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PARTICULATE ANALYSIS

Overview

The Environmental Protection Agency's (EPA) guidance for reducing pollution for Urban Areas is contained in a document entitled, *National Management Measures to Control Nonpoint source Pollution from Urban Areas* (November 20005, EPA-841-B-05-004). The specific section dealing with particulates is *Management Measure 5: New Development Runoff Treatment*. It is important to understand that any discussion of particulates needs to be taken in the context of this Management Measure. The context is "New Development" in "Urban" areas. This is an important distinction because the particulate material washing off of mostly natural, highly landscaped, or agricultural areas will more closely reflect background soil conditions, where newly developed urban sites are highly impervious surfaces and any landscaped areas are man-made amended soils. There are some areas left entirely "natural" in urban development sites, but this is the exception, not the rule. The lack of extensive background soil content limits the clay and silt sized particulate matter for these sites and explains why the EPA management measure guidance indicates that moving away from small particle bias is essential to good pollutant capture and control for these types of sites.

The goals of Management Measure 5 are threefold and often misstated. Section 5.1 contains the exact wording of this measure, but in general, the particulate loads (Total Suspended Solids or TSS) are required to be no greater than the predevelopment loads, or they can be reduced to 80 percent of the influent levels on the site prior to pretreatment. The definition of predevelopment is the condition of the land prior to the new development, not prior to any human-induced land disturbance. The guidance does allow for the use of a baseline condition, such as a local meadow or forested site to be used as the standard for sites where excessive erosion or sediment export is the "pre-developed" condition. Despite the fact that the guidance explicitly allows a development to be simply "better" than the existing conditions, almost always new development is held to the "80 percent reduction of TSS" standard, and other options are not explored. This emphasis on reducing particulates by 80 percent makes it imperative to understand exactly how "Total Suspended Solids" is defined, and how influent and effluent particulates are measured.

Total Suspended Solids (TSS)

In Section 5.2.1.1, the guidance states: "Many pollutants bind to and are entrained in sediment or particulate loadings. Particulates include suspended, settleable, and bedload solids. Metals, phosphorus, nitrogen, hydrocarbons and pesticides are commonly found in urban sediments." Following this is the definition of TSS, "TSS is a measure of the concentrations of sediment and other solid particles suspended in the water column of a stream, lake, or other water resource. TSS is an important parameter because it quantifies the amount of sediment entrained in runoff." The guidance is completely clear that TSS refers to all particulate matter in runoff, regardless of size, composition, or source. The link between particulate matter and pollutants is first defined, and then the particulate matter is defined. Further clarifying the fact that both large and small particles are important, the guidance addresses two studies in the following text immediately following. The first study indicates that the relative proportional mass of heavy metals seems to increase with decreasing particle size, and the second observes that the greatest mass of contaminants in highway runoff is found on particles in the 425 to 850 micron range. These statements seem to be contradictory, but the guidance explains that it makes sense to address all particulates of concern, which may vary by region or conditions on a specific site within a region.

The most important thing to understand is that the EPA guidance mandates the removal of pollutants, and associates pollutants with particulates of all sizes. This can be accomplished by treating all the run-off up to a particular sized storm and showing the ability to remove 80 percent of the particulates. The removal of the particulates is not claimed to be equivalent to pollution removal, but it is suggested that by removing most of the particulates will remove most of the pollutants that tend to associate with particulates. Some level of particulate removal is allowed to be a surrogate or substitute for the removal of actual pollutants. The concept is a good one, but it has flaws.

One flaw is the assumption that removal of the smaller fraction of particles during low flow storm events will meet the pollution removal goals. This is the "first flush" treatment scenario. The logic is that because some pollutants tend to attach more readily to small particles, surely nothing more needs to be done. This is likely true for a meadow where natural soils exist and where pesticides are sprayed on vegetation, but it is completely wrong for an urbanized site where impervious surfaces dominate and natural soils do not exist. On that type of site, catching a few pounds of fine material while tons of larger material are literally bypassed around a low flow system is the worst possible scenario. This has been allowed and even encouraged by well meaning regulators who do not understand the physics of particulate movement and capture. In their quest to develop "tougher" standards by lowering particle size requirements in their test protocols, they force systems to bypass the larger flows and miss the bulk of pollutants coming off of urbanized sites. If there is a requirement for pretreatment systems to treat the larger flows in advance of a low flow/small particle system, this practice can be effective. When the entire system treating the water quality flow is subjected to the small particle type of regulation it is certain to be ineffective because it never encounters the bulk of pollutants that are attached to and contained in the majority of particles which are larger and only move then the system is off line and bypassing the larger flows.

TSS as an Analysis Method versus TSS as a Particulate Measurement

One of the factors that lends support to improper design standards is confusion about Total Suspended Solids (TSS meaning particulates) and the EPA analysis method, unfortunately bearing the same name, "TSS". The analysis method is properly referred to as "EPA 160.2 TSS". This is not a testing protocol or an efficiency standard, it is simply a laboratory analysis procedure. The intent of the analysis procedure is to determine the weight of particulates in the sample (in milligrams) that is contained in the liquid volume of the sample (in liters). The analysis yields a value in "mg/L." There is a well documented bias in the EPA 160.2 TSS analysis procedure towards small particles. The analysis method was developed for the wastewater treatment industry, and works very well for small, suspended particles in treated wastewater samples. It also works very well in lake or estuarine environments. It is not recommended for moving natural waters like rivers or streams, and it is certainly not useful for stormwater flows. The reason for this is that EPA 160.2 TSS does not measure the entire sample. The sample is first agitated in an attempt to distribute the particulates evenly throughout the sample, and then a small sub-sample is drawn out through a pipette. The small sub-sample is all that is actually tested. This means that large particles, which tend to settle quickly are less likely to be at the sampling level of the pipette than smaller ones, and that the narrow opening of the pipette excludes larger particles altogether. The interval between the agitation and the sampling can vary, as can the sampling level of the pipette, based on the skill of the operator. In addition, with variable sized particles that have variable densities as well, obtaining an even distribution of particles at any given moment is practically impossible. This is why EPA 160.2 TSS is simply the wrong test for particulates in stormwater. Not only is it small particle biased, it is not repeatable within most quality control/quality assurance testing standards. The exact same sample when analyzed by EPA 160.2 TSS multiple times will give multiple answers. This failure to be repeatable is a serious shortcoming. It is unfortunate that in the early days of water quality analysis, almost all of the existing data for stormwater was developed using EPA 160.2 TSS. It is equally unfortunate that many people continue to use "TSS" interchangeably to mean "Total Suspended Solids" (particulates) versus "TSS" the analysis method. This indicates that the results of TSS style analysis reflect the total particulates in a water sample, and it absolutely does not.

TSS versus SSC as an Analysis Method

The gap between the TSS analysis method's results and the actual weight of particulates in a water sample is glaringly obvious when a sample is analyzed by both the TSS method and the SSC (Suspended Sediment Concentration) method as recommended by the USGS (United States Geological Survey). The actual name of this analysis methodology is ASTM D3977-97. The USGS has experience measuring suspended sediments dating back far before the Clean Water Act and does not accept that EPA 160.2 TSS is appropriate for stormwater. In side-by-side comparisons on samples, the SSC method of analysis has proven to be more accurate and repeatable than TSS analysis which always under-reports the actual concentration of particulates in water samples. This is due to the analysis techniques used in SSC. With the SSC method, the entire sample is measured, not just a sub-sample. The entire sample is poured through a filter which catches all the particulates, which are then weighed in their entirety. Since the entire volume of the sample is known, the results are simply expressed as the total milligrams in the total volume in the same units as the TSS method, mg/L. When a one liter stormwater sample is analyzed by the SSC method and it contains 100 milligrams of sediments, it means that the laboratory ended up with an actual weight of 100 milligrams of solid materials from that one liter sample. The same sample analyzed by the EPA 160.2 TSS might show as little as 20 mg/L, depending on the size of the particles in the sample. The SSC analysis method is considered to be more accurate because it measures all of the particles and all of the water, all of the time.

It is remarkable that some regulators actually question the accuracy of total suspended solids (particulates) measurements when the SSC methodology is used. This assessment flies in the face of the science that confirms the inaccuracy of EPA 160.2 TSS and confirms the accuracy of the SSC methodology as recommended by the USGS. In all cases, SSC would be the scientifically preferred method of analysis. The reasoning behind continuing to utilize the EPA 160.2 TSS method is one of cost. The SSC analysis method is much more costly than EPA 160.2 TSS. If the issue is determining the best water quality results, the extra cost is easily justified. To further substantiate the use of SSC analysis over EPA 160.2 TSS, one only needs to review the research of the Federal Interagency Sedimentation Project (FISP) and their reports on proper analysis. This group is comprised of seven Federal Agencies including: the U.S. Environmental Protection Agency, the U.S. Geological Survey, the U.S. Army Corps of Engineers, the U.S. Bureau of Land Management, the U.S.D.A. Forest Service, the U.S.D.A. Agricultural Research Service, and the U.S. Bureau of Reclamation. In their Technical Committee Memorandum 2007.01, "FISP Policy of Collection and Use of Total Suspended Solids Data", they state, "The SSC analytical method, ASTM D 3977, Standard Test for Determining Sediment Concentration in Water Samples (ASTM, 2006), is the **accepted standard** for determining concentrations of suspended material in surface water samples." It further states, "When collection of samples to determine TSS is required, concurrent collection of samples for suspended-sediment concentration (SSC) must be done. Concurrent SSC analysis can only be discontinued after it is conclusively documented in a publicly available report that the TSS data, on a site-by-site basis, can adequately represent SSC data over the whole range of flows that can be expected.". These statements reflect the overwhelming consensus of current research that proves the reliability of SSC analysis and seriously calls into question the use of TSS analysis. It is clear that any agency that bases BMP evaluations, removal models, or regulations on data derived from EPA 160.2 TSS is not on solid scientific ground.

There is some good news for the EPA 160.2 TSS analysis method. It is still very good in small particle dominated environments, such as lakes, estuaries and other still water environments. It is also very good for many effluent samples below stormwater BMPs. When the TSS and SSC methods were used "side by side" on the same samples downstream of BMPs that were tested in the ETV program, the results agreed much more closely. This makes sense, as the BMPs were removing most of the larger particles which throw off the EPA 160.2 TSS analysis. The TSS method still under-reported, but it did so in a more consistent fashion that might lend itself to some adjustment factor. Because of the inability of EPA 160.2 TSS to "see" larger particles, there can be no possible correlation of TSS and SSC data on the influent side. Efforts to make some mathematical adjustment to SSC values to reduce them to EPA 160.2 TSS values are completely invalid for two reasons. The most important reason is that the "true" value is found in the SSC number which cannot over-report the mass of sediments, so the TSS should be adjusted to match the SSC number, not the other way around. Secondly, without detailed particle size analysis to show which particles would be "missed" by the TSS analysis, no reasonable adjustment factor could be proposed.

Summary

The guidance in *Management Measure 5* is clear. In general, it calls for the reduction of the pollutants entrained in stormwater runoff to be reduced to pre-development levels. It associates pollutants with particulates and cites studies that indicate the contaminants can be and usually are associated with both large and small particles. Particulate analysis has been traditionally done by the ASTM D3977-97. The EPA 160.2 analysis method has been shown to be inappropriate for stormwater particulates because of its small particle bias. The ASTM D3977-97 (SSC) analysis method is more accurate, reliable, and repeatable. Although some agencies try to make adjustments for TSS versus SSC data, that practice is problematic at best. Both methods attempt to report the concentration of particulates in stormwater samples. Whatever that concentration happens to be, it is a finite number which both methods try to measure. The TSS analysis simply gives erroneous results for stormwater samples.

Based on TSS results, some jurisdictions are using protocols that concentrate wrongly on small particles, and force BMP treatment systems to only treat low flows for two reasons. The first reason is to allow enough time for smaller particles to settle out or be filtered out. The second is to avoid re-suspension of captured particles, or to stay within the flow through capacity of filters. When this practice leads to systems that bypass higher flows and larger particles, it is counter-productive to water quality. When dealing with background soils and dissolved chemicals, this practice may be justifiable, but when dealing with highly urbanized sites that are mostly impervious, it clearly is not. No water quality rules or protocols for urban sites should be written based on data gathered and analyzed by the EPA 160.2 TSS methodology.