls to across the community through the use of watershed loading models is questionable.

Most importantly with respect to the evaluation of the effectiveness of various BMP programs, if a trend is discerned through outfall sampling, how does one determine the underlying cause? An observed increase in concentrations does not mean that particular BMP programs affecting that pollutant are not beneficial, because the reduction by the program may be masked by new sources. Similar statements can be made with respect to no change or to a reduction. If the sources of the targeted pollutant are multiple, which BMP program contributed to the change and at what unit cost?

Evaluation of the Individual BMP Source-Control Effectiveness

At the opposite end of discharge monitoring is evaluation of the individual program, commonly done by surveys (Elzufon 2000, Rowe and Schueler 2006). This approach relies upon surveys that identify the change in awareness and implementation of various source-control or nonstructural BMP programs. However, this approach does not effectively translate to quantification of the reduction that may occur because of the increased awareness. Cost surveys have been done, identifying the total cost of individual programs and the per capita cost (Currier et al. 2005), but without corresponding loading reductions, program cost-effectiveness cannot be measured. A third approach is to monitor sales of relevant products such as pesticides and fertilizers within a community or region.

Alternatively, focused field studies can provide an indication of possible pollutant loading reductions. As examples, one study evaluated landscaped areas with and without fertilizer application (Talasaea 2000). The concentration and loading reductions for total phosphorus were 86% and 94%, respectively. Barten et al. (2006) concluded that a reduction of about 15% was possible with an outright ban on phosphorus fertilizers. The study, however, involved the sampling of 570 events over a five-year period. A third study found little change in behavior or stormwater water quality following an intensive homeowner education on lawn care and fertilizer use (Dietz et al. 2002).

The discomfort from the three studies cited is the wide range in the potential improvements from zero to 94%, making highly suspect an evaluation of cost-effectiveness based on dollars per pound of pollutant reduced. Regardless, none of these indicates progress under normal BMP implementation. There are likely a large number of such studies that have not been made widely known.

Use of Street Dirt Chemistry As an Indicator of Change

Our thesis is that the measurement of progress of many nonstructural source-control programs is possible through the monitoring of street dirt chemistry. The proposed concept overcomes many of the limitations cited for discharge monitoring. Detection limits are not an issue. The collection equipment is simple and inexpensive. A modest technical background is needed to use the equipment and to make judgments as to the sampling points. Properly supervised interns can conduct the sampling. Sampling can occur during good weather. Nothing is left in the field that may be vandalized.

The cost of equipment per outfall for discharge monitoring is on the order of $10,000. The cost of equipment for dirt sampling is on the order of $1,500. Equipment includes traffic cones and personnel vests, a portable generator, extensive cord, a stainless steel shop vacuum, a 2.5-micron Dacron filter cloth cover, vacuum hoses, a paint brush, resealable plastic zipper storage bags, and a weighing scale.

The cost of discharge monitoring for one outfall over the period of a year is on the order of $50,000 to $100,000 for labor, exclusive of sample analyses. Consider that a crew of two collecting street dirt samples can perform about six samplings of street dirt per day. At normal labor and analytical unit costs, the cost per dirt sample is on the order of $500 to $1,000. Hence, for the cost of monitoring one outfall over the period of a year, about 1,000 samples of street direct can be collected within a watershed of interest. Because the sampling is not constrained by weather, these 1,000 samples can be collected over a period of a few months by several crews, rather than a year for an outfall.

BMP Practices That May Be Amenable to Progress Monitoring

An early study of street dirt chemistry found the presence of pesticides (Sartor and Boyd 1972). This early study indicates the potential for using street dirt chemistry as a progress indicator inasmuch as the only means (vector) for pesticides to reach streets is by aerial drift, a common concern in the agricultural community. Pesticide education and reduction programs are therefore amenable to progress monitoring by a change in street dirt chemistry.

The ban on leaded gasoline that occurred in the mid- to late 1980s is an excellent example of the efficacy of this approach. Lead concentrations found in the street dirt of the 1970s and early 1980s were very high, whereas data collected in the late 1990s and 2000s all show greatly reduced concentrations of lead. Table 1 lists nonstructural programs in which dirt chemistry may serve as a progress indicator for various targeted pollutants.

What We Know and Do Not Know About Street Dirt Chemistry

Our understanding of the chemistry of street dirt, how the chemistry is affected by land use, and factors within each land use is in its infancy. It is at the level of our understanding of stormwater quality in the late 1970s, prior to the National Urban Runoff Program. Approximately two dozen studies have been conducting in which the chemistry of street dirt has been evaluated. Data from several of these studies are presented in Table 2. Street types have included rural, suburban, commercial, industrial, and freeway. Observed concentrations (milligram per kilogram) vary widely within and between studies.

A review of the studies conducted to date suggests the following:

Concentrations at a sampling site vary significantly from month to month.
The variation does not appear to be seasonal in wet climate regions.
Higher concentrations may be observed in cold climates regions during the winter months.
The relationship of chemistry to particle size has been inconsistent, but likely indicates a need to normalize data relative to particle size.
Nitrogen and phosphorus concentrations appear to be affected by the presence of organic matter, indicating need to normalize nutrient data relative to both particle size and organic content.
Phosphorus concentration may increase with tree canopy, i.e., organic matter.
Metals concentrations increase with increasing traffic volume.
Lead content of street dirt has decreased significantly since the 1970s, reflecting the ban in leaded gasoline

There is much that we do not know, in part due to the relatively modest amount of data, but more because we have not considered the use of street dirt chemistry in the context that is being proposed in this article.

Why do concentrations vary from month to month?
What is the relevance of socioeconomic factors on contaminant concentrations?
What are the seasonal differences?
Why hasn't chemistry as related to particle size been consistent?
What are the relative contributions of sources for a particular pollutant?
What are the relative contributions of sources outside the community, from the region and internationally?
Can we distinguish between various sources of a pollutant by how a pollutant is complexed in the dirt?
What are the impacts of road characteristics such as pavement type, condition, slope, and the presence of curbs and drain inlet sumps?
How much sampling of a street with the same apparent characteristics must be done to meet statistical requirements?

What We Need to Do

A beginning point is to conduct a detailed study of one watershed to address the above list of unknowns. The watershed would vary with respect to expected factors such as land use, traffic volumes, and socioeconomic conditions. Hundreds of street dirt samples would be obtained and evaluated appropriately from dozens of sites over the period of 12 months. The data could then be used to answer many of the questions outlined above.

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