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Geotextile behavior relevant to filtering low density suspended organic particles

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ABSTRACT: This paper describes experiments on the feasibility of using geotextiles to filter organics from runoff and combined sewer overflows. A horizontal flow permittivity test apparatus was used as a prototype to test 15cm x 20cm coupons. Non-woven, needlepunched products supported both depth (interior) and cake (surface) filtration modes. Crushed anthracite in the #100-#200 mesh range was used as an inert, replicable analogue of low density, irregularly shaped suspended particles. The AOS detected with this material differs from that measured with standard media, indicating different interaction with the geotextile pore structure. Drag forces maintained a cake on the upstream face of the filter even at low hydraulic gradients. The permittivity decreased as this coating thickened. When flow ceased, the organic cake sloughed off the upstream face of the coupon. Measurements made after several doses showed recovery of much of the original permittivity, with the loss in hydraulic capacity attributed to embedment of particles in the matrix.

1 INTRODUCTION

This paper examines the use of geotextile filters for runoff treatment. Conventional methods such as sedimentation and vortexes remove settleable particles and floating debris from a discharge, but do not readily separate light organic constituents. Because microorganisms attach to these suspended and colloidal particles, further filtration is needed to protect receiving water swimmability and aquatic habitat.

The experiments used commercially available geotextile products to determine the influence of measurable parameters (permittivity, opening size, porosity, etc.) on hydraulic and treatment efficiency. The ultimate result sought is a template for manufacture of new products with internal structures optimized for this new application.

A traditional filter captures solids within its matrix ("depth filter"). Eventually, it must be cleaned or replaced. In contrast, construction silt fences accumulate a sediment cake on the upstream face. This may limit seepage, but with a short service life, eventual clogging is acceptable. In contrast, buried soil filters must operate without maintenance for an indefinite design life. To convey seepage while keeping particles in place, the apparent opening size (AOS) and permittivity (ψ) are selected to form a cake upstream of the soil/filter interface.

In removing organic particles from intermittent discharges at permanent outfalls, some permittivity loss during an event is tolerable. However, the hydraulic capacity must be restored by passive physical or biological means prior to the next storm event.

2 BACKGROUND

Geotextiles have been used for decades as soil filters. The intent is not filtration in the sense of capture, but to prevent solid particle migration. Using geosynthetics to protect landfill leachate collection systems is a more traditional filter application, i.e. interception of solids carried in the flow. Biomass fouling can reduce hydraulic capacity (Cancelli, A and Cazzuffi, D 1987), but it can stabilize with steady leachate permeation. The microorganisms attached to filtered organic particles colonize the matrix and decompose the substrate, thus re-opening pore channels. This sustains seepage and convection of substrate (Koerner, G., et al. 1994).

Eyup Korkut (2003) showed the feasibility of using non-woven geotextiles with interior porosity to treat dissolved and colloidal constituents in wastewater. Most settleable solids had already been removed by sedimentation. Figure 1 is an SEM picture of an exhumed, air-dried filter. The attached biomass grew toward the outer surfaces from capture sites in the interior. With the biomass being a dispersed floc rather than a continuous film, the geotextile maintained a finite permittivity as in the leachate filter example.

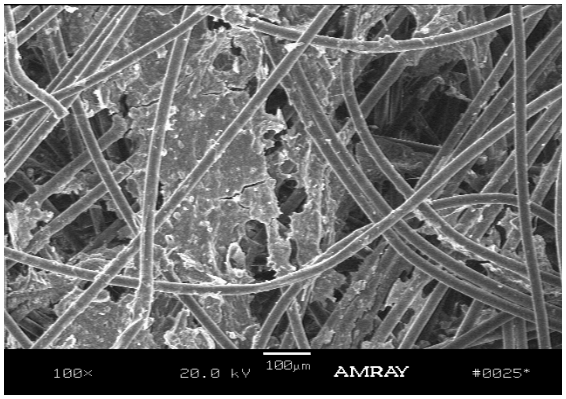

Figure 1. SEM picture of biomass growth in a nonwoven geotextile.

3 PROJECT FOCUS

This study is directed to sustainable filtration of harder, but still lightweight, particles suspended in intermittent meteorologically based flows. The “first flush” of urban runoff and combined sewer overflows (CSOs) includes pollutants that not only vary in nature and concentration during a storm event, but also with the interval since the last discharge (Pitt et al. 1995). Thus, the treatment performance of a Best Management Practice (BMP) unit is not as predictable as with wastewater unit operations. Most BMP’s require surface area and new pipe infrastructure. This restricts their application to retrofitting urban sites that have an existing pipe network, an outfall, and limited space and hydraulic head (Δh). Consequently, compact, subsurface end-of-pipe units are needed to separate pollutants at high velocities. It is also necessary to have a provision to bypass a clogged filter to prevent backup into the drainage system. One such arrangement is described in (Marino et al, 2005) where filters are arrayed as sequential permeable baffles. Flow could clog and then bypass each filter in succession.

Capture of degradable sanitary organics is enhanced as their “stickiness” encourages adsorption, but hard–surface, less degradable vegetative matter can also be captured by conventional types of filtration (Scheidegger, 1957) in the complex structure of non-woven geotextiles.

With the constraint of low allowable headloss, the permittivity, ψ is as important as the interior porosity that dominated the earlier wastewater treatment study. The third index used in conventional geotextile soil filter design is the AOS, an indicator of largest through pore channel. It would appear that the AOS should equal the largest non-settleable suspended particle size in the influent. While pore size distributions are not consistently related to AOS, the larger the AOS, the coarser the weave and the larger the initial permittivity and clogging resistance. However, the target is smaller organic particles with high specific surface, and attached microorganism density. Colloids could pass right through a coarse geotextile. Hence, an optimization between AOS (filter capture) and Q (flow treated) is in order.

4 MATERIALS AND APPARATUS

Crushed anthracite was seen as appropriate for the experiments: It is organic, irregular in shape, and has a specific gravity (1.35) similar to sanitary solids. Because crushed anthracite is non-degradable and durable, it can be used in replication tests. It was further reasoned that if geotextile filters could intercept anthracite particles, they would be even more able to sorb degrading organic particles with a sticky gel coating that attracts microorganisms. Anthracite filter media from a water treatment plant was ground in a coffee grinder. Particle size discretization was obtained by mechanical sieving and wet washing.

Commercially available non-woven needlepunched geotextiles from a single manufacturer were used in three mass per unit area variations. The manufacturer’s reported AOS values were US Sieve Sizes #70 for the 5 oz/sy (170 grams per square meter) candidate, and the #100 sieve for both the 8.5 oz/sy (288g/sm) and 15 oz/sy (509 g/sm) samples. Hence, crushed anthracite in the #100 to #200 sieve range was appropriate for the experiments.

A permittivity apparatus/filter prototype was constructed as shown in Figure 2. It used horizontal flow to include gravitational separation and settling effects. Specifications included a large coupon size to compensate for variations in the fiber density, capability for low hydraulic gradients, and transparency to observe behavior. The overall dimensions of the Plexiglas unit are 36” (91.4 cm) long x 9” (22.9 cm) wide x 17.5” (44.5 cm) high, with a center channel 6” wide x 8” high. Flow through the geotextile is governed on the upstream end by the permittivity of the geotextile and the applied hydraulic head. Downstream outflow was through two (2) 3/4” (1.91 cm) diameter orifices. At no point in the testing sequence were these orifices submerged. Therefore, flow out of the vessel was not restricted.

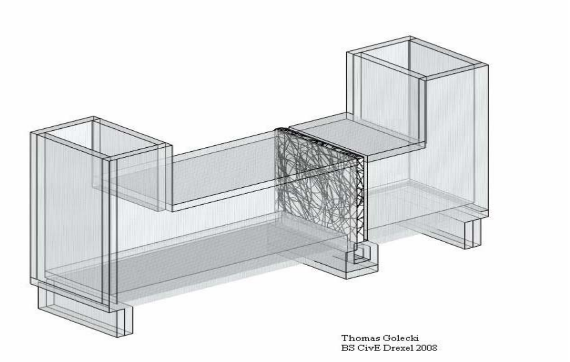

Figure 2. Geotextile Permittivity Testing Apparatus

The hydraulic head was monitored with manometers adjacent to the upstream and downstream sides of the coupon being tested. Three Δh values and flow rates were used in the experiments for each of the three geotextile densities to confirm applicability of Darcy's Law as well as to vary the drag forces on suspended solids. For all test runs, the initial flow rate was determined by volume sampling over time (ΔV/Δt). The head differentials were standardized at 1/8", 1/4", and 3/8". These resulted in the lowest flow rate being 1.18 gpm for a 15 oz/sy sample for Δh = 1/8", and the highest flow rate being 10.71 gpm for a 5 oz/sy coupon at Δh = 3/8". Darcy's law was found valid across this range.

Average permittivity values (ψ) for each series of geotextile tested with clean water were computed as: 2.23, 1.44, and 0.70 sec^{-1} for the 5 oz/sy, 8.5 oz/sy., and 15 oz/sy coupons, respectively.

After these clean water baseline permittivity tests, anthracite slurry was applied in ten individual doses. The first dose showed that seepage drag force held the anthracite cake on the face of the filter. Shortly after flow stopped, the cake sloughed off into a sediment trap. Figure 3 illustrates the initiation of one such "peeling". This suggested that the filters could rapidly reestablish some permittivity at the end of a storm event. This sloughing phenomenon reduced the necessity of reliance on biodegradation to restore permittivity, and less frequent filter maintenance and/or replacement.

It was decided that monitoring the behavior dose by dose would illustrate permittivity stability. After each pair of slurry doses, and the cake collapse after flow stopped, the residual permittivity was measured. This was repeated five times for each coupon until a total of ten (10) doses were applied. Figure 4 presents results in a "sawtooth" pattern for all three geotextile weights tested at a hydraulic head of 1/8".

Figure 3. Showing Sloughing After Discontinued Influent Stream

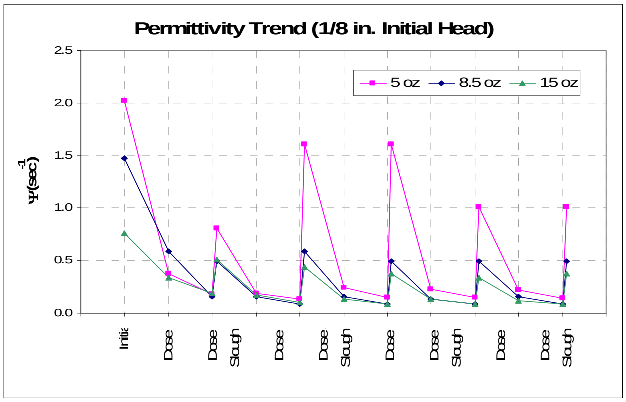

Figure 4. Permittivity Trend for Anthracite Slurry Dosing At 1/8" head

The variability in measured flow and computed permittivity decreased as the filter mass density increased, i.e., the flow and filtration performance was more reliable. For example, the 1/4" head resulted in flow rates of 7.50, 4.0, and 1.60 gpm respectively for the 5, 8.5, and 15 oz/sy geotextiles. The results of the 1/4" head permittivity test are shown on Figure 5.

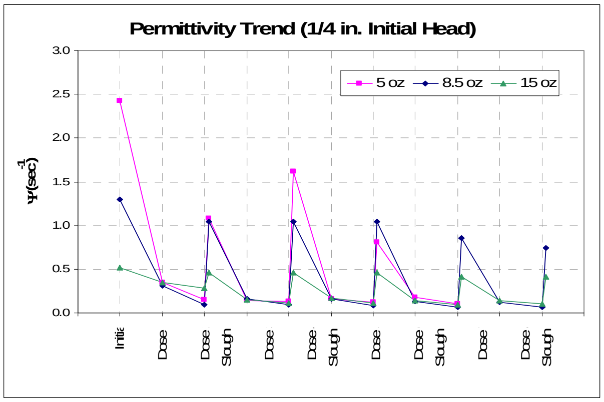

Figure 5. Permittivity Trend for Anthracite Slurry Dosing At 1/4" head

With the high flow rate through the 5 oz/sy geotextile, backwater exceeded the height of the inlet reservoir when the coupon was loaded with the eighth dose. Therefore, hydraulic failure (surface clogging) had occurred through progressive increase in the particle mass embedded in the interior porosity. Thus, there is no data reported on the following chart for the 5 oz/sy coupon for the fifth dose/ event.

The mass capture (in grams) of the crushed anthracite is shown in Figures 6 and 7 for the 1/8" and 1/4" head trials. It is apparent that the performance of the 8.5 oz/sy coupons exceeded that of the coarser and thinner 5 oz/sy and the finer, thicker 15 oz/sy samples.

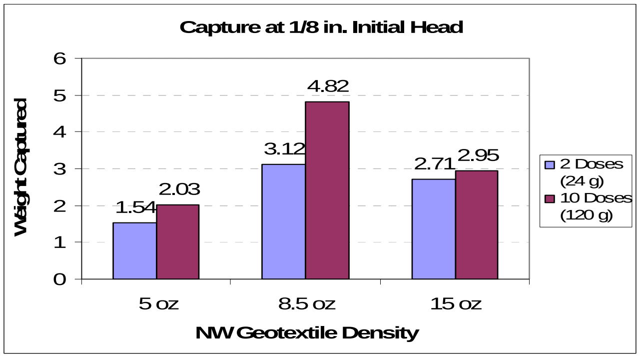

Figure 6. Crushed Solids Capture for Different Geotextile Mass per Unit Areas at 1/8" Head

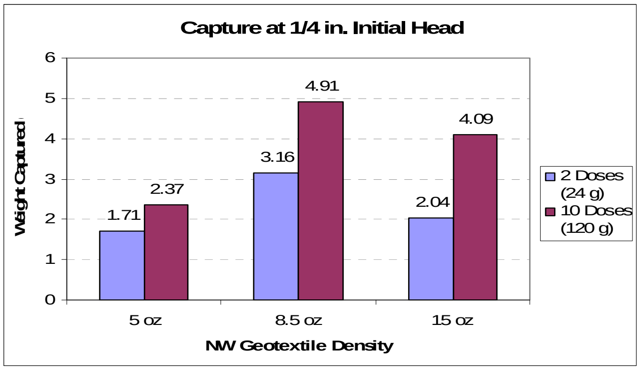

Figure 7. Crushed Solids Capture for Different Geotextile Mass per Unit Areas at 1/4" Head

Table 1 presents filtration efficiencies for the geotextile densities tested - where efficiency is defined as both the capture and the rejection of solids. Additionally, the average residual permittivity values obtained for each coupon density after the sloughing events are shown. The data suggests that, of the three geotextile densities evaluated, the 8.5 oz. is the best candidate for capture, rejection, and residual permittivity. Although the 5 oz/sy coupons maintained a higher permittivity, they provide little internal storage and therefore, are not candidates for depth filtration. The 15 oz/sy coupons provide more internal storage, but less capture due to pore channel tortuosity, and also provide less permittivity than the 8.5 oz. candidate.

Geotextile Coupon Density (oz./sy)	5	8.5	15
Average Residual Permittivity (sec^{-1})	1.2	0.7	0.4
Average Capture (%)	5.4	9.9	6.5
Average Total Efficiency (%)	90.4	97.1	93.7

Table 1. Average Filtration Efficiencies for Different Density Geotextiles

5 CONCLUSIONS

Three commercially available geotextiles, having different mass per unit areas, were evaluated for application as filters for storm water and combined sewer overflow waste streams. Non-woven needle punched geotextiles were selected as the filter media because their fibrous structure provides the opportunity for both depth and cake filtration. Therefore, internal capture (in the pore channels), and external rejection (on the upstream face of the filter), of suspended solids was anticipated.

A permittivity apparatus/ filter prototype was constructed to determine both the average permittivities of each fabric and the capture and rejection potential of the candidates. Crushed anthracite was used as an analogue for waste water due to its similar characteristics (specific gravity of 1.35, inert nature, organic structure, amorphous shape). Several trials were run with the anthracite slurry through the prototype, and capture, rejection, filter efficiency, and reestablished permittivity values after sloughing were recorded.

The results suggest that geotextiles are indeed viable as a filtration media for the intended application. Of the three candidates evaluated, the 8.5 oz/sy fabric outperformed the other two candidates in filtration efficiency (the most critical parameter), capture (mass treated per flow volume), and provided nearly twice the permittivity of the candidate with the nearest filtration efficiency.

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