Particle size matters when sizing stormwater treatment systems

By Sean McNeely

Municipalities across Canada are now beginning to give stormwater pollution the much-needed attention it deserves. Media searches reveal articles from coast to coast, reporting how cities and regions are developing stormwater management plans, establishing stormwater boards, or adopting stricter regulations for future development.

A growing number of cities are now adding a fact sheet to their web sites, educating users about the harmful effects of polluted stormwater, as well as offering homeowners tips for reducing runoff in their neighborhood. Over the last five years, British Columbia's Ministry of the Environment has developed an extensive stormwater planning guidebook to be followed by all regions and municipalities for any kind of urban or rural development.

With stormwater pollution squarely on the map, this increased attention has accelerated the installation of stormwater treatment systems, particularly in urban developments. However, when designing and sizing a proprietary treatment device, some municipalities appear to be ignoring a crucial piece of data that has a significant impact on effectively stopping pollutants from reaching natural waterways – *Particle Size Distribution* (PSD).

A defined PSD identifies all sediment particle sizes found in a stormwater runoff sample, including diameters, content and concentration. It's a blueprint of exactly what is barreling down the pavement during each rainfall.

When sizing a stormwater treatment device, PSD can be the most critical design parameter. It determines the size of the actual structure and what the unit is targeted to remove. However, when assessing and sizing treatment devices, PSD is rarely raised, let alone considered. Instead, stormwater treatment devices are often sized by their ability to meet a water quality objective defined by the removal of Total Suspended Solids (TSS) which can be defined as the dry mass of solids retained on a 1-µm filter.

Many regulating authorities are content with achieving a standard water quality objective of removing 80% of TSS. But the question is, 80% of what?

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The answer is 80% of whatever solids are trapped by this filter, regardless of particle size. The breakdown of that 80% in terms of gravel, sand, clay and silts is anyone's guess. Exactly what is being stopped and what is allowed to pass is unknown, though it is likely the bulk of particles trapped are the largest.

By not using a defined PSD in sizing stormwater treatment devices, inadequate systems may be implemented, capturing larger coarser particles, but letting smaller particles pass completely untreated. And yet it is the smaller particles that are the most harmful to natural waterways. Letting these smaller particles pass is the equivalent of exposing our rivers and waterways to second-hand smoke, with their ability to pollute clear water.

In December 2005, The Center for Research in Water Resources (CRWR) at the University of Texas in Austin, released a report titled, *Particle Size Distribution of Highway Runoff and Modification through Stormwater Treatment.* The report's message – we should all be far more concerned with smaller particles than the larger ones.

Why are finer particles such as clays and silts so dangerous as opposed to sands and gravel? They have the most surface area by mass, which allows them to carry more pollutants (heavy metals, hydrocarbons, nutrients, etc.) found in stormwater runoff. As the CRWR noted, "The concentration of metal, zinc for example, in terms of total per cent of stormwater solid mass, increased as the particle size decreased." As well, smaller particles were found to carry higher concentrations of copper, phosphorus and nitrogen.

Add to this, how much further finer

particles travel. "Larger particles in stormwater runoff settle out, but smaller particles remain suspended in stormwater runoff and travel greater distances," reads the report.

All of these characteristics led the CRWR to conclude: "Treatment systems must be able to effectively remove fine particles in runoff to significantly reduce the pollutant loads."

This is certainly not news to Barry Bohn, the Principal of Watertech Engineering Research and Health Inc. and a former engineer with the City of Calgary. Having conducted PSD tests for the City of Calgary, Bohn encourages jurisdictions across the country to consider examining just what their stormwater treatment devices are capturing and removing. They might be surprised at the results.

"Take a very good look at what your PSD is, do some monitoring, collect some samples," urged Bohn. "It's not a one size fits all thing anymore."

While conducting studies on BMP separation devices for the City of Calgary, Bohn was involved in a series of tests to see if the city's stormwater treatment devices installed around the metropolitan area were effective in stopping stormwater pollutants.

In one constructed area, the PSD was not what he expected. "When we were looking at the influent samples and the effluent samples, we weren't finding a lot of big particles, we were finding a lot of silt-range particles and a lot of clay-sized particles," said Bohn. "The assumptions we had made about particle size distribution and these larger particles just wasn't holding."

He chalked up the findings as unique to that particular site and then conducted similar tests at a large parking lot and assumed he would find very different results. "Low and behold, we found exactly the same thing," said Bohn.

"In Calgary and around southern Alberta we have a lot of these silty clay type materials," continued Bohn. "When you expose them, they are easily erodable - a couple of raindrops hit them and they're mobilized right away." That mobility sends finer particles from stormwater right into the receiving stream where they may affect fish, cause algae blooms due to excess nutrients associated with particles (such as phosphorus), or carry hydrocarbons which may contaminate water bodies.

Because of these destructive effects, it's the smallest particle in a PSD that should dictate a stormwater treatment system's size for effective stormwater management.

Merely being satisfied by the amount of material being treated in terms of mass, or even in terms of stopping an average particle size, provides a false sense of security. However, finances are a factor here - a stormwater treatment system designed to remove larger particles like gravel and coarse sand is smaller and less expensive than a system designed to remove fine silts and clays.

To capture finer particles in stormwater runoff, the key element is time – providing the necessary area and time for smaller, finer particles to settle. Because of this time factor, some current vortex stormwater treatment devices that rely on velocity for separation may not be effective. As fine particles enter and circulate in such units, there simply isn't enough time for them to settle. While some larger particles are allowed to settle under the forces of gravity, smaller particles essentially go for a spin, remain in suspension, and can exit these systems virtually untouched.

Stormwater treatment devices that use only gravity settling as their mechanism for separation and maximize retention time are arguably the most effective option. Capable of capturing and containing a wide range of particle sizes, devices that use gravity create a calm treatment environment, allowing stormwater to slow down. This gives fine silts and clays the necessary space and time to settle.

However, determining just how much space and time is needed is not easy. To take the guesswork out of accurately sizing and designing a stormwater treatment device, continuous modeling software tools like US EPA's SWMM (Storm Water Management Model) are required.

SWMM simulates local up-to-date rainfall and also identifies a wide selection of particle sizes (including fine particles), helping the user to design the best suited system for a particular site. And that's the philosophy behind responsible stormwater management – each site is unique, with a specific PSD that needs to be identified as it represents the starting point in treating stormwater runoff.

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