Recent street sweeping pilot studies are flawed

Roger C. Sutherland, P.E.
President
Pacific Water Resources, Inc.
Beaverton, Oregon
Presenter, 2009 APWA Congress

A great deal of controversy surrounds the question of how much of the pollution found in urban stormwater runoff can be removed by street sweeping practices. Several calibrated modeling studies using observed road dirt accumulation data and stormwater quality data have concluded that street sweeping can be a very effective best management practice (BMP) with annual total suspended solids (TSS) reductions well over 60% (Sutherland, et al., 2006; Sutherland, et al., 2001; Sutherland and Jelen, 1997). Others believe that this isn't the case and cite the recent pilot study in Madison, Wisconsin (Selbig and Bannerman, 2007) and Baltimore, Maryland (CWP, 2008) where analyses of collected data and some modeling efforts seem to support the conclusion that street cleaning shows limited effectiveness in reducing the concentrations of pollutants found in urban runoff (Geosyntec, 2008).

The TSS data collected in both of these pilot studies were flawed. First, these studies did not measure all of the particulate material being transported by the runoff. And second, the modeling tools used in each study cannot accurately simulate the sediment accumulation, washoff and street sweeping removal behaviors that are occurring (Sutherland and Minton, 2009).

Both of the pilot studies used automatic samplers. In general, the particles that are most effectively removed by street sweepers are less effectively captured (or sampled) by automated samplers. For example, research has reported the potential bias of automated samplers that may not accurately characterize the presence of particles as small as 75 µm in stormwater (ASCE 2007) and can "miss" an increasing proportion of sediment in stormwater with increasing particle size (Selbig 2008). Burton and Pitt (2002) summarize the percentage of total sediment load that may be lost based on the size of the particle and sampler intake velocity. Using this information, it can be conservatively estimated that the sampler may have missed 25% of the particles in stormwater up to 3 mm (or 3,000 µm) in size. As a consequence, the usefulness of standard monitoring protocols to determine the effectiveness of street sweeping by comparing pretreatment and treatment stormwater pollutant loads is questionable.

How do we know that standard sampling techniques are a problem? A 1998 study of runoff from an Interstate highway in Cincinnati, Ohio, used gravimetric-based sampling techniques to collect whole volume discrete samples including all of the sediment being transported at that time. The entire volume of these discrete samples obtained throughout each sampled runoff event were filtered and analyzed. The study concluded that 20% by mass of the particulate material transported in the runoff ranged from 600 to 1,000 microns and 30% from 1,000 to 10,000 microns (Sansalone, et al., 1998). Recent discrete runoff sampling of eight storms captured from an elevated section of the I-10 Interstate highway in Baton Rouge, Louisiana, used both gravimetric sampling techniques and whole effluent analyses. This study found particles in transport that ranged from 1 to 24,500 microns in size (Kim and Sansalone, 2008).

Given the results of Sansalone's research, one must conclude that the concentrations of sediments found in runoff from highway pavements have been routinely under-sampled and thus understated. Many might argue that these courser fractions are not that important since conventional wisdom says that the bulk of the metals, phosphorus, petroleum and related hydrocarbons and pesticides are associated with the finer particulate fractions that are being captured. Unfortunately that belief is not the case. Metals, phosphorus, petroleum and related hydrocarbons, and pesticides, are all hydrophobic and, therefore, sorb to larger particles. Since these larger particles are not being collected these pollutants are also being understated. Sansalone and Cristina (2004) found that more than 60% of the particulate-bound metal mass observed in highway pavement runoff (i.e., Cd, Cu, Pb and Zn) was associated with particles greater than 250 microns.

Those that have been critical of street sweeping as an effective BMP often lack a good understanding of the complicated processes that relate to both the accumulation and transport by runoff of particulate material from urban streets. They often don't grasp how the effective removal of this accumulated material by cleaning practices can essentially deplete its available supply. The pilot studies that recently concluded street cleaning is not an effective BMP used very simple models or models whose washoff components were not based on sediment transport principles (Selbig and Bannerman, 2007; Center for Watershed Protection, 2008).

Pacific Water Resources (PWR) has developed a sediment transport-based model called SIMPTM that accurately reproduces these behaviors (Sutherland and Jelen, 1996). One important interaction included in the model is called wet weather washon. Wet weather washon is the transport of both particulate and associated pollutant loadings from adjacent paved and unpaved areas to the street and parking lot surfaces where they can be transported in subsequent runoff events downstream to storm system inlets or the waterways themselves. Some mistakenly believed that PWR's modeling studies do not account for any "off-street" loadings sources.

For example, an appendix on highway sweeping published by WSDOT in a March 2008 White Paper on BMP Effectiveness incorrectly stated that PWR's models rely solely on street buildup and washoff equations for the introduction of pollutants into runoff and that all other processes for how pollutants are entrained into runoff are assumed to be negligible (Geosyntec, 2008). In fact, the SIMPTM authors proved over 12 years ago that sediment and pollutant washoff can only be accurately modeled storm by storm, one season to another, year after year when the process of wet weather washon is accounted for (Sutherland and Jelen, 1996).

In addition, PWR seems to be the only researchers in the country that emphasize the importance of a street sweeper's ability to pick up and contain the entire range of accumulated particulate material. PWR studies using SIMPTM (Sutherland and Jelen, 1998) estimated, for example, that regenerative air sweeping on single-family residential areas in Livonia, Michigan, once every two weeks would remove from stormwater an estimated 63% of the TSS annual mass loadings (Sutherland, et. al., 2001).

Street dirt accumulation monitoring, Livonia, Michigan

Some have stated that PWR's street sweeping pollutant removal estimates "are highly questionable" (Geosyntec, 2008). Let's examine some numbers to see whether that statement is valid or not. The recent street sweeping pilot study of an urban residential watershed in Baltimore, Maryland, estimated that monthly regenerative air sweeping would reduce TSS by only 22% (CWP, 2008). The Livonia, Michigan, modeling study using SIMPTM calibrated to accurately simulate measured street dirt accumulations on a residential site concluded that monthly residential sweeping with regenerative air would reduce the entire range of TSS stormwater washoff by 48% (Sutherland, et. al. 2001).

Errors in both sampling and analytical methods used in the Baltimore study are estimated to have limited the observed TSS washoff to only half of the actual sediment mass being transported (Personal Communication with Dr. Sansalone, 2007). So if we assume that was the case in the Baltimore study, then the 22% TSS washoff reduction due to monthly regenerative air sweeping only really applies to the 50% of the sediments that were actually measured. If monthly regenerative air street sweeping were to remove from the washoff 75% of the other 50% of the courser sediments that weren't measured, then a 48% overall washoff reduction for TSS would be an accurate estimate.

So the question is whether monthly regenerative air street sweeping could reduce the transported TSS sediments that aren't being observed by traditional sampling practices by 75%. Since the runoff sediments that aren't being measured are most certainly greater than 200 microns, then a 75% reduction in the washoff of this courser fraction appears to be very reasonable. July 2008 testing of an Elgin Crosswind regenerative air machine operating at 5 miles per hour under real-world sweeping conditions found that the machine picked up 96.4% of the initial accumulated material (Sutherland, 2009). The pickup performance of the particulates greater than 250 microns was measured at 97.5%.

Pickup performance testing of an Elgin Crosswind regenerative air sweeper

Granted, street sweeper pickup is not the same thing as sediment washoff reduction, but they are closely related, especially for these courser sediments where washoff only occurs during more intense and generally higher-depth storms. Plus these higher-depth storms have longer return intervals that can generally equal or exceed the frequency of the monthly cleaning operations in our example. So the likelihood of keeping the available supply of these courser sediments low is quite good, especially when the pickup efficiency for this particle size group is so high. Therefore, a 75% reduction in the washoff of these courser sediments which weren't measured in Baltimore is very realistic. So what may appear to be "highly questionable estimates" to some are in fact very reasonable estimates when the complex processes are fully understood and all the sediments in transport are accounted for.

The question that should now be answered is whether these larger particulates that are estimated to make up half of the sediments in highway runoff are also that dominate in runoff from other urban areas like single-family residential and commercial land uses. We must also ask what impact has this fine sediment sampling bias had on the interpretation of the data collected to date.

Given the serious problems with the bias in data collection that have been used by recent street cleaning pilot studies, PWR strongly believes that these data sets should be reevaluated using physically-based explicit models like SIMPTM. Data analyses using these types of tools will result in a much better understanding of how effective urban cleaning practices truly are. Until this occurs, we at PWR believe it would be prudent for stormwater managers and public works personnel to recognize that the conclusions of these recent studies are flawed. If we truly did care about the maximum extent practicable (MEP) and cost-effective removal of pollutants from urban runoff, then the resources would be found to undertake a reexamination of these and other data sets. Until this occurs, the controversy surrounding the true effectiveness of urban street cleaning practices will continue and the water quality of our urban waterways will continue to suffer as a result.

Roger C. Sutherland will give a presentation on this topic at the 2009 APWA Congress in Columbus, Ohio. His session is entitled "Urban Myths Associated with Street Cleaning" and takes place on Monday, September 14, at 10:30 a.m. He can be reached at (503) 671-9709 or Roger.Sutherland@PacificWR.com.

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