Product Evaluation

Evaluation of the Stormwater Management StormFilter® for the removal of SIL-CO-SIL® 106, a standardized silica product:

ZPG™ StormFilter cartridge at 28 L/min (7.5 gpm)

Overview

A Stormwater Management StormFilter® (StormFilter) ZPG™ cartridge was tested to assess its ability to remove total suspended solids (TSS) and decrease turbidity from simulated stormwater. Under controlled conditions, 7 runoff simulations (sims) were performed using influent TSS with a silt texture (20% sand, 80% silt, 0% clay), variable event mean concentrations (EMCs) between 0 and 300 mg/L, and a filtration rate of 28 L/min (7.5 gpm) (100% design, per cartridge, operating rate for this configuration). The mean TSS (silt) removal efficiency for this StormFilter cartridge configuration was determined using regression statistics and found to be 87% ($P=0.05$: $L_1=86\%$, $L_2=89\%$) over the range of influent EMCs tested. Turbidity data was also collected and indicated that this StormFilter cartridge configuration was capable of a 51% ($P=0.05$: $L_1=47\%$, $L_2=55\%$) mean decrease in turbidity.

Introduction

The goal of testing the ZPG™ StormFilter cartridge was to determine its TSS and turbidity removal performance given a standardized commercial product as the contaminant surrogate. Utilizing a standardized contaminant surrogate eliminates contaminant characteristics as a variable, thereby providing opportunities to compare StormFilter performance with that of other StormFilter configurations or treatment systems tested using the same contaminant surrogate. To assure the comparability of this experiment with other StormFilter performance evaluations, the methodology used for this experiment is identical to that used in previous cartridge-scale StormFilter evaluations for solids removal (Stormwater360, 2002; SMI, 2002a).

Procedure

Media

A StormFilter ZPG™ cartridge was used for this experiment. This specific type of cartridge contains ZPG™ multipurpose media, a proprietary blend of organic and inorganic media (as per Stormwater360 product specifications). ZPG™ media is effective in the removal of solids, metals and organic chemicals.

Prior to testing, the ZPG™ StormFilter cartridge used for testing was flushed so as to remove the residual dust within the media left over from the cartridge production process, as well as to allow the media to approach a typical, wet operating condition. Individual, ~400-L, tap water flushes were performed according to the operation segment of the procedure section. Flushing was ceased after eight flushes, at which point the effluent TSS EMC had decreased to 8.8 mg/L from an initial value of 218 mg/L.

Contaminant

A commercial ground silica product, SIL-CO-SIL® 106 (SCS 106), was used as the surrogate for TSS. This product is manufactured by the US Silica Company* and the sample used for testing originated from the Mill Creek, OK plant. SCS 106 has a uniform specific gravity of 2.65 and is specified by the State of Washington Department of Ecology (WADOE) for the laboratory evaluation of stormwater treatment technologies (WADOE, 2002) for TSS removal. An average particle size distribution is shown in Figure 1, revealing a silt texture (USDA scale) consisting of 20% sand, 80% silt, and 0% clay-sized particles (Stormwater360, 2002).

Based upon a 400-L influent volume, target TSS EMCs were determined for each planned contaminated simulation and associated masses of contaminant were placed in 1-L HDPE bottles of tap water--one bottle of concentrate per planned contaminated simulation. Target TSS EMCs were distributed between 0 and 300 mg/L. The order in which they were used was randomly selected using random number techniques so as not to bias the performance results. The SCS 106 concentrates were given the opportunity to hydrate prior to experimentation so as to promote the disintegration of any aggregate particles that may have been present. The concentrates were then left out at room temperature and periodically shaken to encourage the dissolution of any aggregates.

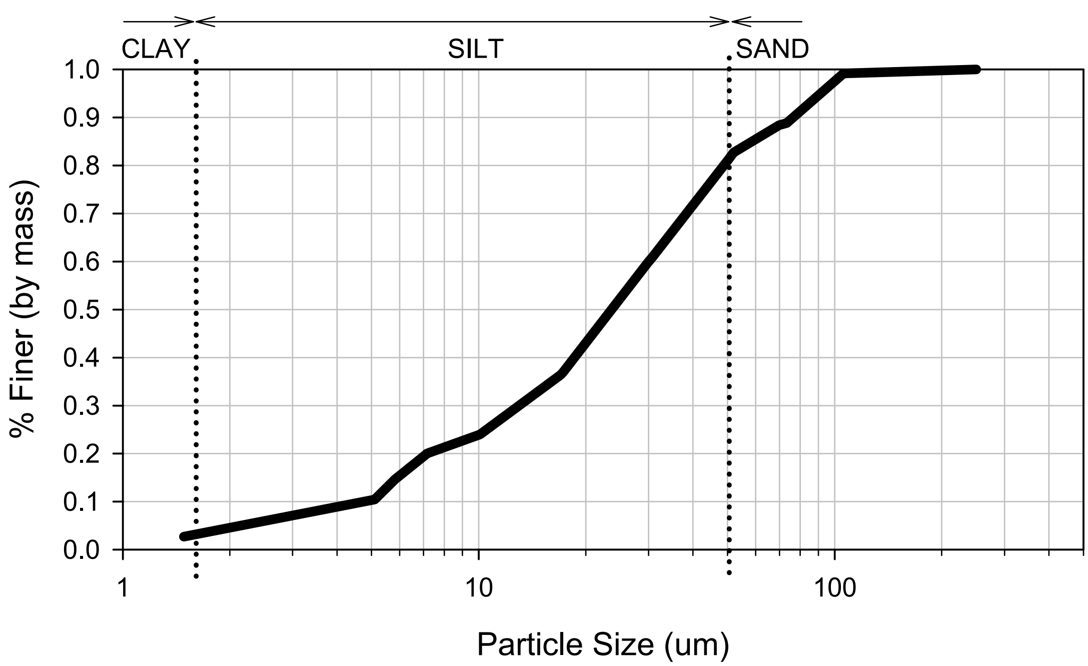

Figure 1. Particle size distribution for SCS 106. Sand/silt/clay fractions according to USDA definitions are approximately 20%, 80%, and 0% for SCS 106, indicating that the texture corresponds to a silt material.

Test Apparatus

The typical precast StormFilter system is composed of three bays: the inlet bay, the filtration bay, and the outlet bay. Stormwater first enters the inlet bay of the StormFilter vault through the inlet pipe. Stormwater in the inlet bay is then directed through the flow spreader, which traps some floatables, oils, and surface scum, and over the energy dissipator into the filtration bay where treatment takes place. Once in the filtration bay, the stormwater begins to

*U.S. Silica Company, P.O. Box 187, Berkeley Springs, WV 25411; (800) 243-7500; www.u-s-silica.com pond and percolate horizontally through the media contained in the StormFilter cartridges. After passing through the media, the treated water in each cartridge collects in the cartridge's center tube from where it is directed into the outlet bay by an under-drain manifold. The treated water in the outlet bay is then discharged through the single outlet pipe to a collection pipe or to an open channel drainage way.

The test apparatus used for this experiment simulates the filtration bay component of a full-scale StormFilter system, including the energy dissipator. Since the design of full-scale StormFilter systems varies, and since the operation of a full-scale system in the laboratory environment would require very large volumes of water, the use of the most common components among all of the possible designs, the StormFilter cartridge and the associated volume of filtration bay area, were selected so as to provide a very conservative estimate of StormFilter performance.

Unlike chemical removal testing, suspended solids removal testing is challenging due to the relatively large, dense, insoluble nature of the contaminant. Care must be taken to maintain the suspension of solids within the influent and effluent reservoirs, maintain the suspension of solids within the conveyance system, avoid the fouling of flow metering devices, avoid the destruction of individual solids by the pumping system, and avoid the destruction of the pumping system by the solids.

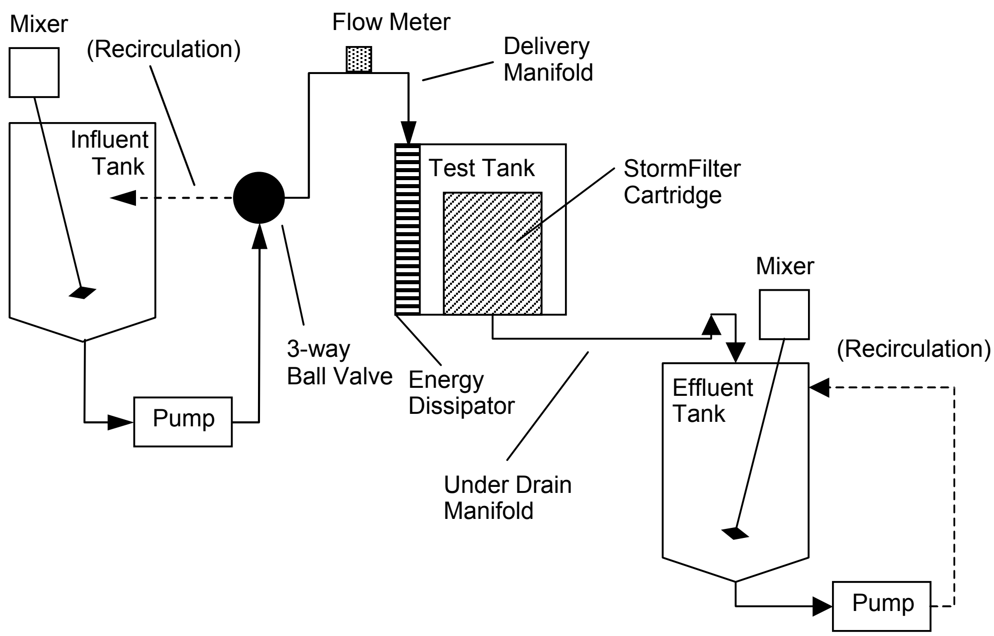

Figure 2. Schematic diagram of the cartridge-scale test apparatus. Arrows indicate flow pathways. Dashed arrows indicate recirculation pathways employed during influent and effluent sampling.

The apparatus used for this experiment was carefully designed to meet these challenges. Figure 2 demonstrates the layout of the test apparatus. Influent and effluent storage is provided by individual 950-L (250 gallon), conical bottom polyethylene tanks (Chem-Tainer). The conical bottom design ensures full drainage of the tanks, in addition to the movement of all solids out of the tanks. Four, evenly-spaced, vertically-oriented baffles, measuring 91 x 8 x 1-cm (36 x 3 x 0.5-in) (L x W x Thickness), affixed to the sidewalls of the influent and effluent tank prevent a mixer-induced vortex. Suspension of solids within the tanks is maintained by individual, 1/2-hp, electric propeller mixers with stainless steel mixing assemblies (J.L. Wingert, B-3-TE-PRP/316). The propeller design maximizes the vertical circulation of solids within the tank and ensures the homogeneity of the mixture. Magnetic drive pumps (Little Giant, TE-6-MD-HC) are used to transfer the influent, and also to re-circulate water through the underlying manifolds of both tanks during sampling so as to eliminate any possibility of sediment accumulation in the manifolds.

Influent is carried from the influent tank by the magnetic drive pump plumbed with 25-mm (1-in) PVC hose into a PVC intake manifold below the influent tank and discharging into a delivery manifold of 25-mm PVC pipe. Despite the associated head loss, 25-mm diameter hose and pipe are used to ensure high flow velocities that maintain the suspension of solids during transfer. A 25-mm, 3-way, side-control, ball valve used for flow control assures very high flow velocities in the intake manifold, allows some degree of re-circulation back into the reservoir, and allows the high power pump to operate relatively unrestricted.

Discharge from the delivery manifold into the 56 x 56 x 62-cm (22 x 22 x 24.5-in) (L x W x H) polypropylene StormFilter cartridge test tank is by discharge into the tank-mounted energy dissipater, which consists of a vertical length of 76-mm (3-in) PVC pipe with an open bottom and multiple 3-mm (0.125-in) wide horizontal slots along its entire length. The energy dissipater is a typical component of a StormFilter system and is used to minimize the re-suspension of settled material within the test tank by restricting turbulence to the region within the dissipater. Discharge from the StormFilter cartridge test tank into the effluent tank is through free discharge from the under-drain manifold component of the test tank positioned over the top of the effluent tank.

Flow into the StormFilter cartridge test tank is controlled by the 3-way ball valve placed between the pump and the delivery manifold, and flow is monitored with a paddle-wheel type electronic flow meter (GF Signet, Rotor-X Low Flow) coupled with a flow transmitter with totalizer (GF Signet, Processpro).

Operation

The operational procedure consisted of performing multiple runoff simulations (sims) using the same StormFilter cartridge test tank and apparatus described in the Test Apparatus section above. Sims proceeded as follows.

The influent tank was filled with ~400-L of tap water, and the predetermined contaminant concentrate was added to the influent tank. The influent tank was then mixed thoroughly with the mechanical mixer while influent was re-circulated through the underlying manifold and allowed to equilibrate for 5 to 10 minutes before sampling.

Following influent sample collection, a portion of flow was redirected to the test tank energy dissipator via the delivery manifold through adjustment of the 3-way valve. Flow rate was controlled through periodic adjustment of the 3-way valve so as to maintain a constant flow rate reading of 28 L/min ± 2 L/min (7.5 gpm ± 0.5 gpm). Mixing and re-circulation of the effluent reservoir was started towards the end of a sim to allow effluent equilibration prior to sample collection.

The influent pump was operated until as much of the influent had been pumped from the influent reservoir and underlying manifold as was possible, at which point the influent pump was shut down and the StormFilter cartridge test tank was allowed to drain. Once the float valve within the StormFilter cartridge closed, effluent was sampled and the total sim volume reported by the totalizer was recorded.

Sampling

Composite samples of influent and effluent were collected for TSS and turbidity analysis. One set of samples was collected for TSS analysis by North Creek Analytical (NCA), Beaverton, OR, and an additional set was collected for internal turbidity analysis. For this document, a set is defined as a collection of influent and effluent sample pairs corresponding to a specific sim.

Sample handling was performed in accordance with standard handling techniques. All samples to be tested for TSS were promptly refrigerated following collection. Samples were shipped to the laboratory in coolers, accompanied by ice-packs and chain-of-custody documentation for analysis within seven days. NCA performed TSS analysis according to

ASTM method D3977, which is essentially the same as the "whole-sample" variation of EPA method 160.2 (SMI, 2002b).

Samples were extracted with a 1-L PE, 1.2-m ladle using a sweeping motion across and through the center of the reservoir. Six 1-L grab samples were collected in an 8-L churn sample splitter (Bel-Art Products) for composite sample extraction according to manufacturer instructions. Care was taken to transfer all solids from the ladle through quick emptying of the ladle while using a swirling motion. The churn splitter was used to dispense approximately 250-mL of composite sample into 250-mL (8-oz) HDPE bottles for TSS analysis and an additional 500-mL composite sample was dispensed to a 1-L (32-oz) HDPE bottle for turbidity analysis. The sampling ladle and churn splitter were subject to a high-pressure wash between uses.

Internal Analysis

Turbidity, a measure of the light-dispersing characteristics of a fluid, was measured using a bench-top turbidimeter (LaMotte Model 2020). The sample was swirled in its bottle immediately before pouring a subsample to the turbidimeter tube. The tube was wiped clean of moisture using lint-free wipes and then swirled, taking care to prevent bubbles in the sample and to maintain a clean tube surface, prior to insertion into the turbidimeter. The turbidimeter tube was rinsed with deionized water between each use.

Results

TSS removal and turbidity results are shown in Table 1. The discrete efficiencies, efficiencies of individual pairs of associated influent and effluent TSS EMCs, suggest an increase with increasing influent TSS EMC. A similar trend is evident for the generally increasing turbidity reduction contrasted to increasing average influent turbidity.

Table 1. Summary of influent and effluent TSS EMCs and turbidity along with TSS removal and turbidity decrease results shown according to increasing influent TSS EMC.

Influent TSS EMC (mg/L)	Effluent TSS EMC (mg/L)	Discrete TSS Removal Efficiency (%)	Average Influent Turbidity (NTU)	Average Effluent Turbidity (NTU)	Discrete Turbidity Decrease (%)	Sim	Sim Volume (L)
ND (4.00)	7.09	addition	0.45	2.3	addition	7	401
25.4	14.2	44.1	4.1	5.4	addition	4	398
49.1	17.0	65.4	8.8	7.7	12.5	6	397
107	21.1	80.3	17	10.2	40.0	1	393
144	28.2	80.4	25	15	40.0	2	396
188	33.2	82.3	35	19	45.7	5	393
292	45.5	84.4	53	29	45.3	3	389

Discussion

Quality Control

For TSS analysis, Method Blank and Duplicate quality control samples are typically used to measure bias and precision. Method Blank results as reported by the analytical laboratory were non-detect (<4 mg/L) for the four sets of analyses that comprised the data set shown in Table 1. Unfortunately, since the "whole-sample" nature of ASTM method D3977 involves the use of the entire sample volume, none of the sample volume is left over for traditional Duplicate analysis. Thus dedicated Duplicate samples were collected for 2 of the 14 TSS analyses (14% duplicates) and are displayed in Table 2. The results of the Method Blank and Duplicate analyses demonstrate an acceptable level of bias and precision according to SMI (2002c).

Table 2. Summary of Quality Control results.

Sim	Influent/Effluent (I or E)	Official Result (mg/L)	Duplicate Result (mg/L)	Relative Percent Difference (%)
2	I	144	143	0.7
2	E	28.2	29.0	2.8

TSS and Turbidity Removal Performance Evaluation

The graphed results of the external TSS analysis, displayed in Figure 3, show a regressed removal efficiency of 87% (P=0.05: L1=86%, L2=89%), which is calculated by subtracting the regression coefficient (slope) from 1. Based upon an analysis of variance (ANOVA), the regression is significant at the P<0.001 level (<0.1% probability of no correlation between influent and effluent TSS EMC's). Coupled with y-intercept and regression coefficients that are both significant at the P<0.001 levels, this signals a good fit of the data points to the regression equation, which is visually supported by the tight 95% confidence intervals. At P<0.001, the confidence in the TSS EMC removal performance estimate is within the 0.05 limit considered by SMI (2002d) to indicate a valid estimate.

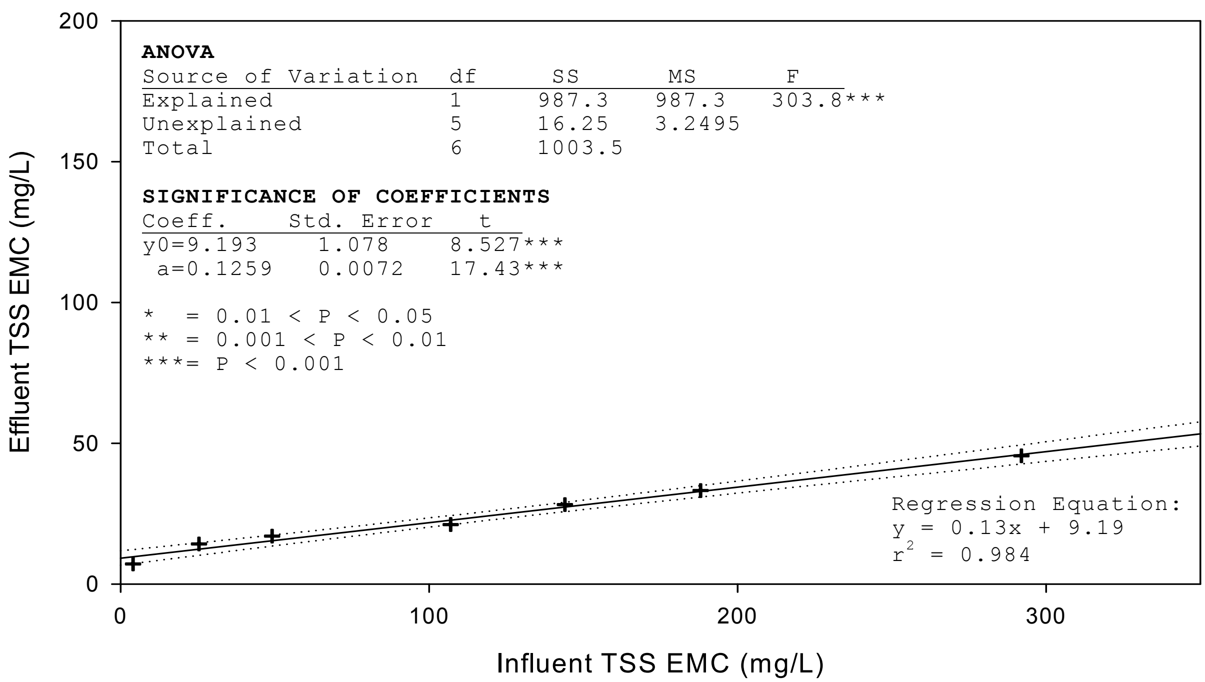

Figure 3. Regression analysis applied to the TSS data associated with the estimation of the SCS 106 TSS removal efficiency of the ZPG™ StormFilter cartridge at 28 L/min. The solid line is the regression. The dotted lines signify the lower and upper 95% confidence intervals. ANOVA indicates a significant (P<0.001) linear relationship between influent and effluent TSS EMC.

The decrease in turbidity associated with the ZPG™ cartridge test is less than the reduction of TSS. The mean turbidity reduction, shown in Figure 4, was observed to be 51% (P=0.05: L_1=47%, L_2=55%) based upon regression analysis that is significant at the P<0.001 level. The y-intercept and regression coefficients, significant at the P<0.01 and P<0.001 levels, respectively, provide ample confidence in the observed relationship.

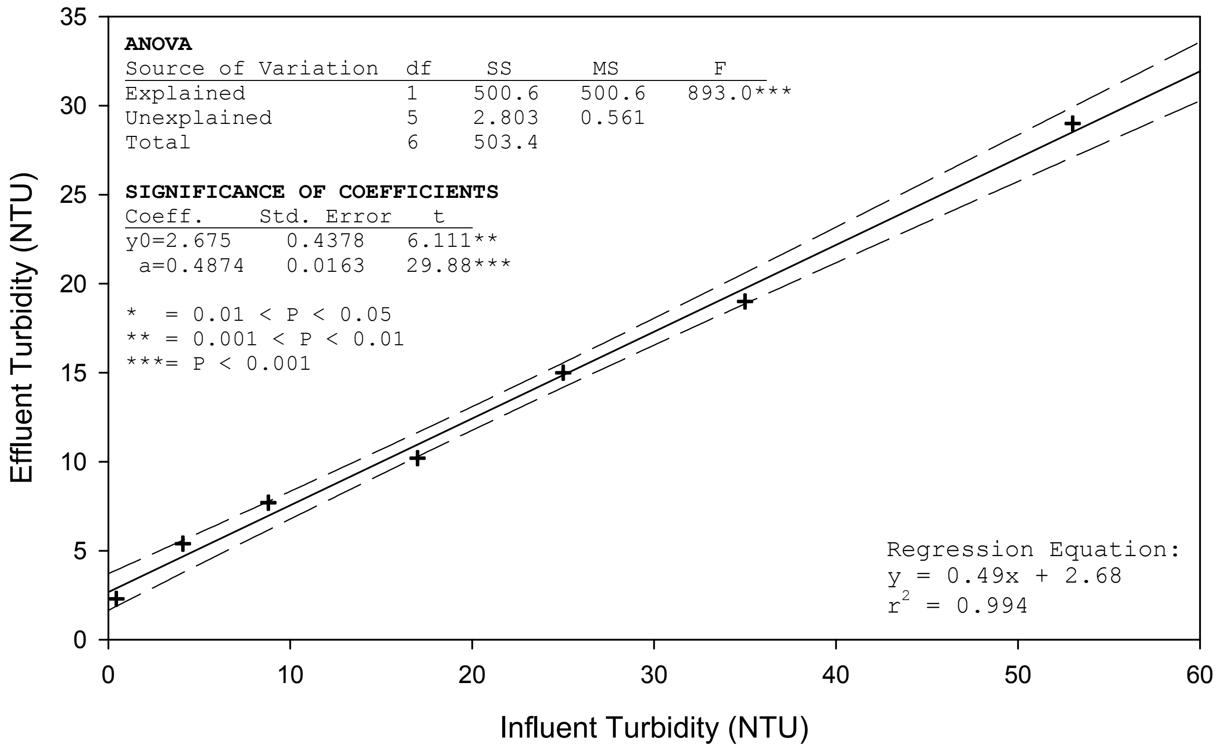

Figure 4. SCS 106 turbidity reduction by the ZPG™ StormFilter cartridge at 28 L/min. The solid line is the regression. The dotted lines signify the upper and lower 95% confidence intervals. ANOVA indicates a significant (P<0.001) linear relationship between influent and effluent turbidity.

TSS Removal Performance with Regard to Particle Size

Based upon the particle size distribution presented in Figure 1, SCS 106 consists primarily of silt-sized silica particles (80% by mass between 2 and 50 microns). Combined with the TSS removal estimate of 87% (by mass) demonstrated in Figure 3, some qualitative inferences concerning the particle size specific removal efficiency of the system can be made.

Assuming that larger particles are preferentially removed over smaller particles, it could be said that the system under review removed particles down to the 6 micron level since, conservatively, 87% (by mass) of SCS 106 is composed of silica particles larger than 6 microns. Since it is likely that some particles smaller than 6 microns were retained and some particles larger than 6 microns were lost by the system, the efficiency of the system under review with regard to particle size is probably best represented by a size range. With this in mind, a better qualitative statement with regard to the particle size removal efficiency of the system under review would be that it is capable of removing silica particles in the vicinity of 10 microns.

Conclusions

The tests utilizing SCS 106 as a contaminant generated results for the assessment of the silt TSS and turbidity removal efficiency of the ZPG™ StormFilter cartridge. The use of a standardized contaminant surrogate allows the results from laboratory evaluations of the TSS removal performance of stormwater treatment systems to be easily compared. In summary:

1. A ZPG™ StormFilter cartridge test unit, operating at 28 L/min, and subject to TSS with a silt texture (20% sand, 80% silt, and 0% clay by mass) originating from SCS 106 provides a mean TSS removal efficiency of 87% (P=0.05: L_1=86%, L_2=89%);
2. A ZPG™ StormFilter cartridge test unit, operating at 28 L/min, and subject to TSS with a silt texture (20% sand, 80% silt, and 0% clay by mass) originating from SCS 106 provides a mean turbidity reduction of 51% (P=0.05: L_1=47%, L_2=55%);
3. A ZPG™ StormFilter cartridge test unit, operating at 28 L/min is effective on silica particles down to the 10 micron size range;

It is important to emphasize that these conclusions reflect laboratory-based testing performed under controlled conditions. Field conditions are notoriously variable with regard to TSS characteristics and sampling methods, and comparison of this experiment to field-derived data will be accordingly affected. Laboratory studies are beneficial for the evaluation of system performance potential as part of the product development or system comparison process.

Stormwater360, Stormwater Management Inc, and Vortechnics Inc. are now CONTECH Stormwater Solutions Inc.

References

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Revision Summary

PE-E062
Document rebranded.

PE-E061
Document number changed; document rebranded; no substantial changes.

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Original