TechLink Research Summary #3325

Removal of Urban and Post-Construction Storm Water Pollutants with Filtrexx® Treatment Train™

Did you think Filtrexx® Sediment control was only used for sediment control on construction sites? Although Sediment control is most commonly used for this application, scientific evidence is showing that the benefit to using Filtrexx® FilterMedia™ filled Sediment control goes far beyond simple sediment control. Recent research is showing that this eco-friendly technology has the ability to filter soluble pollutants typically found in storm water flows originating from urban and suburban post-construction surfaces, such as roadways, parking lots, and roof tops (Faucette and Tyler, 2006; Faucette et al., 2006). The humus fraction of FilterMedia™ has the ability to chemically adsorb free ions, such as soluble phosphorus (P) and ammonium nitrogen (N) (Brady and Weil, 1996). The USDA ARS (Sadhegi et al., 2006) recently reported removal efficiencies for FilterSoxx™ between 14 and 28% for soluble P, and between 1 and 17% for nitrite-nitrate N. Faucette and Tyler (2006) also reported minor removal concentrations between 1 and 7 mg L-1 for nitrate-N and total P, and motor oil removal efficiencies between 85 and 99% when initial runoff concentrations of motor oil ranged between 1,000 and 10,000 mg L-1.

In 1998, the US EPA national water quality assessment stated 35% of streams were found to be severely impaired while nearly 75% of the US population lives within 10 miles of an impaired water body (US EPA, 2007). In response, as part of the 1972 Clean Water Act the US EPA has frequently listed streams for Total Maximum Daily Load (TMDL) designation for specific pollutants. Since 1995, pathogens (5081 listed), metals (5054 listed), and nutrients (3511 listed) have been the three most frequently cited TMDL water impairing pollutants, respectively; and additionally are the number one (8913 cases), fourth (6473 cases) and fifth (5625 cases) leading causes of impaired water quality (US EPA, 2007). Non-point sources of thse pollutants are generally the most difficult to control. Source examples include storm runoff from impervious services such as parking lots, roadways, and rooftops in urban and suburban areas. In disturbed soils, where soils are prone to detachment and transport (such as on construction sites), these pollutants are often attached to sediment; however, sediment bound pollutants can quickly become desorbed, therefore transforming into soluble pollutant forms (Westermann et al., 2001). Where sedimentation is minimal due to effective erosion control and/or stabilized post-construction surfaces, soluble pollutants can be more than 80% of the total pollutant load (Berg and Carter, 1980). Consequently, soluble pollutants are often more reactive, or bioavailable, to aquatic organisms, than sediment-bound pollutants. In order to protect and improve receiving water quality, particularly around soils where fertilizers have been applied for vegetation establishment, around impervious surfaces that typically transport metals, hydrocarbons, and harmful bacteria in storm water, and where water bodies have been designated to meet TMDL requirements, BMPs need to reduce soluble pollutant loading.

The objective of this study was to conduct individual experiments to evaluate the removal efficiency potential of typical urban and post-construction storm water pollutants using Filtrexx® Sediment control with specific material additives (Filtrexx® Treatment Train™). Specific storm water pollutants to be evaluated included: bacteria (total coliform, E. coli), heavy metals (copper, cadmium, chromium, nickel, lead, zinc), nitrogen (ammonium-N and nitrate-N), fine sediments (clay and silt), and petroleum hydrocarbons (PHC) (motor oil, gasoline, and diesel fuel).

Materials and Methods: Experimental Design

Research conducted collaboratively with the USDA-Agricultural Research Service (USDA-ARS) in Beltsville, MD, was performed to quantify the effectiveness of Filtrexx® Treatment Train™ products on the removal of common urban and suburban storm water pollutants. Filtrexx Sediment Control with Treatment Train™ additives were installed on a Hatbro silt loam soil at the base of 10% slope and exposed to rainfall-runoff conditions for 30 minutes at 3.5 in/hr, with the exception of the PHC experiment which utilized a 1 in (2.5 cm) concrete veneer on top of the soil surface to simulate an urban watershed surface. Soil chamber boxes 1 ft (0.3 m) wide by 3 ft (0.9 m) long were used to establish the effective rainfall-runoff treatment area and to contain the soil (and concrete veneer for the PHC experiment), Filtrexx Sediment control, and pollutant additions. All experiments included a control (bare soil or concrete), Filtrexx Sediment Control with various Treatment Train™ additives added to the Sediment control to target a specific pollutant. All treatments, including controls (bare soil or concrete) were conducted in triplicate. All runoff was collected in successive 1 L Nalgene bottles and used to determine total runoff, runoff rate, and to create hydrographs (with the exception of the PHC experiment). These runoff samples were used for analysis of identified pollutants. Unless otherwise stated, each respective sample pollutant concentration was determined and multipled by sample volume to determine average load in runoff. Loads were used to determine removal efficiency values using results from the control versus the treatment. For the PHC experiment, per replicate, all runoff was collected in separate 5 gal (19 L) buckets to determine total volume. Sub-samples were taken separately for each of the three PHCs (1 L for motor oil and diesel fuel, 40 mL for gasoline), in special amber and sealed bottles/viles to prevent transformation

(degradation or volatilization). PHC bottles were supplied, and analysis was conducted by Test America Labs, Inc. Loads for each PHC were used to determine total runoff volume measured in the buckets.

Application and Analysis of Pollutants

Per experiment, the soil or concrete surfaces were loaded with specific pollutants prior to rainfall-runoff simulations. The experiment evaluating potential bacteria removal utilized fresh cow manure collected on USDA-ARS grounds and applied at 45 tons/acre (4.4 lbs) equivalent to test plots, the recommended USDA-NRCS nitrogen application rate requirement for pasture grasses. Runoff samples were analyzed for total coliform bacteria (Escherichia, Klebsiella, Enterobacter, and Citrobacter) and E. coli using Colilert. Cells were incubated at 37 C for 24 hrs prior to numeration of positive total coliform and E. coli colonies. Positive cell counts were correlated to table values for most probable number (MPN) concentrations in runoff.

The experiment to evaluate potential nitrogen removal applied 180 lbs N/acre (204 kg/ha) of 34-0-0 mineral nitrogen fertilizer (17.8 g fertilizer or 6.05 g of N). Runoff samples for ammonium-N (method #12-107-06-2-A) and nitrite/nitrate-N (method # 12-107-04-1-B) were filtered (0.45 micron) and analyzed by flow injection analysis on a Lachat Quikchem. Sample concentrations were multiplied by runoff volume to determine loads. Loads from the control were compared to each treatment to determine removal efficiencies.

The experiment to evaluate metals applied 500 mL of a prepared solution containing soluble Cu, Cd, Cr, Fe, Ni, Pb, and Zn to each surface yielding the following pre-application mass (concentration): Cu: 7.32 mg (14.6 mg/L), Cd: 7.92 mg (15.8 mg/L), Cr: 6.74 mg (13.5 mg/L), Ni: 8.07 mg (16.1 mg/L), Pb: 6.03 mg (12.1 mg/L), Zn: 6.55 mg (13.1 mg/L). These metals were chosen because they have been identified as the most common metal pollutants effecting urban storm water quality. Metals extractions were performed using 1% nitric acid in a deionized water solution (water extractable metals) and analysis was performed using inductively coupled plasma optical emission spectrometry (ICP) and atomic absorption spectroscopy (AA). Soil metals mass was determined by sampled and analyzed soil concentrations multiplied by the mass of soil eroded from the surface of each plot. Total metals removal efficiencies were determined by metals transported to treatment relative to metals collected in runoff; however, sediment and water metals removal efficiencies were determined using bare soil relative to treatment runoff results.

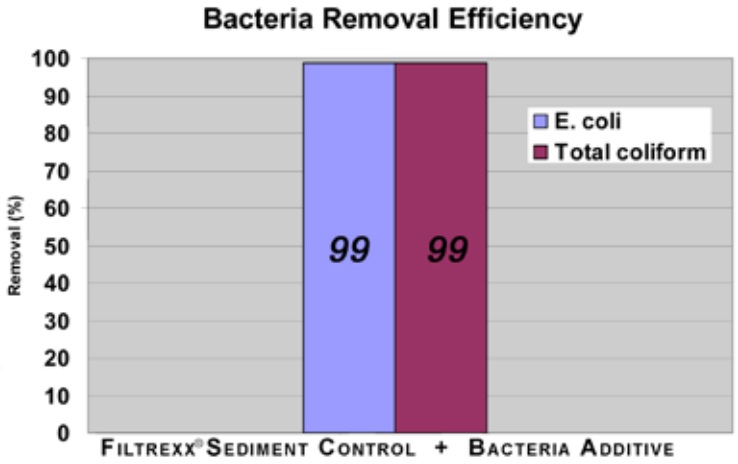
The experiment to evaluate clay (particle sizes <0.002 mm) and silt (particle sizes 0.002-0.05 mm) removal used the total sediment eroded from the soil test plots. Particle size distribution analysis of the runoff sediment was performed on a Horiba (Model LA-920) laser scattering particle size distribution analyzer using sonic dispersion of particles and light diffraction to determine particle diameters and frequency range. Samples were centrifuged prior to analysis. Particles <0.002 mm are identified as clay sediment, particles 0.002-0.05 mm are identified as silt sediment, no particles greater than this range were found in the sediment (i.e. sand sediment).

The experiment to evaluate PHC removal applied 100 mL each of motor oil, diesel fuel, and gasoline to the concrete surface at the top of the slope. Analysis for diesel fuel and gasoline in runoff used EPA Method 8015B for concentration determination of nonhalogenated volatile organic compounds and semivolatile organic compounds for diesel range of organics (DRO) and gasoline range of organics (GRO) using gas chromatography. Analysis for motor oil in runoff used EPA Method 1664A, hexane extractable material (HEM), oil and grease, by gravimetric measurement. Removal efficiencies for PHC's were determined and reported.

Results and Discussion

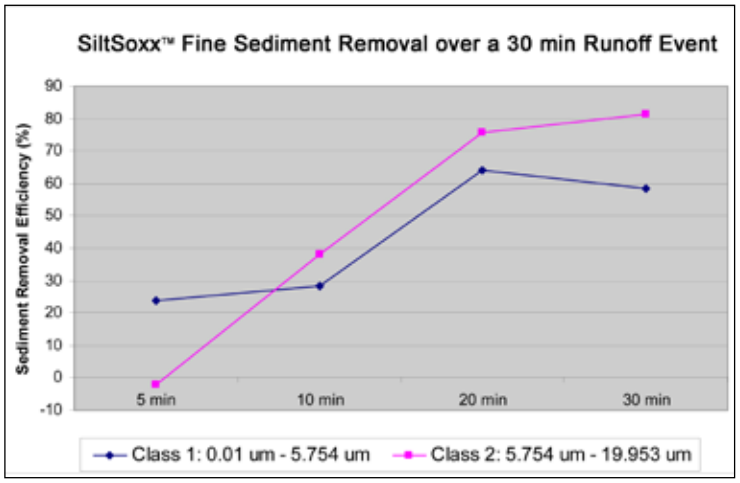
Bacteria

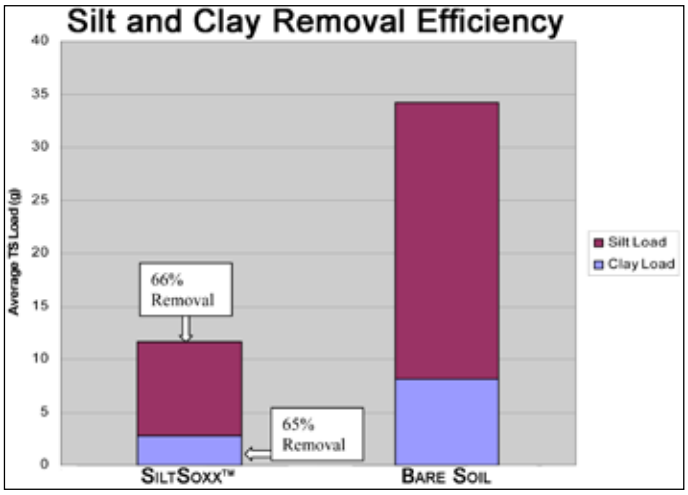
Average runoff bacteria MPN from bare soil for total coliform were 2.02X108/100 mL, and for E. coli was 1.72X108/100 mL. Removal efficiency for total coliforms and E. coli when Filtrexx® Bacteria agent is added to the Sediment control was 99%.



Clay & Silt

Average total sediment load generated from the bare soil was 34 g (8.2 tons/ac), with 24% classified as clay sediment and 76% classified as silt sediment. Results show a 65% and 66% removal efficiancy for clay and silt particulates, respectively. Additionally, results show that removal efficiency for Class 1 (0.01-5.75 µm) sediment particulates is 60%, and for Class 2 (5.75-19.95 µm) sediment particulates is 80%. These sediment fractions are typically responsible for the majority of suspended solids and turbidity found in surface waters negatively affected by storm water.





Heavy Metals

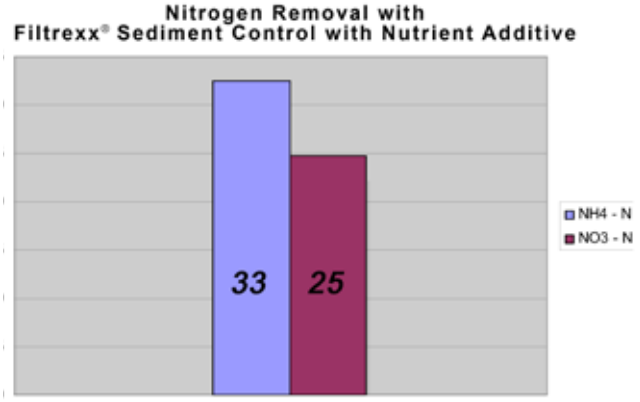
Filtrexx® Sediment Control with Heavy Metals Agent removed all 6 metals used in this experiment, and was effective at removing metals in solution in the runoff as well as metals attached to sediment particulates. FIltrexx® Sediment control with Heavy metal agent added showed a removal efficiency of 47 to 73% for all metals. Removal efficiency of metals in solution for all 6 metals ranged from 29-79%

		METALS (water extractable)					
Treatment	**Parameters (mg)**	**Cd**	**Cr**	**Cu**	**Ni**	**Pb**	**Zn**
Filtrexx® Sediment Control + Heavy Metal Agent	Applied	7.915	6.740	7.320	8.070	6.025	6.545
	Soil Surface	0.004	0.019	6.491	0.144	0.154	2.028
	Total	7.919	6.759	13.811	8.214	6.179	8.573
	Transported to Sediment Control	0.812	0.490	1.640	1.056	0.937	1.669
	Runoff Water	0.210	0.221	0.383	0.301	0.144	0.621
	Removal Efficiency*	72	29	70	69	79	57
	Runoff Sediment	0.014	0.039	0.122	0.029	0.105	0.161
	Removal Efficiency*	77	78	45	63	61	47
	Total Runoff	0.224	0.260	0.505	0.330	0.249	0.782
	Removal Efficiency (%)	73	47	70	69	73	53

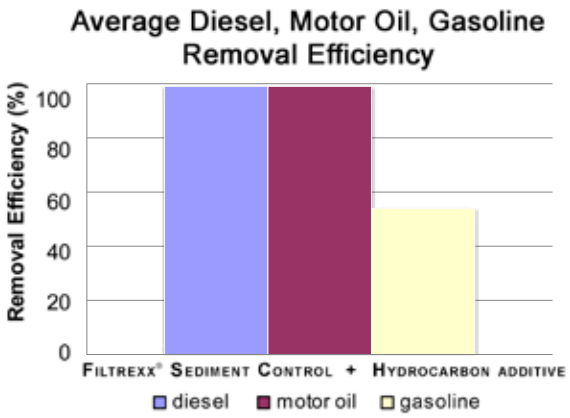
**Relative to Bare Soil w/out Treatment;*
Note: Cd concentrations in untreated runoff (0.07 mg/L) were above surface water quality limits (0.02 mg/L);
Note: Cu concentrations in soils (75-135 mg/kg) were above common range max (100 mg/kg).

Nitrogen

Runoff nitrogen load from the bare soil was 72 and 86 mg of ammonium-N (NH4-N) and nitrate-N (NO3-N), respectively. The Filtrexx® Sediment Control + Filtrexx® Nutrient agent removed 33% of runoff NH4-N and 25% of NO3-N.



Petroleum Hydrocarbons
Runoff loads from the control for diesel fuel, motor oil, and gasoline were 77,440mg; 20,820mg; and 1070mg, respectively; while runoff concentrations were 5400 mg/L, 1410 mg/L, and 74 mg/L, respectively. Removal efficiency by the Filtrexx® Sediment Control with Hydrocarbon Agent for diesel fuel, motor oil, and gasoline in storm runoff was 99%, 99% and 54% respectively.



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