***PUBLISHED IN:*** **2ND INTERAGENCY CONFERENCE ON RESEARCH IN WATERSHEDS PROCEEDINGS, MAY 2006**

# REMOVING STORM WATER POLLUTANTS AND DETERMINING RELATIONS BETWEEN HYDRAULIC FLOW-THROUGH RATES, POLLUTANT REMOVAL EFFICIENCY, AND PHYSICAL CHARACTERISTICS OF COMPOST FILTER MEDIA

Britt Faucette, Ph.D.[1], Frank Shields[2], Kate Kurtz[3]

[1]Research Ecologist/Director of Research and Development, Filtrexx International, 1352 North Ave NE Suite 10, Atlanta, GA 30307; [2]Laboratory and Analytics Director, Soil Control Lab, Inc., 42 Hangar Way, Watsonville, CA, 95076; [3]Laboratory Analyst, Soil Control Lab, Inc.

Abstract--Compost filter socks are generally used to control sediment on construction sites or land disturbing activities. Higher sediment removal efficiencies of compost filter socks, relative to silt fence, have been attributed to its larger surface area and sediment storage capacity, due to its tubular construction. Compost has been used widely to bioremediate polluted soils. By adding new materials to the compost filter media within the sock, these innovative sediment control devices may be used for storm water pollutant removal applications beyond sediment. Under laboratory test conditions, similar to test methods designed to evaluate silt fence (ATSM D-5141), results from 12 in and 18 in compost filter socks show TSS removal efficiency of runoff of 70% and a turbidity reduction of 74 and 84%, respectively. When compost filter media is specified and designed for high runoff flow conditions, generally, flow through rates are increased at the expense of suspended solids and turbidity reduction. By adding anionic polymers to the compost filter media, such as PAM or a polysaccharide biopolymer, turbidity reduction of runoff can increase from 21% to 90 and 77%, respectively; and TSS removal efficiency can improve from 58% to 90 and 88%, respectively. Additionally, polymers can be added to the filter media to remove hard to capture soluble pollutants, such as dissolved reactive phosphorus. By adding a polymer to the filter media that can adsorb soluble P, test results show that removal efficiencies from storm water runoff can increase from 6% to 93%. Based on 45 samples of compost filter media tested for physical characteristics and runoff pollution control performance, the mean hydraulic flow through rate was 24 gpm/linear ft, mean total solids removal was 92%, mean suspended solids removal was 30%, mean turbidity reduction was 24%, and mean motor oil removal rate was 89%. Based on preliminary correlations, particle size distribution of filter media is the best indicator of hydraulic flow through rate and pollutant removal efficiency, although bulk density of the filter media may be used if particle sizes are unknown, and void space of the filter media may be used to predict flow through rate but not pollutant removal efficiency. The greater the hydraulic flow through rate of a filter media, generally the lower the pollutant removal efficiency. Results from this study indicate that compost filter socks are an effective sediment control device and by adding new materials to the filter sock its applications expand beyond only sediment control to storm runoff filtration capable of capturing target soluble pollutants, such as petroleum hydrocarbons and phosphorus. These practices should be considered to improve receiving water quality and in watersheds where there is a potential for pollution from sediment or soluble pollutants.

## INTRODUCTION

Sedimentation rates from construction sites are typically 10 to 20 times greater than from agricultural operations, and 1000 to 2000 times greater than forestlands (US EPA 2005). In a short period of time, sedimentation from a construction activity can exceed decades of natural sedimentation that causes physical, chemical, and biological harm to our nation's water system (US EPA 2005). In 1990, as an extension of the 1972 Clean Water Act, the National Pollution Discharge Elimination System (NPDES) permit program included storm water discharges from construction sites for the first time (US EPA 2005). Enacted in 1999, but not required until 2003, Phase II of this program reduced the minimum construction site area requiring a storm water discharge permit from 5 acres to 1 acre (US EPA 2005).

Organic filter media used to control sediment from construction sites has been widely used but little researched. In unreplicated field trials in Oregon, Ettlin and Stewart (1993) reported that compost filter berms reduced sedimentation of total solids by 83% relative to bare soil, and by 72% relative to silt fence over 5 natural rainfall events on a 34% slope. Additionally, the compost filter berm reduced total suspended solids by 93% relative to bare soil and by 91% relative to silt fence.

In a similar study in Connecticut, using unreplicated field plots, Demars and others (2000) reported on a 2:1 slope that a mulch filter berm reduced sedimentation by 97% relative to straw bales and 80% relative to silt fence during a ¾ in rain event. During a 4.35 in rain event, the mulch filter berm reduced sedimentation by 91% relative to a straw bale and by 92% relative to silt fence. In a preliminary study Demars and Long (1998) reported that a mulch filter berm reduced suspended solids by 93% relative to a bare soil under 1.7 in of natural rainfall using the same experimental site and set-up. In a follow-up study, Demars and Long (2001) reported that hydraulic flow through a mulch filter berm using one liter of runoff containing 500,000 mg $L^{-1}$ silty sand on a 2:1 slope, in a flume 6 in wide by 8 in high by 36 in, deep was approximately 850 ml/sec.

In replicated field plots, a study at the University of Georgia by Faucette and others (2005) reported that on hydroseeded sandy clay loam subsoils, on a 10% slope over three simulated rain events, with storm intensities in excess of 3 in/hr for 1 hr duration, mulch filter berms reduced total solids loads on a meter squared basis by 35% relative to silt fence, and 98% relative to a bare soil. They also reported that average peak runoff flow rates for a single storm were 0.015 mm/sec and total solids loads from a bare soil with no sediment control treatment (control) were 308,544 g. Faucette and others (2005) found that during the second storm event the filter berm reduced total N loading by 52%, nitrate N loading by 63%, total P loading by 32%, and soluble P loading by 26% compared to silt fence.

In a replicated flume study used to evaluate hydraulic flow through rates of silt fence and compost filter socks at Ohio State University, Keener and others (2006) reported using a sediment-laden runoff concentration of 10,000 mg $L^{-1}$, containing only clay and silt (no sand), on a 20 degree slope for 30 minutes. Results showed that runoff flow through rates of compost filter socks on average were 50% greater than silt fence and the ponding height behind a 24 in silt fence was 75% greater than a 12 in compost filter sock. At flow rates less than 5 gpm/linear ft an 8 in compost filter sock overtopped at the same time as a 24 in silt fence, while a 12 in compost filter sock took longer to overtop relative to a 36 in silt fence. At 6 gpm/linear a 12 in compost filter sock overtopped at the same time as a 36 in silt fence, while a 18 in compost filter sock did not overtop as quick as a 36 silt fence (Keener and others 2006). The researchers concluded from these results that the design height of a compost filter sock does not need to be as high as a silt fence, due to higher flow through rates of the filter socks, and that they could be specified on design plans to control sediment on larger watershed areas or longer slope lengths, relative to silt fence. This may be a substantial financial advantage to builders or contractors where fewer linear ft of a sediment control practice need to be purchased, installed, maintained, removed and ultimately disposed.

Using the same apparatus and test methods described later in this study, Faucette and Tyler (2006), found that filter media used for compost filter socks removed an average of 98% total solids, 71% suspended solids, and reduced turbidity by 55%. No physical characterization of the compost filter media was reported.

While specifications for silt fence used for sediment control are not new, specifications for compost filter media (compost specified for use in a berm or a sock) are relatively new. Although many state agencies have approved and adopted specifications for compost filter socks and/or filter berms, the specifications published by the US EPA National Menu of BMPs for Storm Water Phase II Construction Sites (2006), the Association of State Highway Transportation Officials (2003), Filtrexx International (2006), the Texas Department of Transportation (2005), and the New England Transportation Consortium are generally regarded as the best and most comprehensive.

It is important to note that specifications for compost used for sediment control are quite different than those commonly used for vegetation and planting applications, such as in potting mixes, landscaping, nursery operations, and gardening and agriculture. Specifically, the particle size distribution of the compost filter media is much larger. Table 1 lists particle size distributions in a variety of standard specifications for compost used in sediment control applications. Table 2 lists the hydraulic flow through rate, sediment removal efficiencies, and their associated particle size distribution for filter berms and filter socks reported in the research literature. Although the specifications vary, the research indicates that smaller particle size distributions have higher sediment removal efficiencies; particularly, the greater the amount of fine particles (<1/4 in) the better the resultant sediment removal. In light of this, particle size specifications listed here may be too coarse to remove fine particulates characteristic to sediments that are commonly in suspension (clay and silt), e.g. sediments less than 2 mm. However, as shown in Table 2, hydraulic flow through rate is dependant on sediment concentration of runoff, and greater sediment removal efficiency may be associated with slower hydraulic flow through of runoff (or greater retention time of runoff) - which is also characteristic to smaller particle size distributions of the filter media.

Although standard test methods have been established for evaluating silt fence performance (ASTM D 5141- Standard Test Method for Determining Filtering Efficiency and Flow Rate of a Geotextile for Silt Fence Application Using Site Specific Soil), none have been established for any other sediment control device (for example, tubular sediment control devices). ASTM standard test method D-5141 uses a 12 in silt fence, 6:1 slope, runoff sediment concentration of 2890 mg $L^{-1}$ using site specific soil, 50 liters of runoff, in plots 48 in long by 34 in wide, and the silt fence is pre-wet using 50 L of clean water. Barrett and others (1995) found that many of the sediment removal efficiencies reported for silt fence, employing this test method, use predominately sand (instead of silt or clay), which is relatively easy to remove from runoff water due to its larger and heavier characteristics that prevent it from becoming suspended in water – which consequently has little influence on reported turbidity and suspended solids values. Barrett and others (1995) went on to report that 92% of the total suspended solids in runoff are clay and silt, which are an order of magnitude smaller than the openings in the silt fence fabric, and due to very low settling velocities are normally not removed by this method of sedimentation (Barrett and others 1998). They concluded that effective sediment trapping efficiency of silt fence is a result of increased ponding behind the silt fence, while a similar study by Kouwen (1990) concluded that excessive ponding is largely due to eroded sediment clogging the fabric of the silt fence. By these reports, the same function that causes silt fence to trap sediment, is also the function that severely reduces flow through rates, which often causes it to fall over and fail (assuming it has been installed correctly).

The test methods used to evaluate compost filter media in this study are similar to ASTM D-5141 for silt fence. The Standard Test Method for Sediment and Chemical Removal of Filter Media Used in Filtrexx Filter Soxx has been reviewed and published in the 2006 International Erosion Control Association (IECA) Annual Proceedings, Long Beach, CA (Faucette and Tyler 2006). This test method uses a 3:1 slope, an 8 in compost Silt Soxx, runoff sediment concentration of 3000 mg $L^{-1}$ of 33% sand and 67% silt, using 50 liters of runoff, in a flume 4 ft long by 12 in wide, and the compost filter media is pre-wet using 50 L of clean water.

Because the particle size distribution of compost filter media can be easily manipulated, compost filter socks can be customized for high concentrated flow applications, such as ditch checks or inlet protection practices. When the compost filter media is specified for high flow conditions, generally, flow through rates are increased at the expense of suspended solids and turbidity reduction. Polymers such as polyacrylamides (PAM) have been used to reduce turbidity in erosion control applications (Hayes and others 2005). By adding anionic polymers, such as PAM or a polysaccharide biopolymer, to the compost filter media, turbidity reduction and TSS removal efficiency from storm runoff may be improved.

In a 1998 water quality assessment conducted for the US EPA, 35% of streams sampled were found to be severely impaired and nutrient loading was the main cause of 30% of those listed (US EPA 2000). Total maximum daily load (TMDL) listed streams for phosphorus have become increasingly common in recent years. While erosion and sediment control BMPs may reduce sediment bound P, they do little to reduce soluble P in runoff. Additionally, when soil becomes detached, sediment bound P can quickly become desorbed, therefore transforming into soluble P (Westermann and others 2001). Where sedimentation is minimal due to effective erosion control management practices, soluble P can be more than 80% of total P (Berg and Carter 1980). In order improve receiving water quality, and in particular to meet TMDL requirements for phosphorus, BMPs need to be developed to reduce soluble P loading to streams. Soluble P is more reactive, or bioavailable, than sediment-bound P to aquatic plants, therefore, it is more likely to cause algae blooms and eutrophic conditions which contributes to the degradation of our nation's surface waters.

Studies have shown that using polymers can reduce soluble P in sediment ponds (Leytem and Bjorneberg 2005) and total phosphorus in storm runoff by as much as 75 to 90% (Moore 1999, Harper and others 1999). These polymers may be added to the filter media to remove hard to capture soluble pollutants, such as dissolved phosphorus. If effective, filter sock applications may expand beyond being primarily a tool to control sediment to a storm water filtration device capable of capturing soluble pollutants in a wide variety of applications used to improve storm water runoff quality and ultimately our nation's surface waters as well.

The objectives of this study on compost filter socks were: 1) to determine pollutant removal efficiencies for suspended solids, turbidity, and soluble P, and how the addition of selected polymers affect removal efficiencies for targeted pollutants; 2) to determine if physical properties of the filter media affect the hydraulic flow through rate and pollutant removal efficiency of the filter media; 3) to determine if there is a relationship between hydraulic flow through rate and pollutant removal efficiency.

## MATERIALS AND METHODS

Beginning in the spring of 2004, compost products were sampled and tested for efficacy as sediment control and storm water runoff filter media. Forty-five compost products were sampled from commercial and municipal composting operations from the United States, Canada, Japan, and New Zealand. The compost products used in this study were produced from a range of carbonaceous feedstocks (i.e.: yard waste and tree trimmings). It should be noted that the dimensions of the testing apparatus, the sediment-laden runoff concentrations, and runoff volume used for this study are similar to ASTM D-5141 used to determine flow through rate and sediment removal efficiency for silt fence technology.

### Sampling Procedure and Design

To test for filtration efficacy, compost filter medium were subjected to a laboratory scale storm runoff event, meant to simulate the conditions of storm water passing through an 8 in diameter compost-filled Filtrexx Filter Sock. To achieve this, a tilt table was designed and produced (by Soil Control Lab of Watsonville, CA) to hold the compost filter media while water washed down a slope and through the material. The tilt table used was 4 ft in length where water flows from one end of the table, through the filter medium, and out the other end of the table, where runoff water samples can be taken. The part of the tilt table responsible for holding the filter material (the basket) is adjustable in its height (up to 10 in) and its length (6-24 in), while the width is set at 8 in across. For the purpose of these studies the basket was maintained at 8 in high, 8 in long, and 8 in across to mimic an 8 in diameter Filtrexx Filter Sock. The basket provided a secure fit around the filter media, therefore preventing water from bypassing the tested material. The basket was composed of two 10 in by 8 in rectangles of ½ cm steel mesh and wrapped in Filtrexx Filter Sock mesh material. This steel mesh spanned across the tilt table, snugly fitting across the bottom and the two sides (8 in across). Inside the basket the 8 square in of filter media to be tested is compacted. In order to mimic slopes encountered where sediment control devices are generally specified for construction activities, the tilt table had adjustable slope ratios from 4:1 to 1:1. In this study, however, the slope was maintained at a ratio of 3:1. The runoff distributors were situated at the top of the slope to generate an even runoff sheet flow. The runoff distributors were connected to a 57 L open-top water tank, equipped with a pump -enabled siphon tube. For the duration of this study, 2 gal/min/linear ft of runoff was pumped through the runoff distribution system.

### Test Procedure

After the sample filter media was packed into the Filtrexx Filter Sock-lined basket, City of Watsonville, CA tap water was run down the tilt table and through the filter media for 10 min. After this 10 minute period the inflow tap water and outflow (post filtration water) was sampled and tested for soluble salts (EC). Additionally, at this time the maximum flow rate of the filter media was calculated by measuring the height of the water ponded behind the filter media. After these measurements were taken, the runoff distributors supplied a pollutant-laden storm water runoff containing a predetermined amount of nutrients, metals, organic matter, sand, silt, and clay. Sediment concentrations were approximately 3000 mg $L^{-1}$, unless the purpose of the test was to evaluate sediment removal efficiency under higher sediment-laden runoff conditions. After 10 min of running the pollutant-laden water through the filter media, the inflow and outflow runoff were sampled and tested for physical and chemical constituents. After this sampling, clean tap water was then run through the runoff distribution system and through the filter material. While tap water was running, motor oil was dripped into the inflow stream, at a constant rate, for a period of 10 min. After this time an outflow sample was taken and tested for oil and grease concentration. The total inflow application of motor oil was determined by calculating the weight of dripping oil for a known period of time.

### Water Analysis

The first inflow/outflow samples collected after tap water was run through the system for ten minutes were analyzed for soluble salts (EC) (SM 2510 B). The inflow and the outflow of the pollutant-laden runoff water were analyzed for the following physical and chemical constituents and test methods: Total solids (ASTM D3977-97C), suspended solids (SM 2540 D), total suspended solids (ASTM D3977-97C), turbidity (SM 2130 B), Ammonia (SM 4500-$NH_3$ H), Nitrate (SM 4500-$NO_3^-$ C), total N (calc.), organic N (Leco), reactive P (SM 4500-P), organic P (SM 4500-P), acid hydrolysable P (SM 4500-P), total P (SM 4500-P), total Potassium (EPA 3050/EPA 6010 ICP), total Calcium (EPA 3050/EPA 6010 ICP), total Magnesium (EPA 3050/EPA 6010 ICP), total Sulfate (EPA 3050/EPA 6010 ICP), total Copper (EPA 3050/EPA 6010 ICP), total Zinc (EPA 3050/EPA 6010 ICP), total Iron (EPA 3050/EPA 6010 ICP), total Manganese (EPA 3050/EPA 6010 ICP), total non-soluble Carbon (Leco), pH (SM 4500H+ B), electrical conductivity (SM 2510 B). The motor oil-contaminated outflow sample was tested for oil and grease content by partition gravimetric method (SM 5520 B).

Compost Analysis

A sub sample of the compost filter material taken prior to runoff performance analysis was analyzed for the following constituents using the assigned test methods: Particle size distribution (TMECC 02.02 B), bulk density (TMECC 03.03A), moisture (TMECC 03.09), and packed void space by sand displacement (Soil Control Lab). Packed void space was determined by taking a 500 cc sub-sample of filter media. The wet weight and dry weight of the sample were recorded, and then the dried sample was screened through 4mm mesh. Using an Imhoff cone, the volume and weight of material passing through the 4mm screen was measured. The volume of material that was greater than 4mm in size was measured. Using 500 cc of sand and an Imhoff cone, the sand was added to the cone containing wood chips greater than 4mm. The volume of sand and wood chips was measured. The amount of void space was calculated based on the amount of volume displaced by the sand.

The test procedure described above was conducted on 45 different compost filter media as part of a survey and larger study to evaluate the performance of filter media under these runoff conditions, only the following will be reported in this study:

A 12 in and 18 in filter sock were tested for TSS removal and turbidity reduction efficiency to determine if a larger filter sock performs at a higher removal efficiency.

Polymers were added to the compost filter media to evaluate their potential to remove soil colloids and soluble P from runoff. A PAM and biopolymer were each added separately to filter media to target fine soil colloids typically suspended in water and to reduce TSS and turbidity in runoff. An alum based polymer was added to the filter media of an 8 in wide filter sock, at 25, 50 and 150 g/linear ft, to target soluble P in runoff to potentially remove this pollutant from storm runoff. All polymers were weighed (dry) and manually mixed with the filter media prior to installation and testing on the tilt table.

Particle size distribution, void space, and bulk density of filter media was determined for 45 filter media samples as part of the survey mentioned above. These results were used to determine potential relationships on hydraulic flow through rate and pollutant removal efficiency from runoff of these filter media, respectively. TSS, turbidity, and motor oil were selected as pollutants to be analyzed in the survey, since these are commonly found in storm runoff at or near construction sites and land disturbing activities. The relationship between hydraulic flow through rate and pollutant removal efficiency of the filter media was also investigated.

RESULTS AND DISCUSSION

Compost filter socks are available in a variety of design diameters (8 in, 12 in, 18 in, 24 in), similar to design heights for silt fence (24 in, 30 in, 36 in). Total suspended solids (TSS) removal efficiency and percent turbidity reduction were used to evaluate potential differences in performance between a 12 in and an 18 in filter sock. Results in Figure 1 show no difference in TSS removal efficiency, both approximately 70%, however the 18 in filter sock did increase percent turbidity reduction, relative to the 12 in sock, from 74 to 84%. TSS concentrations may have remained the same due to the fact that the porosity of the filter is essentially the same for both filter socks, e.g. the particle sizes of the filter media used are exactly the same, and therefore solids in runoff moving through one should readily move through the other. The 10% increase in turbidity reduction from the 18 in sock may be due to the size of the filter. The larger the silt barrier, the longer it may take for storm runoff to pass through the filter, allowing for some additional sediment deposition to occur in the process. It should be noted that the main reason for using larger diameter filter socks is to increase the design height to handle potentially high runoff flow conditions or large watershed drainage areas flowing to the sock, or where increased sediment storage capacity and less maintenance are desired.

Although compost filter socks have high total solids removal efficiencies (Faucette and Tyler, 2006), removing finer sediment particles, such as clay and silt, which are characteristic to suspended solids and turbidity values, can be a greater challenge. Testing has shown that by reducing the particle size distribution of the compost filter media, TSS and turbidity can be greatly reduced, however a concomitant reduction in flow through rate may also occur, therefore reducing its ability to flow storm water (possibly requiring a larger diameter filter sock to prevent overflow and/or reduce maintenance of sediment removal behind the sock due to increased rate of sediment accumulation). By adding polymers such as polyacrylamides (PAM) and polysaccharides (biopolymer) to the compost filter sock, turbidity and suspended solids in storm runoff may be greatly reduced (Figure 2 and Figure 3) without manipulating (reducing) the particle size of the filter media and therefore potentially reducing hydraulic flow through rates. These polymers act as an anionic flocculent, thereby flocculating suspended clay particles in storm water and increasing the likelihood of deposition from runoff. They are also coagulants, which act as a mobility buffer to the finer particles transported in storm runoff.

By adding PAM to a filter sock designed for high flow conditions (where removal of fine sediments is more difficult), adding a PAM or a biopolymer can increase turbidity reduction from 21% to 90% and 77%, respectively. The PAM and biopolymer can also increase TSS removal efficiency from 58% to 90 and 88%, respectively. Additionally, turbidity and TSS reduction from runoff were not substantially diminished during a second runoff event, indicating that the PAM and biopolymer were still effective after a first runoff event, and possibly effective for multiple runoff events, thereby increasing its value in the marketplace.

Polymers may also be used as colloidal flocculents to chemically adsorb soluble phosphorus (P) from storm runoff. By adding these polymers to the compost filter sock, through chemical adsorption of runoff soluble P as it flows through the filter media, the filter sock becomes a management practice for removal of soluble P from storm water runoff. Once the soluble P becomes chemically bound to the polymer within the filter sock it has been removed from the runoff and is also no longer bioavailable to aquatic plants, thereby reducing algae growth and subsequent eutrophication effects that can negatively affect surface water quality. By adding 150 g/linear ft of alum-based polymer to an 8 in filter sock, runoff with a soluble P concentration of 100 mg $L^{-1}$ was reduced from 6% (no polymer) to 93% (polymer added) (Figure 4). Additionally, with a runoff soluble P concentration at 100 mg $L^{-1}$, and polymer application rate of 50 g/linear ft, soluble P was reduced by 79%; and reducing the application rate of polymer within the filter sock to 25 g/linear ft, soluble P removal efficiency was 67%. Soluble P reduction (chemical adsorption) fromthe polymer additive was not seen after two consecutive runoff events without additional polymer applications. This may indicate at this runoff soluble P concentration all chemical reaction sites present on the polymer have been filled, thereby reaching its capacity to adsorb P, or the polymer has been transported from the filter sock by the runoff. A small percentage of soluble was removed by the filter sock without polymer addition; this may be due to chemical adsorption of soluble P by humus colloids in the compost filter media.

It is well understood that the more porous a filter is, the greater the rate at which materials move through the filter. It has been assumed that the more porous the compost filter media, the faster runoff will flow through and lower pollutant removal efficiencies will be observed. State and federal standard specifications for compost filter berms and filter socks list particle size distribution requirements to insure adequate hydraulic flow through rates and sediment removal efficiencies in the field. These specifications make the assumption that larger particle size distributions lead to greater hydraulic flow through rates and smaller particle size distributions lead to greater sediment removal efficiency. In addition to particle size distribution of the filter media (within the sock or berm), bulk density and void space of the filter media may give an indication, and be used to predict, hydraulic flow through rate and pollutant removal efficiency.

Based on 45 samples of compost filter media tested, mean void space was 41%, mean bulk density was 26 lbs/cubic yard, mean particle size distribution above 3/8 in was 41%, mean particle size distribution below ¼ in was 44%, mean hydraulic flow through rate was 24 gpm/linear ft, mean total solids removal was 92%, mean suspended solids removal efficiency was 30%, mean turbidity reduction was 24%, and the mean motor oil removal rate was 89%.

Results from this survey showed there was a linear relationship in hydraulic flow though rate and percent of pollutants passing through the filter media. Generally, the lower the flow through rate of the filter media the higher the resultant pollutant removal efficiency. This may be due to sediment deposition from runoff flow restriction, or simply because fewer pores and smaller pore spaces lead to an increased ability to physically trap small sediments in runoff. This relationship was observed for suspended solids, turbidity, and motor oil removal efficiencies relative to hydraulic flow though rates for filter media (Figure 5, Figure 6, Figure 7).

Similarly, there was a correlation in the percent of particle sizes over 3/8 in and under ¼ in and hydraulic flow through rate (Figure 8 and Figure 9). Generally, the greater the percent of particle sizes over 3/8 in, the higher the flow through rate; conversely the greater the percent of particle sizes below ¼ in the lower the flow though rate. This is likely because the greater the amount of small particle sizes in the filter media matrix the lower the porosity (or number of pores) and the smaller the pore spaces. Additionally, more small particles generally means more surface area, which may increase friction on the runoff water passing through the filter media, thereby slowing its movement through the media. Although the relationship does not appear to be as strong, greater void space and lower bulk density of the filter media also lead to higher hydraulic flow through rates (Figure 10 and 11).

Void space, bulk density, and particle size distribution of the filter media may also indicate (and predict) how well the filter media will remove target pollutants from runoff. Figures 12 through 23 graph the relationships between each of these physical parameters of the filter media and their associated performance in reducing pollutants from storm runoff. Based on the results presented in Figures 12 through 23, void space is not a good indicator of pollutant removal efficiency (for TSS, turbidity, motor oil), while bulk density and particle size distribution are good indicators. High bulk density, a low percent of particle sizes above 3/8 in, and a high percent of particle sizes below ¼ in. in the filter media are good indicators that the filter media will have high pollutant removal efficiencies. Small particle sizes present in the filter media likely trap sediment for the same reasons they slow down hydraulic flow through rate described above. Greater surface area within the filter media may also provide for greater potential to trap and remove solids from runoff. Fewer pores and smaller pore spaces, characteristic to smaller particle size distribution of filter media, are more likely to trap smaller sediments transported in runoff, thereby reducing TSS and turbidity.

## SUMMARY AND CONCLUSION

Under laboratory test conditions, similar to ASTM D5141 standard test methods used to evaluate silt fence, results from 12 in and 18 in compost filter media (used in filter socks) show a TSS removal efficiency of 70% and a turbidity reduction of 74 and 84%, respectively. When the compost filter media is specified for high flow conditions, generally, flow through rates are increased at the expense of suspended solids and turbidity reduction. By adding anionic polymers to the compost filter media, such as PAM or a polysaccharide biopolymer, turbidity reduction can increase from 21% to 90% and 77%, respectively; and TSS removal efficiency can improve from 58% to 90 and 88%, respectively. Additionally, polymers can be added to the filter media to remove hard to capture soluble pollutants, such as soluble phosphorus. By adding a polymer to the filter sock that adsorbs soluble P, test results show that removal efficiencies from storm runoff can increase from 6% to 93%. Results from this study indicate that compost filter socks are an effective sediment control device; however, by adding new materials to the filter sock its applications may expand beyond a tool used primarily to control sediment, to a storm water filtration device capable of capturing target pollutants, making it useful in a wide variety of applications where improvement of storm water runoff and receiving water quality is needed. Based on a survey of 45 samples of compost filter media, the mean hydraulic flow through rate was 24 gpm/linear ft, the mean total solids removal was 92%, the mean suspended solids removal was 30%, the mean turbidity reduction was 24%, and the mean motor oil removal rate was 89%. Generally, the greater the hydraulic flow through rate of a filter media, the lower the pollutant removal efficiency. Particle size distribution of filter media was the best indicator of hydraulic flow through rate and pollutant removal efficiency, although bulk density of the filter media may be used if particle sizes are unknown. If pollutant removal efficiency of filter media is inadequate smaller compost particles may be added to increase removal rates; however, this will likely reduce hydraulic flow through rate of the filter media. State and federal standard specifications for compost filter socks and filter berms should determine optimum hydraulic flow through rates and pollutant removal efficiencies based on particle size distribution of the filter media for various soil (sand, silt clay) and rainfall/runoff potential conditions.

## LITERATURE CITED

American Association of State Highway Transportation Officials. 2003. Standard Specification for Transportantion Materials and Methods of Sampling and Testing, Designation M9-03, Compost for Erosion/Sediment Control. Washington, DC.

Barrett, M.E., J.E. Kearney, T.G. McCoy, J.F. Malina. 1995. An Evaluation of the Use and Effectiveness of Temporary Sediment Controls. Center for Research in Water Resources, University of Texas at Austin. www.ce.utexas.edu/centers/crwr/reports/online.html

Barrett, M.E., J.F. Malina, R.J. Charbeneau. 1998. An evaluation of geotextiles for temporary sediment control. Water Environment Research. 70:3, 283-290.

Berg, R.D. and D.L. Carter. 1980. Furrow erosion and sediment losses on irrigated cropland. Journal of Soil and Water Conservation 35(6):267-270.

Demars, K.R. and R.P. Long. 1998. Field Evaluation of Source Separated Compost and CONEG Model Procurement Specifications for Connecticut DOT Projects. JHR 98-264, Project No. 96-5. December, 1998

Demars, K.R., R.P. Long, and J.R. Ives. 2000. New England Transportation Consortium use of wood waste materials for erosion control. NETCR 20, Project No. 97-3. April, 2000.

Demars, K.R. and R.P. Long. 2001. Performance Specifications for Wood Waste Materials as an Erosion Control Mulch and as a Filter Berm. New England Transportation Consortium. NETCR 25, Project No. 97-3. March, 2001.

Ettlin, L., and B. Stewart. 1993. Yard debris compost for erosion control. BioCycle: Journal of Composting and Organics Recycling. JG Press. Emmaus, PA. 34:12. p.46-47.

Faucette L.B., C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman, L.T. West. 2005. Evaluation of Storm Water from Compost and Conventional Erosion Control Practices in Construction Activities. Journal of Soil and Water Conservation. 60:6.

Faucette, L.B., R. Tyler. 2006. Organic BMPs Used for Stormwater Management. International Erosion Control Annual Conference Proceedings, Long Beach, CA, 2006.

Filtrexx International. 2006. The Certified Standard in Erosion Control. www.filtrexx.com

Georgia Department of Transportation. 2002. Section 163.3.05.D.

Gharabaghi, B. [In press] 2006. Advancing Sustainable Environmental Solutions for Ontario – Draft Research Progress Report. Guelph Watershed Research Group, School of Engineering, University of Guelph, Canada.

Harper H.H., J.L. Herr, and E.H. Livingston. 1999. Alum treatment of stormwater runoff: An innovative BMP for urban runoff problems. In: National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments. US EPA. US EPA/625/R-99/002.

Hayes, S.A., R.A. McLaughlin, and D.L. Osmond. 2005. Polyacrylamide use for erosion and turbidity control on construction sites. Journal of Soil and Water Conservation. 60:4: 193-199.

Keener, H., B. Faucette, and M. Klingman. [In press] 2006. Flow-through rates and evaluation of solids separation of compost filter media vs. Silt Fence in sediment control applications. American Society of Agricultural Engineers Annual International Conference, Portland, OR.

Kouwen, N. 1990. Silt Fences to Control Sediment Movement on Construction Sites. Report MAT-90-03. Downsview, Ontario: Research and Development Branch Ontario Ministry of Transportation.

Leytem, A.B., D.L. Bjorneberg, 2005. Removing soluble phosphorus in irrigation return flows with alum additions. Journal of Soil and Water Conservation. 60:4:200-208.

Moore, P.A. 1999. Reducing phosphorus runoff and improving poultry production with alum. Poultry Science 78(5):692-698.

Texas Department of Tranportation, 2005. Item 161.2 Materials and Physical Requirements for Erosion Control Compost.

TMECC. 1997. Test Methods for the Examination of Composting and Compost. The US

Composting Council. First Edition. The United States Composting Council, Amherst, OH.

US EPA. 2006. Compost Filter Socks: Construction Site Storm Water Runoff Control. National Menu of Best Management Practices for Construction Sites, NPDES Phase II. http://cfpub.epa.gov/npdes/stromwater/menuofbmps/con_site.cfm

US EPA 2005. Storm Water Phase II Final Rule: Small Construction Program Overview. Office of Water 4203. Fact Sheet 3.0. EPA 833-F-00-013.

US EPA, 2000. The quality of our nation's waters. A summary of the National Water Quality Inventory:1998 report to congress. US EPA Office of Water, Washington DC, EPA 841-S-00-001.

US EPA, 1983. Methods for chemical analysis of water and wastes, EPA -600/4 4-79-020. United States Environmental Protection Agency, Cincinnati, Ohio.

Westermann, D.T., D.L. Bjorneberg, J.K. Aase, C.W. Robins. 2001. Phosphorus losses in furrow irrigation runoff. Journal of Environmental Quality 30:1009-1015.

Table 1--Particle size specifications for compost filter berms and filter socks.

| **Specifying Agency** | **% Pass 2 in** | **% Pass 1 in** | **% Pass ¾ in** | **% Pass ¼** |
|---|---|---|---|---|
| TX DOT 5049* - berm/sock | 95 | 65 | 65 (5/8 in) | 50 (3/8 in) |
| AASHTO MP 9-03 – berm | 100 (3 in) | 90-100 | 70-100 | 30-75 |
| US EPA – berm | 100 (3 in) | 90-100 | 70-100 | 30-75 |
| US EPA – sock | 100 | | 10-30 (3/8 in) | |
| NETC – berm | 100 (3 in) | | 70-95 | 30-75 (1/20 in) |
| Filtrexx International – sock | 99 | | <30 (3/8 in) | |

* 1:1 blend of compost and untreated wood chips (termed Erosion Control Compost).

Table 2--Particle size distributions of filter media and their reported sediment-laden hydraulic flow through rate and sediment removal efficiencies.

| Treatment | Reference | Hydraulic Flow Through | Sediment Concentration (mg $L^{-1}$) | Total solids (%) | Suspended solids (%) | Particle size % pass | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 in | ¾ in | 1/4 in |
| Filter Berm[1] | Demars and Long 1998 | ND | 15,000 | ND | 93 | 98 | ND | ND |
| Filter Berm[1] | Demars and others 2000 | ND | 340,000 | 99 | ND | 94 | 64 | 55 |
| Filter Berm[2] | Demars and Long 2001 | ND | 500,000 | 99 | ND | 85 | 68 | 38 |
| Filter Berm[3] | Demars and Long 2001 | 1.1 g/min/lin ft | 500,000 | 99 | ND | 45 | 34 | 18 |
| Filter Berm[3] | Demars and Long 2001 | 0.9 g/min/lin ft | 500,000 | 20 | ND | 30 | 18 | 6 |
| Filter Berm[2] | Faucette and others 2005 | 1.0 g/min/lin ft | 1,200,000+ | 98 | ND | 99 | 95 | 93 |
| Filter Sock[4] | Keener and others 2006 | 7.5 g/min/lin ft | 100,000 | 38 | ND | 99 | 73 (1/2 in) | 36 |
| Filter Sock[4] | Gharabaghi 2006 | 7.25-10.91 g/min/lin ft | 0 | ND | ND | 92 | 86 | 25 |
| Filter Sock[4] | Gharabaghi 2006 | 7.25-13.09 g/min/lin ft | 0 | ND | ND | 99 | 91 | 27 |
| Filter Sock[4] | Gharabaghi 2006 | 7.25-13.39 g/min/lin ft | 0 | ND | ND | 99 | 89 | 12 |

[1]Did not meet TX DOT specification for filter berm particle size distribution
[2]Did not meet TXDOT, AASHTO, USEPA, or NETC specification for filter berm particle size distribution
[3]Did not meet AASHTO, USEPA, or NETC specification for filter berm particle size distribution.

[4]Did not meet TX DOT, USEPA, or Filtrexx International specification for filter sock particle size distribution.
ND = no data available

Figure 1--TSS removal efficiency and turbidity reduction for 12 in and 18 in filter socks.

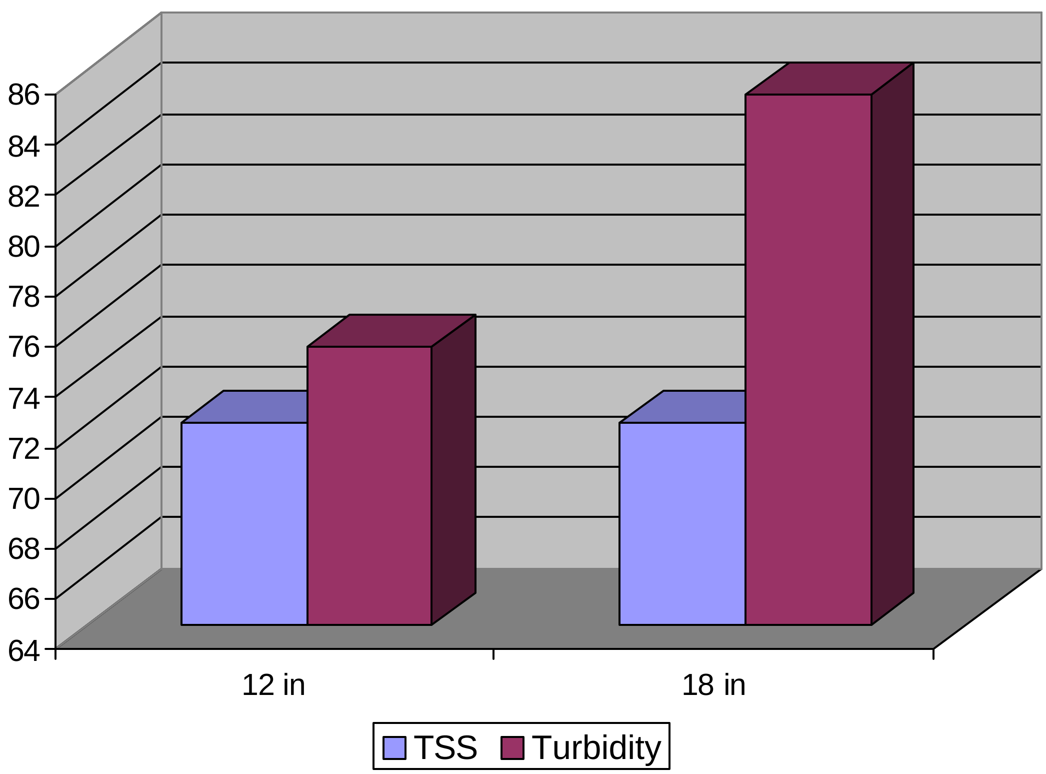


Figure 2--Percent turbidity (NTU) reduction from two consecutive runoff events with polymer added to filter socks.

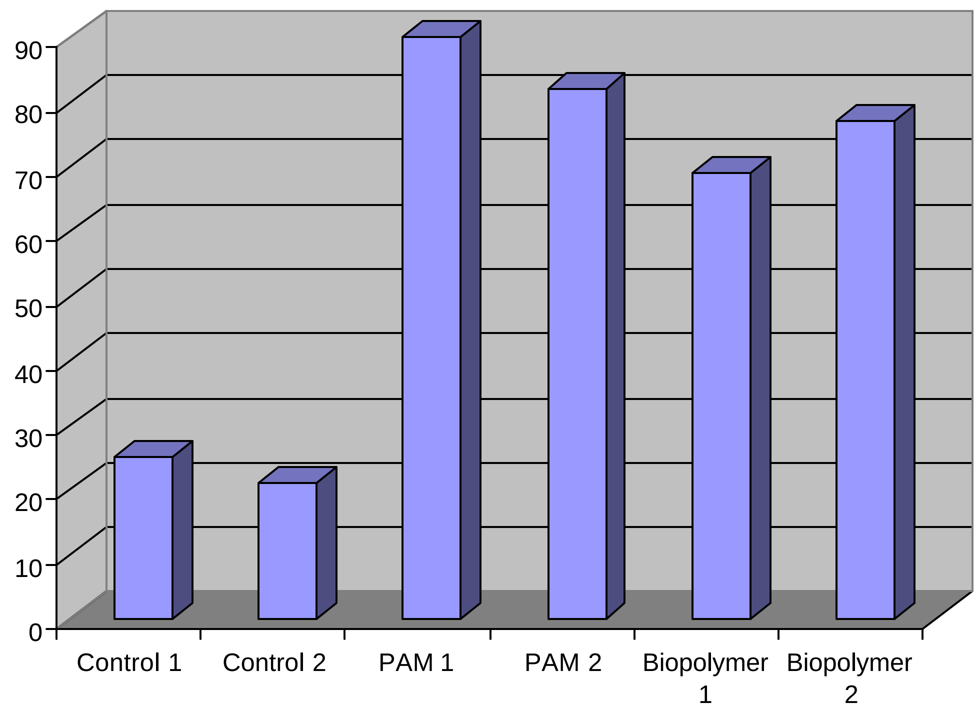


Figure 3--Percent TSS removal efficiency from two consecutive runoff events with polymer added to filter socks.

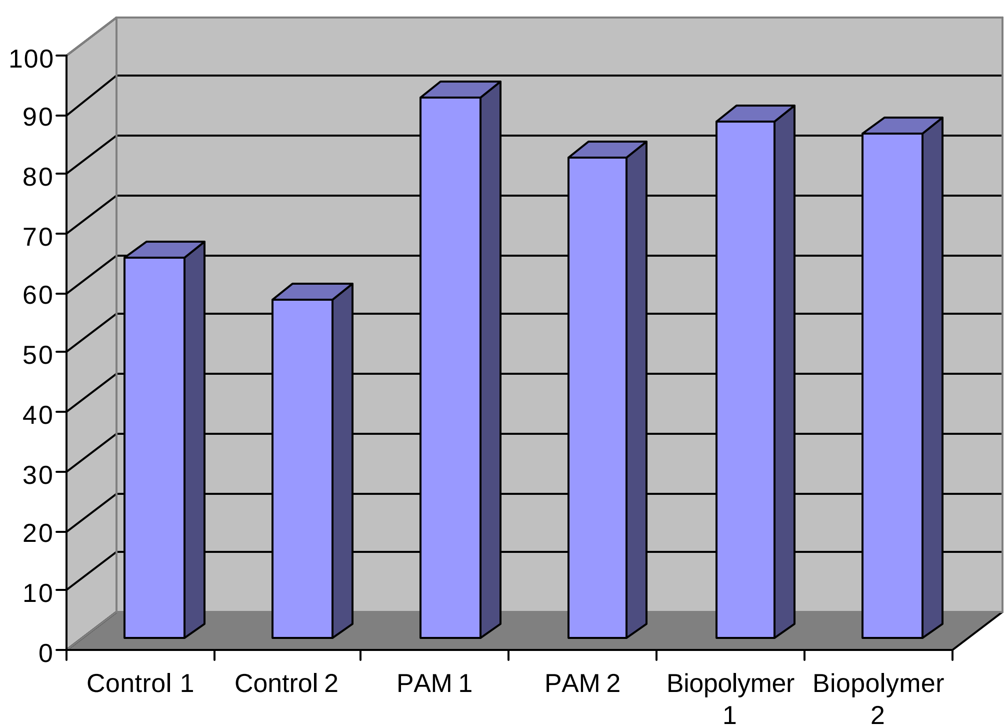


Figure 4--Soluble P removal efficiency from storm water runoff with polymer added to filter sock.

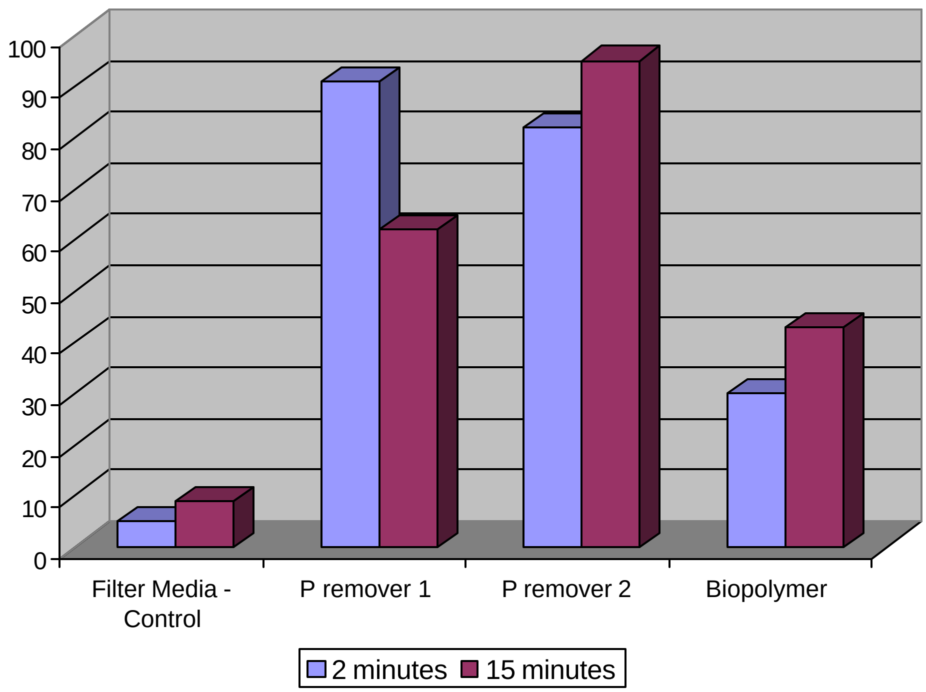


Figure 5--Hydraulic flow through rate of filter media relative to TSS removal efficiency of runoff.

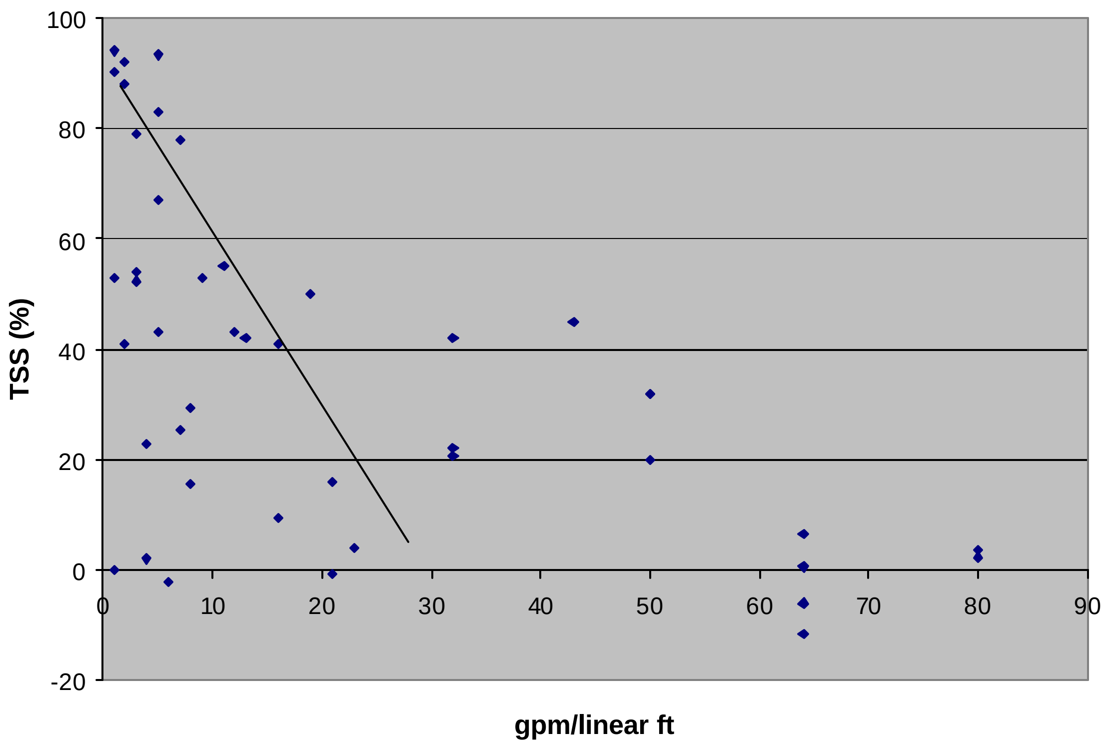

Figure 6--Hydraulic flow through rate of filter media relative to turbidity reduction in runoff.

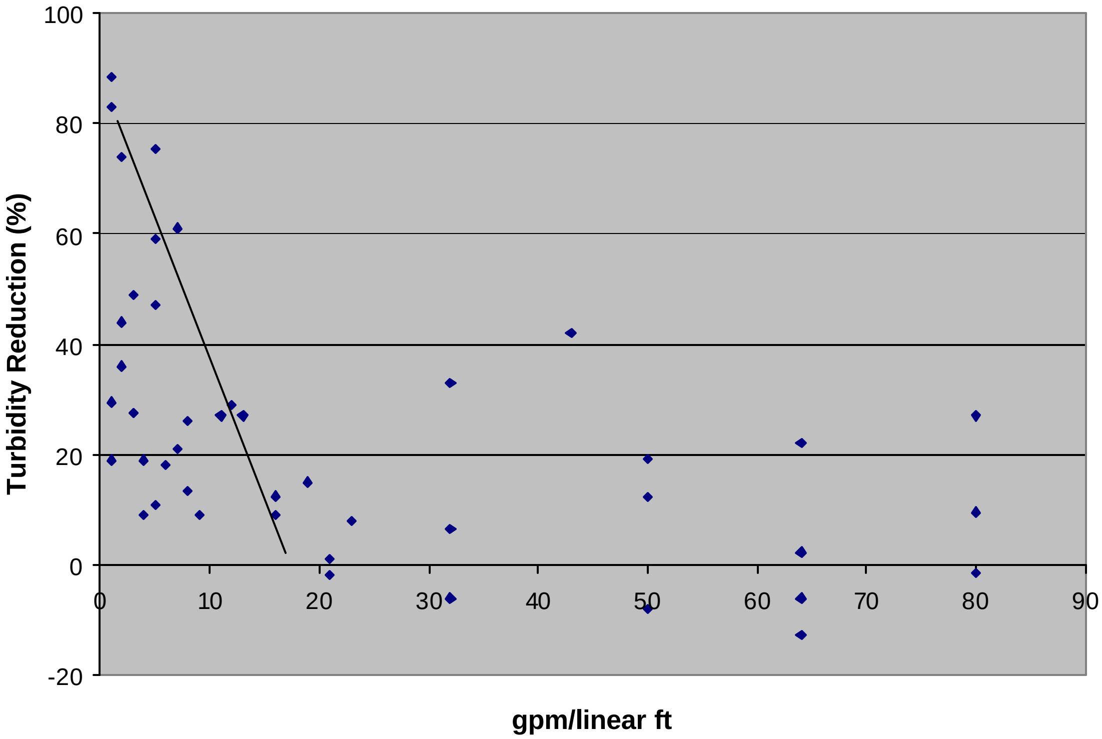


Figure 7--Hydraulic flow through rate of filter media relative to motor oil removal efficiency in runoff.

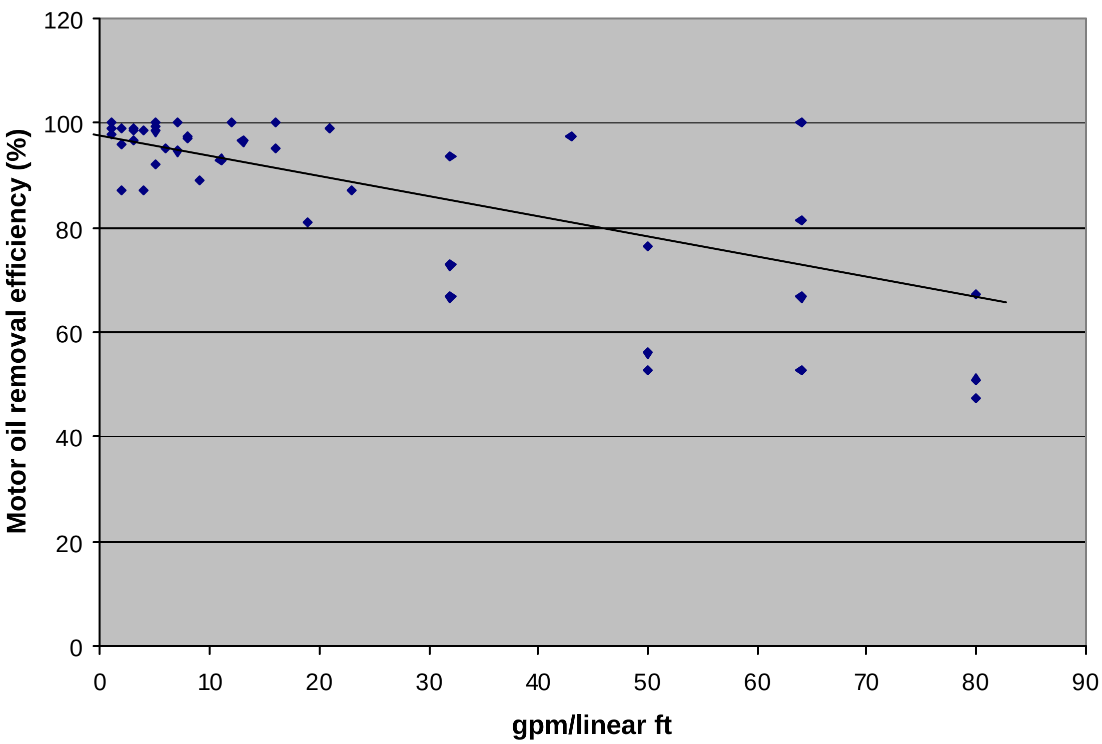

Figure 8--Hydraulic flow through rate relative to particle sizes above 3/8 in for filter media.

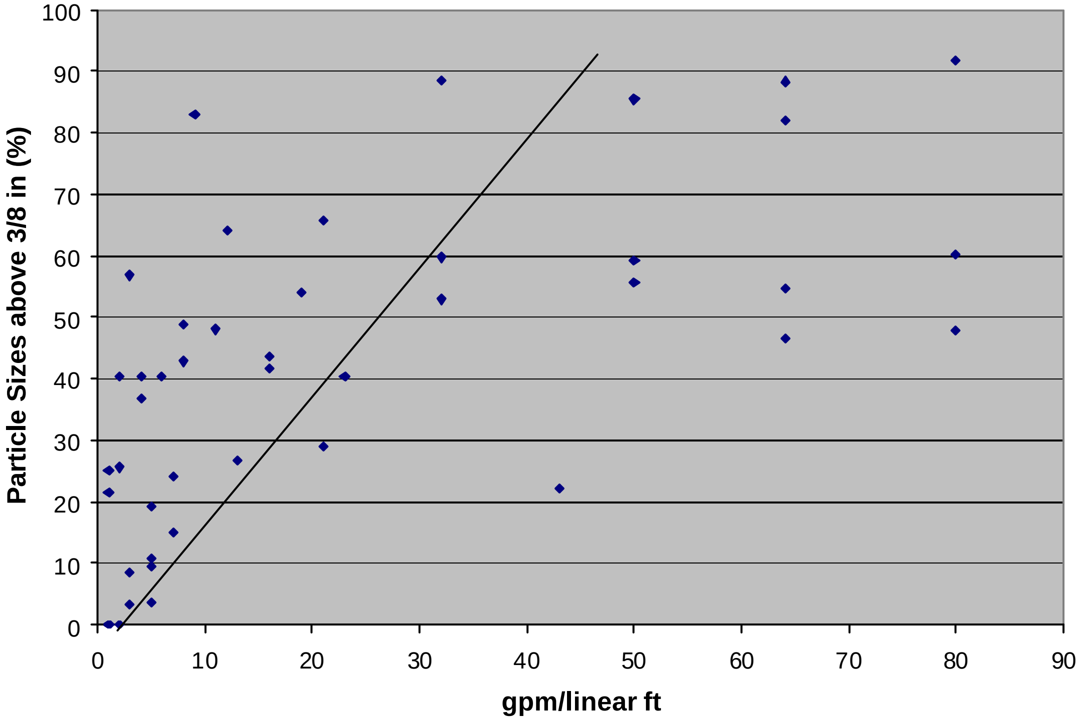


Figure 9--Hydraulic flow through rate relative to particle sizes below 1/4 in for filter media.

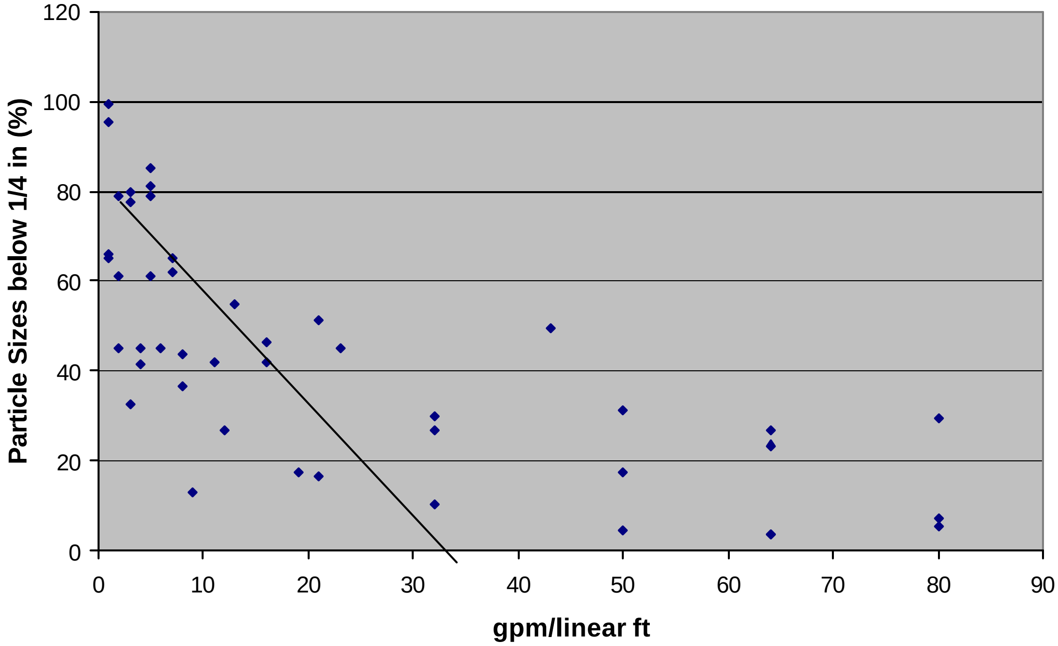


Figure 10--Hydraulic flow through rate relative to percent void space within filter media.

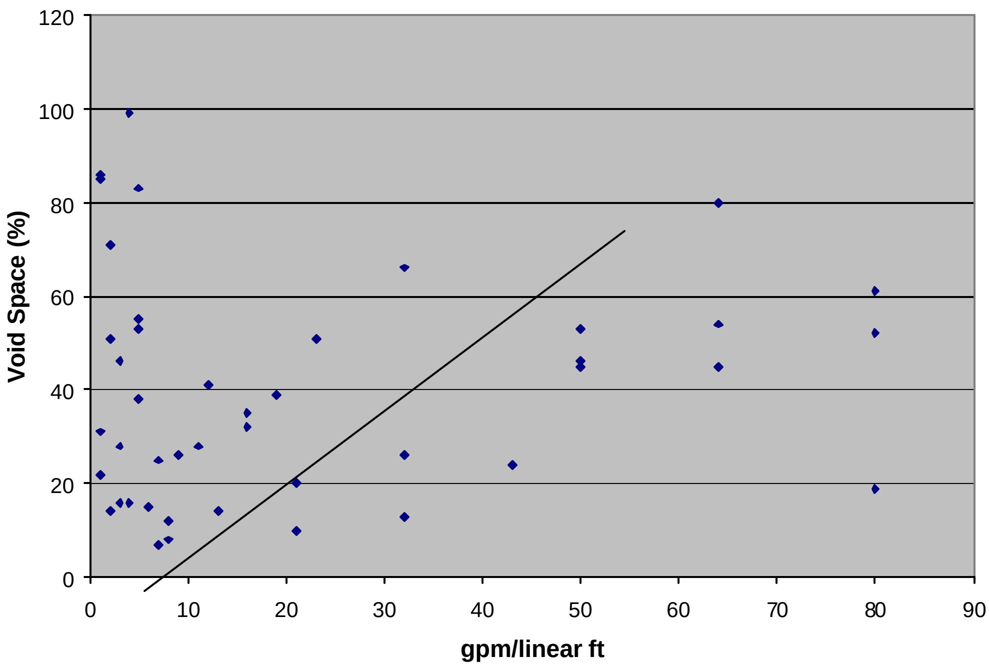


Figure 11--Hydraulic flow through rate relative to bulk density of filter media.

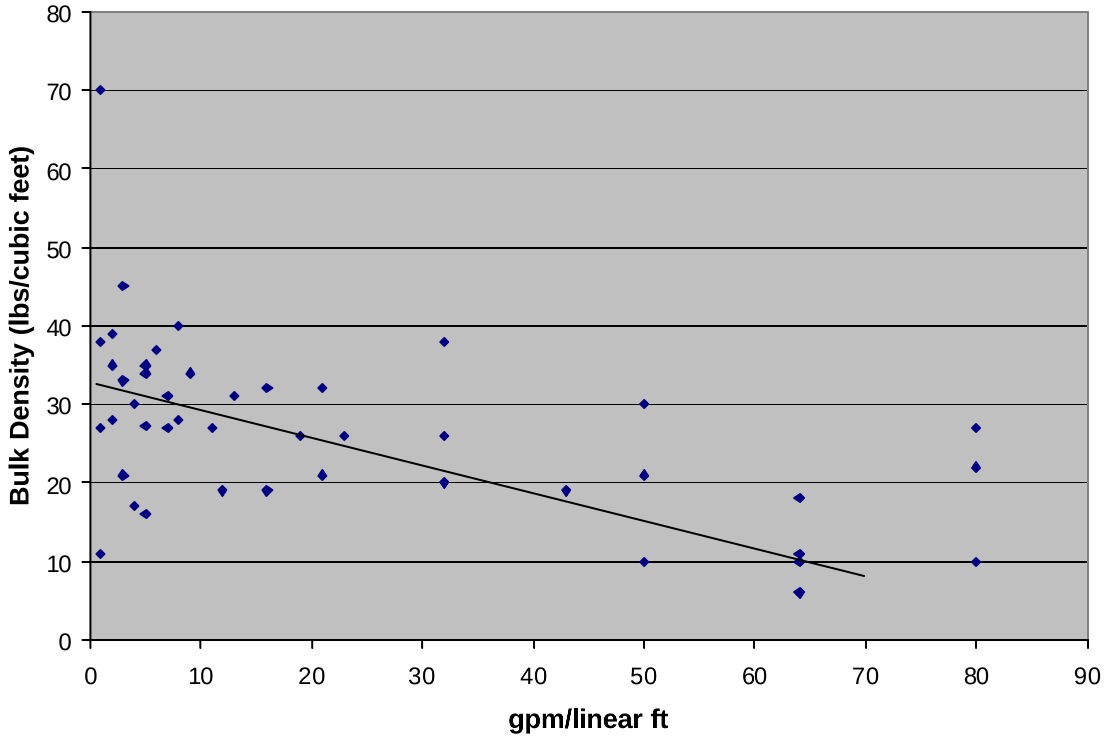


Figure 12--Void space of filter media relative to TSS removal efficiency in runoff.

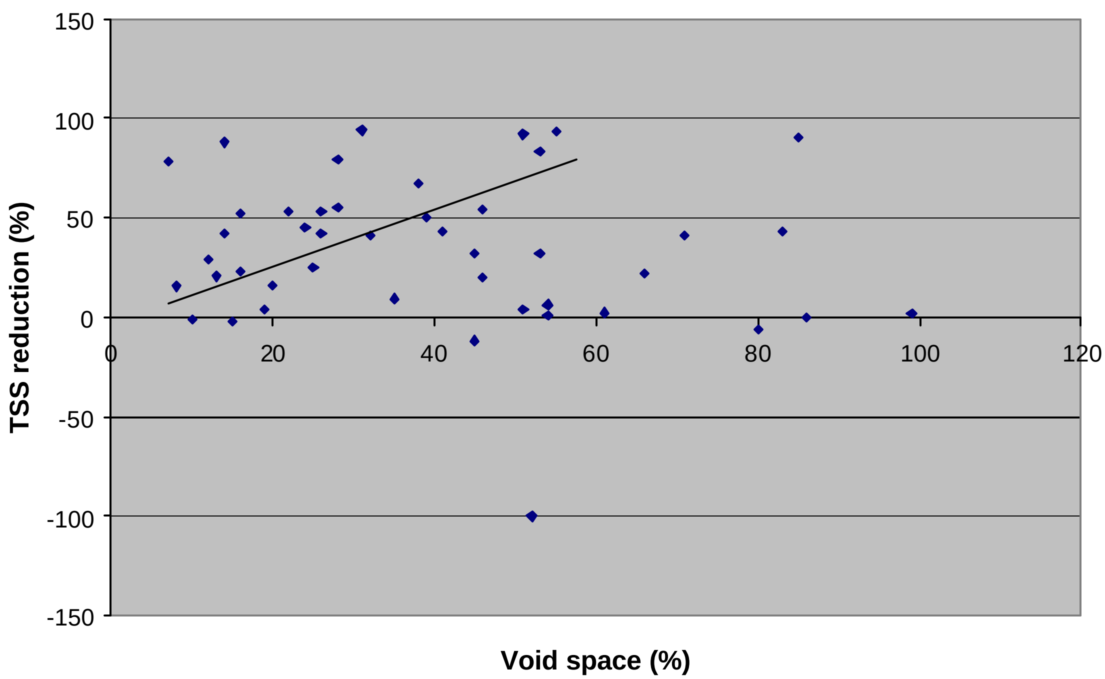

Figure 13--Void space of filter media relative to turbidity reduction in runoff.

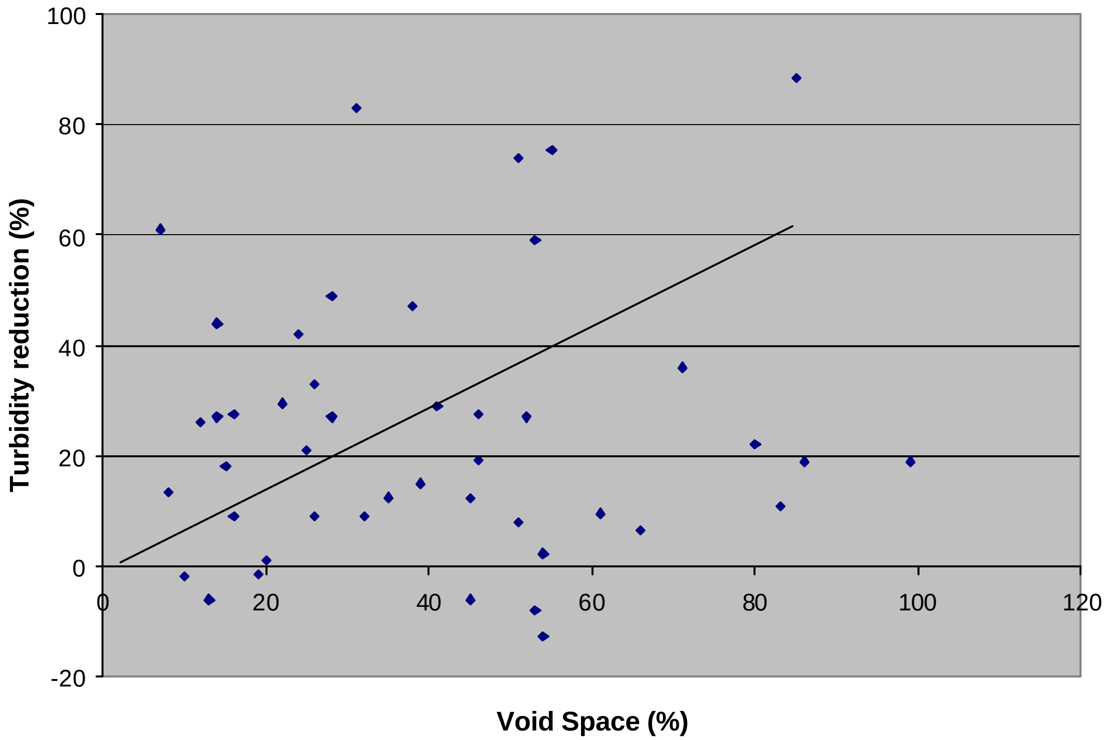


Figure 14--Void space of filter media relative to motor oil removal efficiency in runoff.

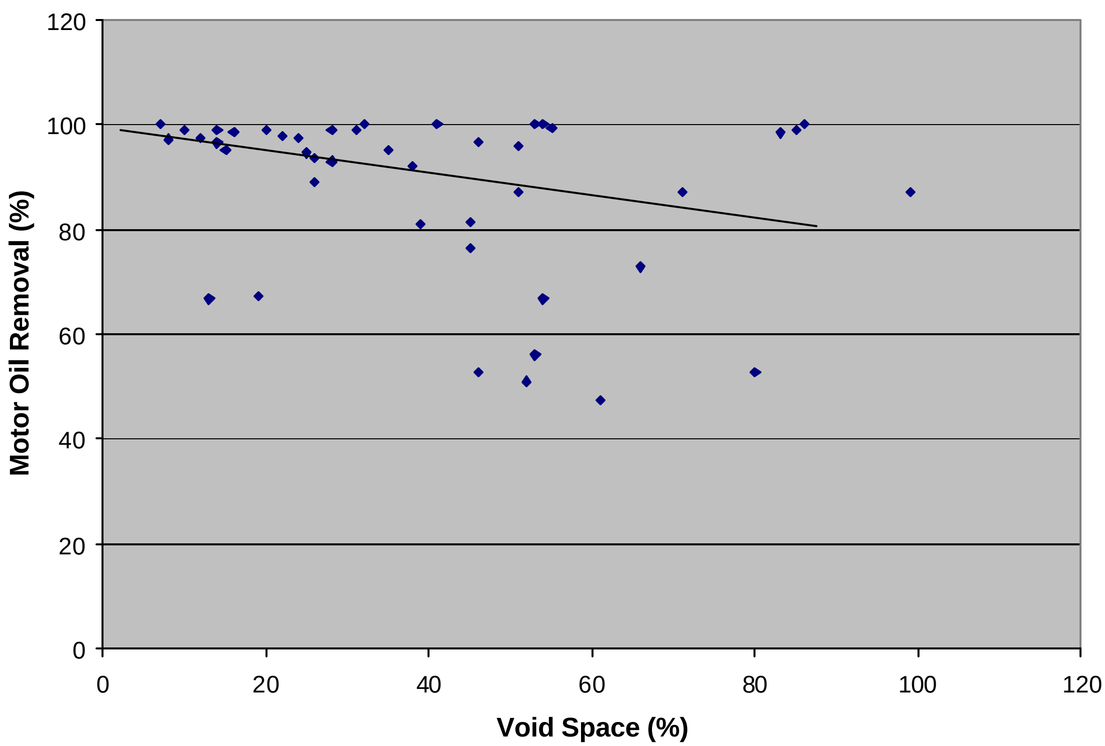

Figure 15--Bulk density of filter media relative to TSS removal efficiency in runoff.

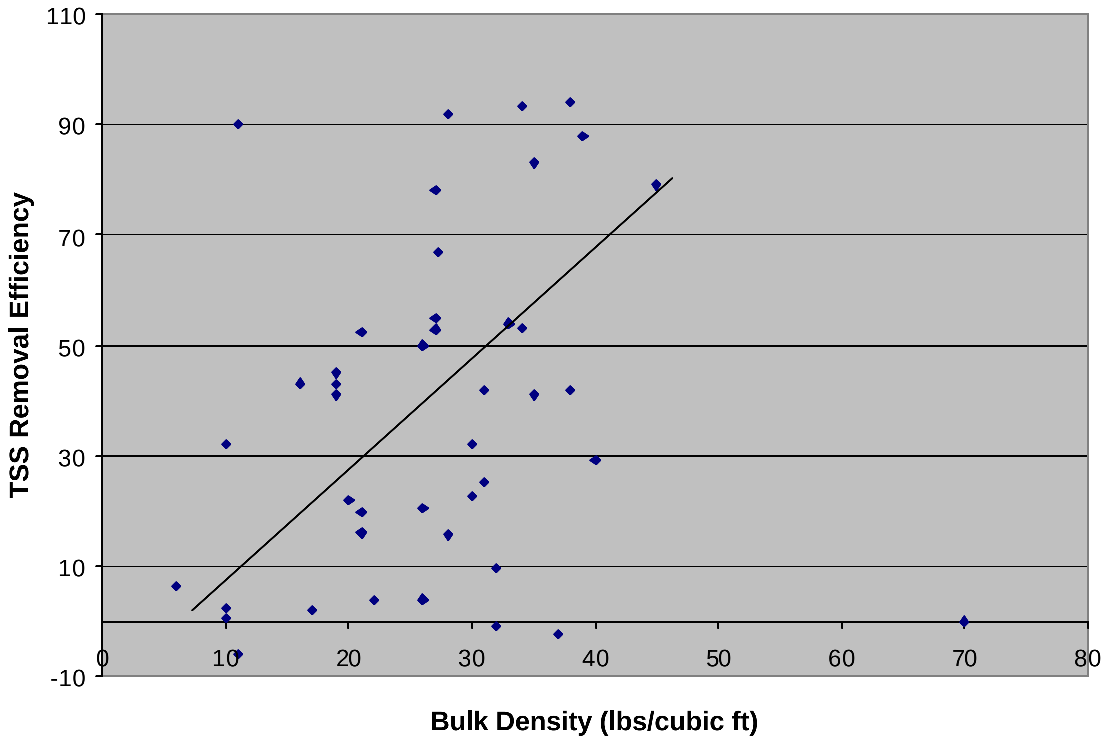


Figure 16--Bulk density of filter media relative to turbidity reduction in runoff.

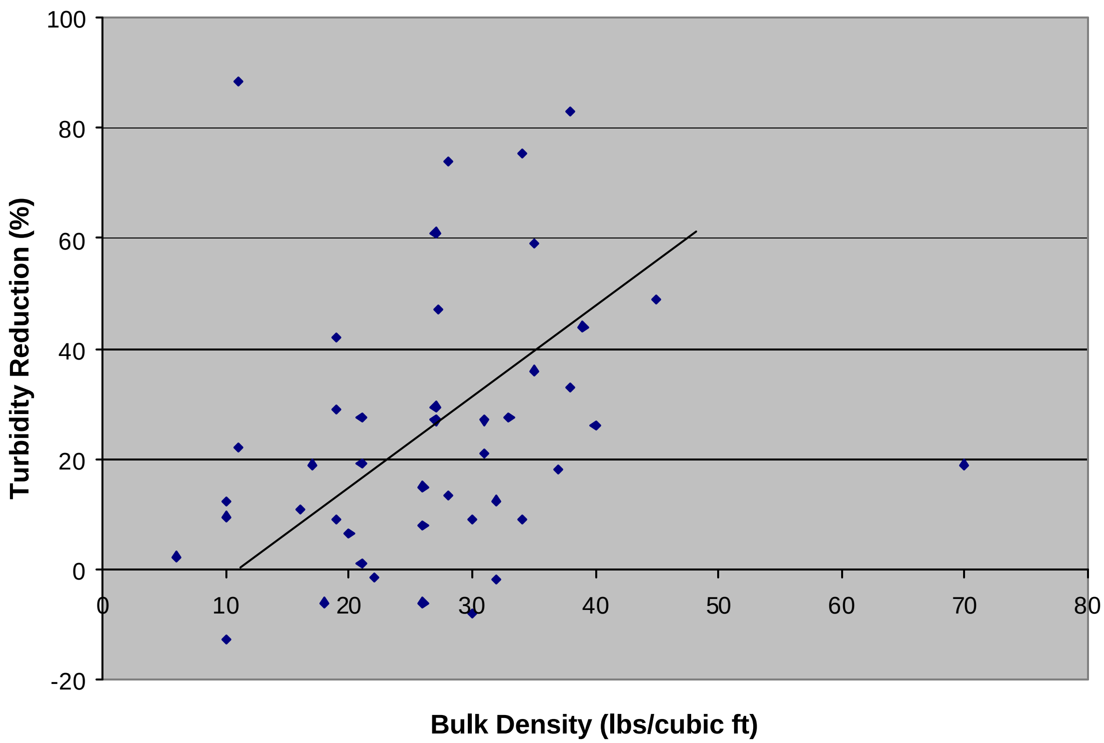

Figure 17--Bulk density of filter media relative to motor oil removal efficiency in runoff.

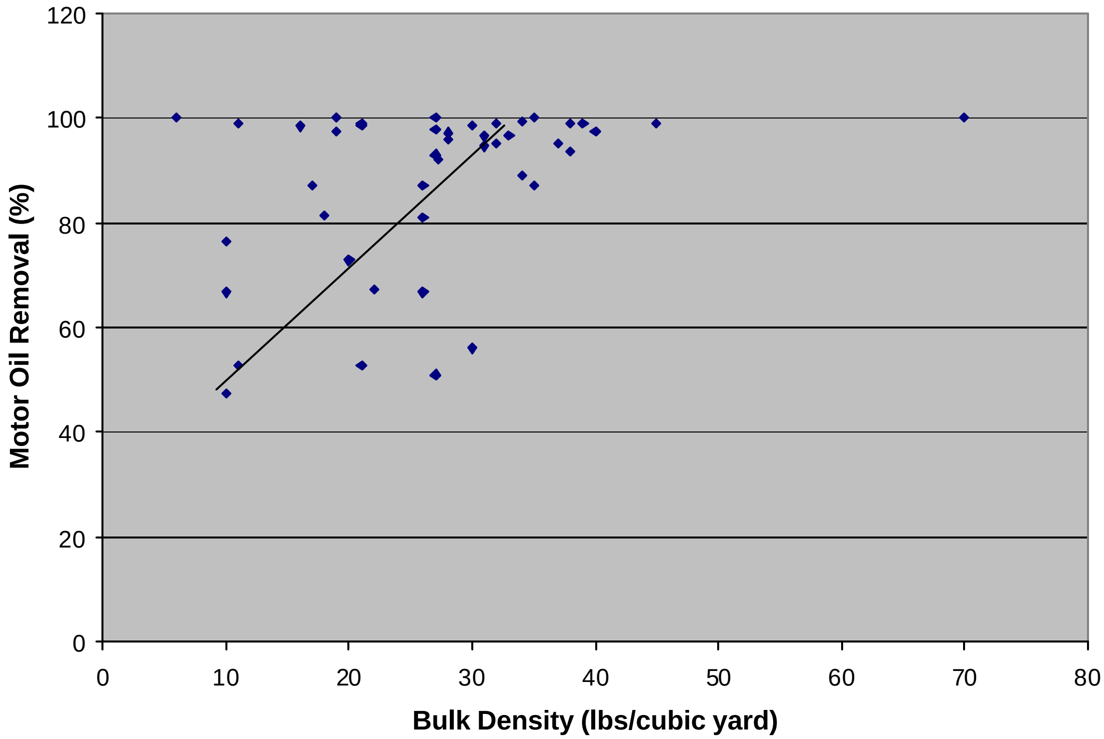


Figure 18--Particle sizes above 3/8 in of filter media relative to TSS removal efficiency in runoff.

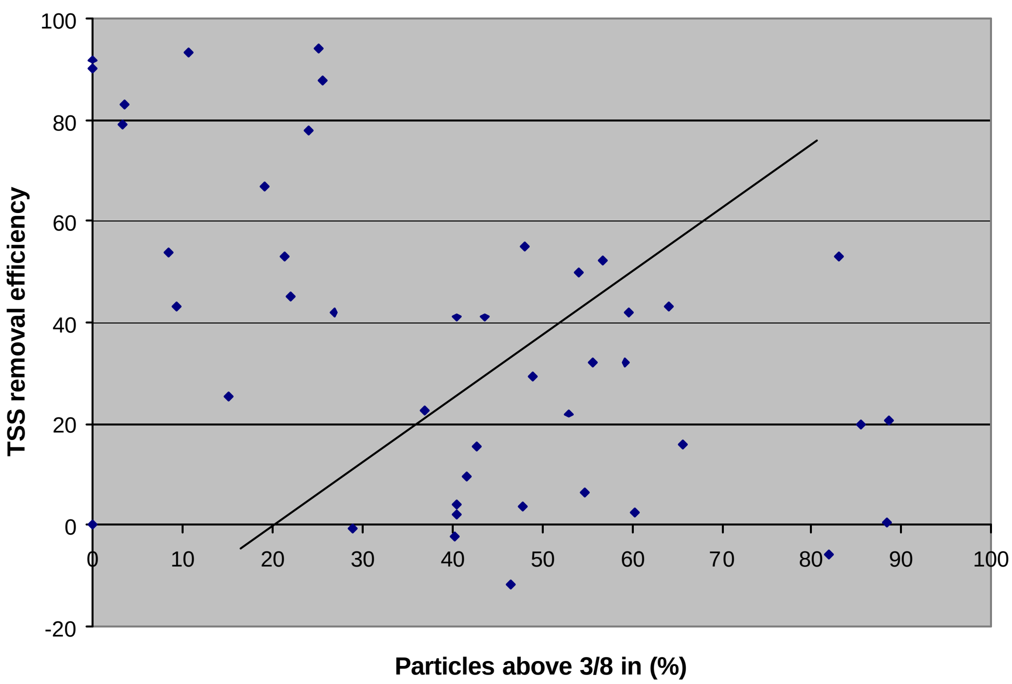

Figure 19--Particle sizes above 3/8 in of filter media relative to turbidity reduction in runoff.

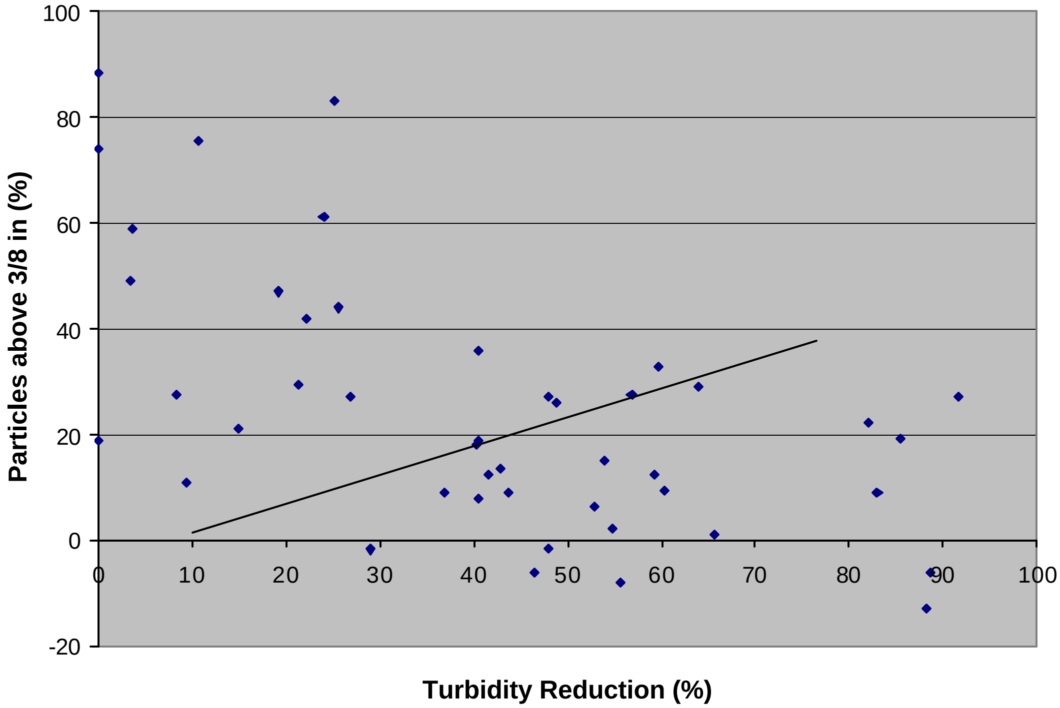


Figure 20--Particle sizes above 3/8 in of filter media relative to motor oil removal efficiency in runoff.

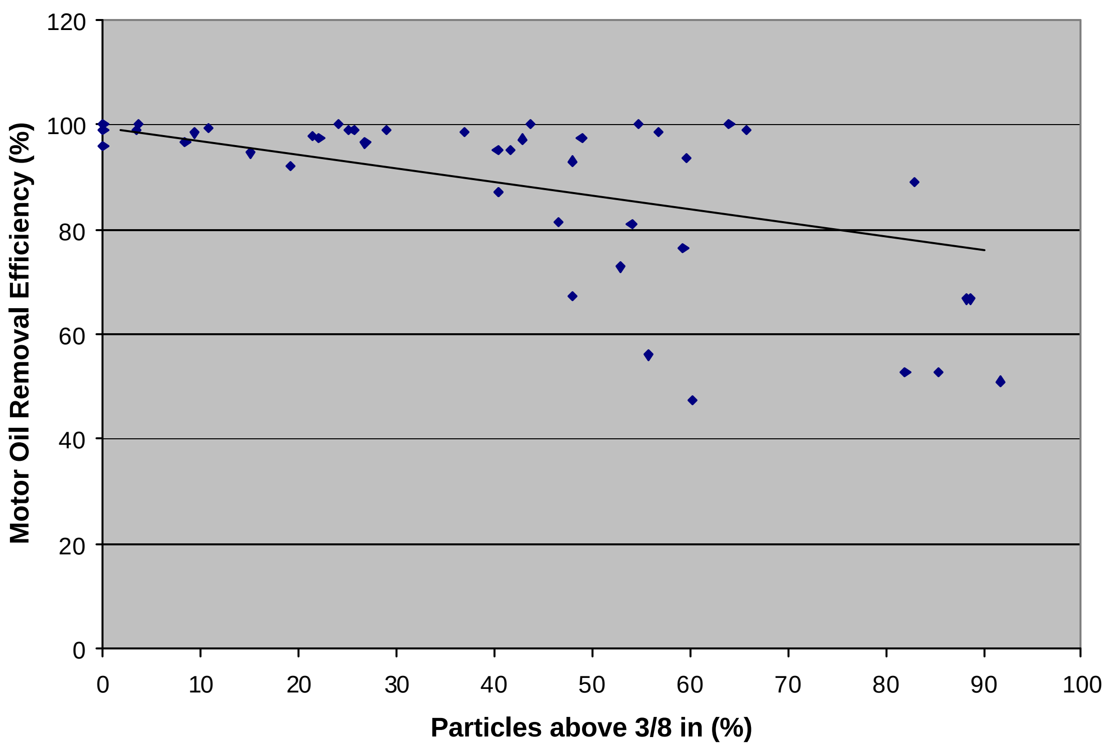

Figure 21--Particle sizes below 1/4 in of filter media relative to TSS removal efficiency in runoff.

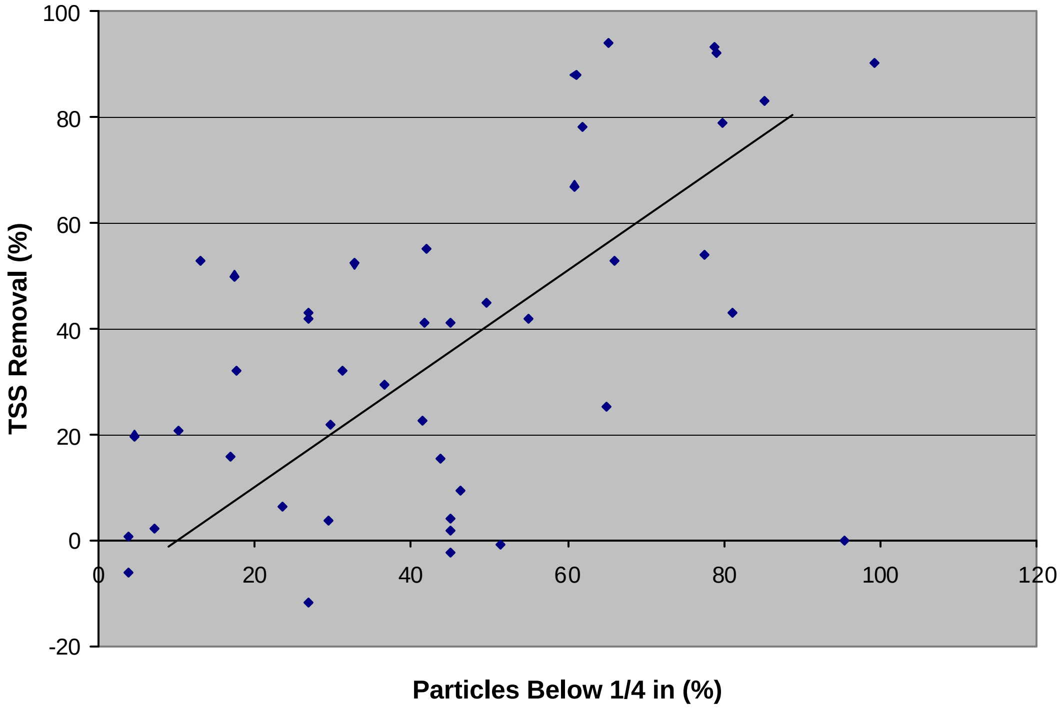


Figure 22--Particle sizes below 1/4 in of filter media relative to turbidity reduction in runoff.

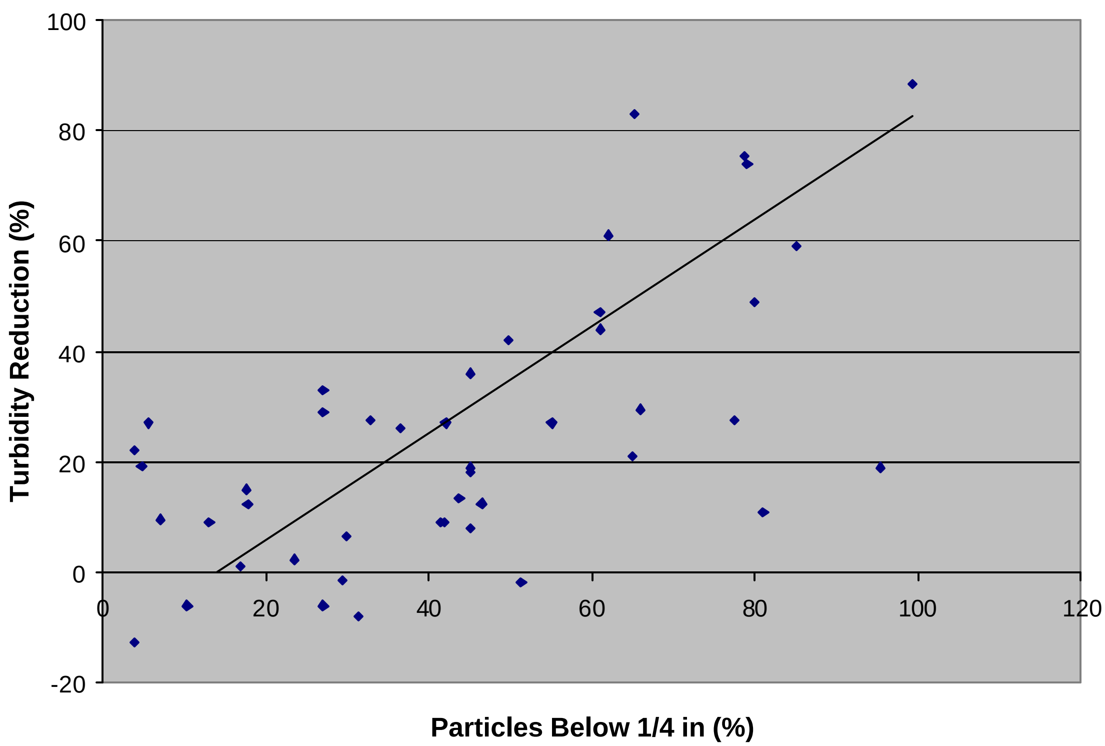

Figure 23--Particle sizes below 1/4 in of filter media relative to motor oil removal efficiency in runoff.