Uday Khambhammettu, Hyderabad, INDIA

Education

M.S. Environmental Engineering
The University of Alabama, 2006

B.E. Environmental Engineering
V T University, Mysore, India 2002

Graduate Research Assistant for Dr. Pitt (Jan, 04 – Jan, 06)

Research

- *Upflow Filters Performance Evaluation for treating stormwater.*

Professional

- *Working as Engineer with Metcalf and Eddy | AECOM, San Diego, CA. Major job responsibilities include designing stormwater BMPs, water and wastewater treatment plants.*

Interests

- *Traveling, books, music (any kind from rock to Indian classical) and learning new languages.*

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Upflow Filtration for the Treatment of Stormwater at Critical Source Areas

Uday Khambhammettu
Metcalf and Eddy, San Diego, CA

Robert Pitt
University of Alabama, Tuscaloosa, AL

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Development of Stormwater Control Devices using Media

- Media filtration has been used for many years for the treatment of stormwater (Maryland, Florida, Texas, etc.)
- EPA-funded research in the 1990s at the University of Alabama at Birmingham examined different media, and multiple treatment processes. Multiple treatment processes can be incorporated into stormwater treatment units to provide:
  - Gross solids and floatables control (screening)
  - Capture of fine solids (settling or filtration)
  - Control of targeted dissolved pollutants (sorption/ion exchange)

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WERF-funded project on Metals Removal from Stormwater to the University of Alabama

Main Project Goals:

- Contribute to the understanding of metals’ capture from urban runoff by filter media and grass swales.
- Provide guidelines to enhance the design of filters and swales for metals’ capture from urban runoff.

Media Filtration Goals:

- Characterize physical properties
- Assess and quantify ability of media to capture metals
- Rank media and select media for in-depth study
- Evaluate effect of varying conditions on rate and extent of capture
- Laboratory- and pilot-scale studies of pollutant removal
- Disposal issues of used media (using TCLP)

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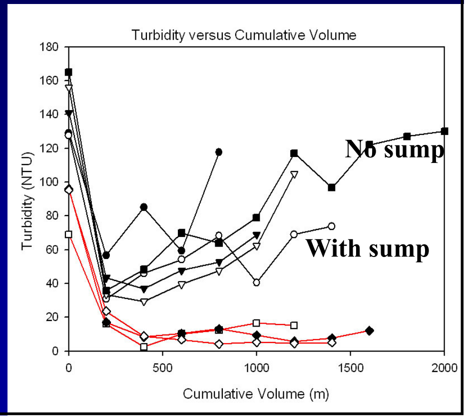
Clogging Problems Originally Addressed by Pre-Treatment. What about Upflow Filtration?

Expected Advantages:

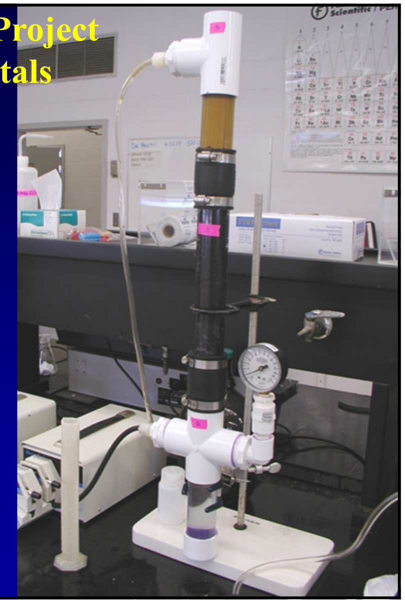
- Reduced Clogging: Sump collects large fraction of sediment load.
- Prolonged Life: Particles trapped on the surface of the media will fall into the sump during quiescent periods.
- High Flow Rates: Since large and heavy solids will be removed by way of settling in the sump prior to encountering the filter, the filters can be operated at higher flow rates.

Upflow Filter Design with Sump

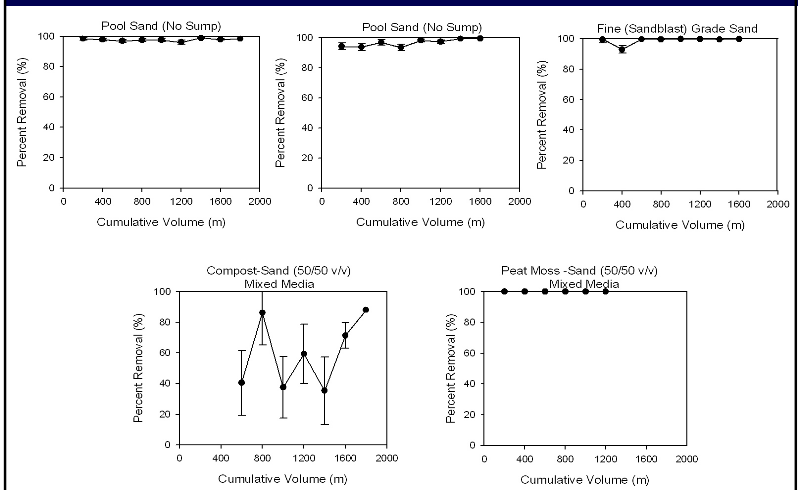


Lab-Scale Tests, WERF Project Upflow Filters for Metals Removal

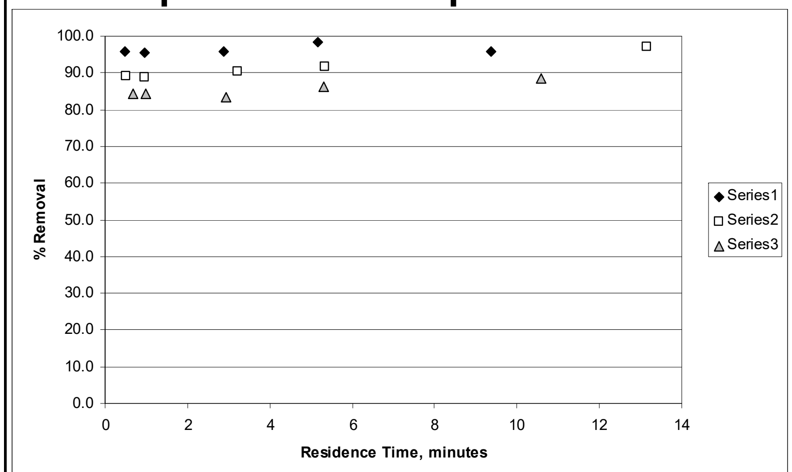
- Particulate Solids: Good removal (>90%) for all media for all runs.
- Particulate Metals: Generally 80-100% removal for Pb, Zn, Cd, and Fe and 60-95% removal for Cu and Cr.
- Peat had the best removal rates for particulate bound metals. Removal rates of compost and zeolite were about the same.



Removals of Stormwater Particulates by Different Media (1 to 175 µm)



Removal of dissolved zinc using sand/peat media in upflow filter mode



Gill 2004

Results of Upflow Filter Flow and Capacity Tests

Media	Quantity tested (kg)	Stormwater volume that can be treated (to meet Zn capacity)	Paved area that can be treated per 1 m rainfall
Activated carbon	18 kg	1 million L	1200 m^2 (0.3 ac)
Carbon plus fine sand	9.2 kg + 22 kg	530,000 L	620 m^2 (0.15 ac)
Pelletized peat plus fine sand	13 kg + 22 kg	310,000 L	365 m^2 (0.1 ac)
Activated carbon, pelletized peat plus fine sand	6.1 kg + 8.8 kg + 15 kg	570,000 L	670 m^2 (0.17 ac)

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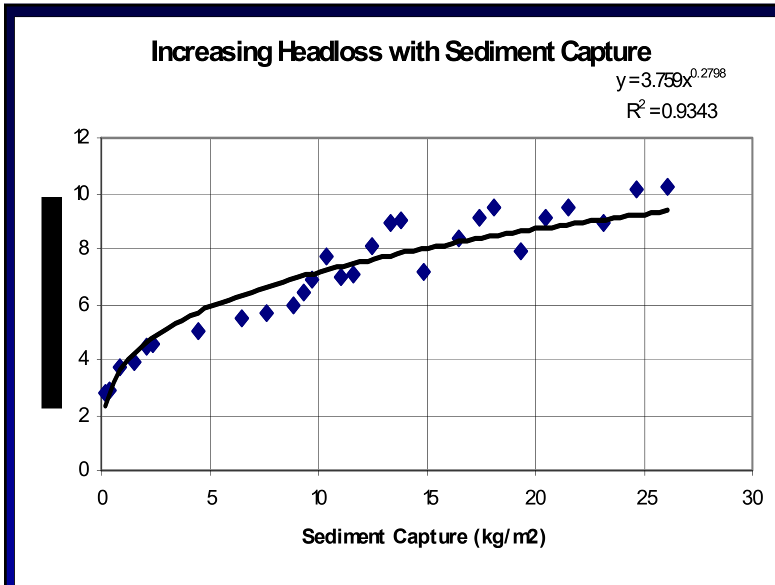

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Prototype upflow filter insert for catchbasins

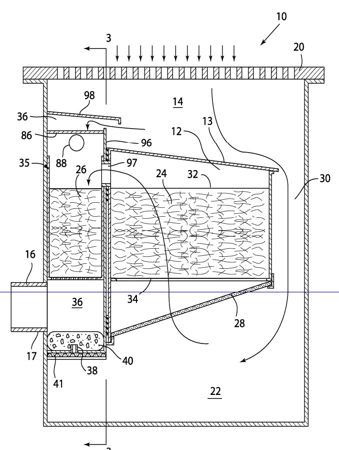

FIG. 1

UpFlow Filter™ patented

The UpFlow Filter™ uses sedimentation (22), gross solids and floatables screening (28), moderate to fine solids capture (34 and 24), and sorption/ion exchange of targeted pollutants (24 and 26). It also incorporates high bypass capacity to eliminate inlet clogging.

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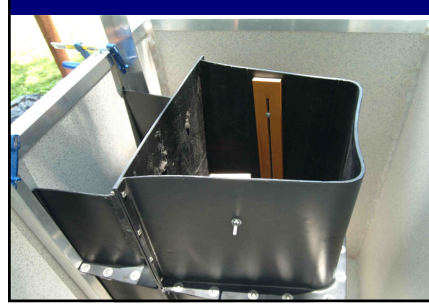
Initial Phase 1 EPA/SBIR tests of UpFlow Stormwater Filter™ in 2003



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Successful flow tests using prototype unit and mixed media as part of EPA SBIR phase 1 project. Phase 2 tests have just been completed and ETV tests are now starting.

15 to 20 gpm/ft^2 obtained for most media tested

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SBIR2 field test site, Tuscaloosa, AL, City Hall and public works vehicle parking area, 0.9 acres.

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Initial inlet that was modified for tests

Test area, new City Hall, Tuscaloosa, AL

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Prototype UpFlow™ filter tested during SBIR phase 2 tests in Tuscaloosa, AL

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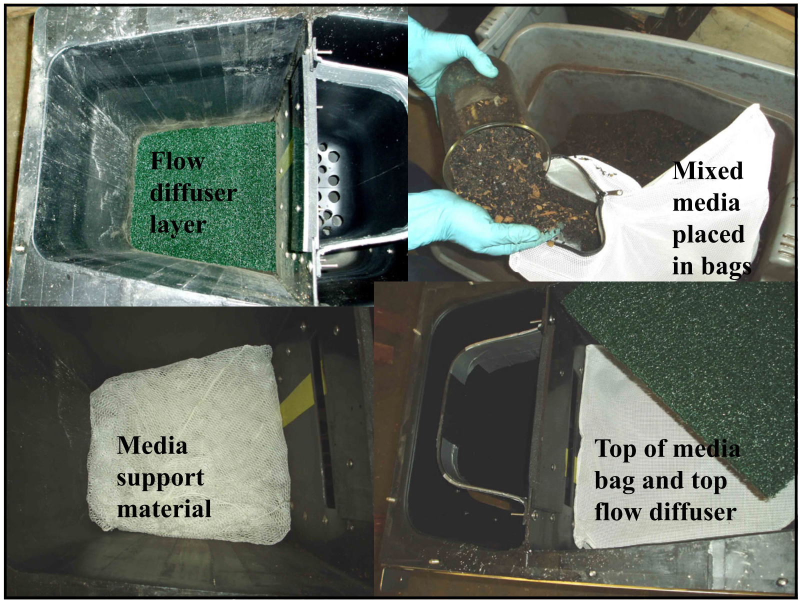

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Flow Tests to Determine Maximum Flow Capacity of Different Media

Date	Media	Flow Rate (GPM)
4-Apr-05	Zeo + Mix (dirty)	30
	Mix+Mix (dirty)	15
	Zeo + Zeo (clean)	35
10-Apr-05	Zeo + Zeo (dirty)	14
	AC+AC (clean)	48
	BC+BC (clean)	44
	Zeo+Zeo (clean)	35

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Suspended Solids Removal Tests

Media (each bag)	Flow (gpm)	Influent SS Conc. (mg/L)	Average Effluent SS Conc. (mg/L)	% SS reduc.
Zeo+ Zeo	High (21)	480	75	84
Zeo+ Zeo	Mid (10)	482	36	92
Zeo+ Zeo	Low (6.3)	461	16	97
Mix + Mix	High (27)	487	75	85
Mix + Mix	Mid (15)	483	42	91
Mix + Mix	Low (5.8)	482	20	96

Zeo: Manganese-coated zeolite
Mix: 45% Mn-Z, 45% bone char, 10% peat moss

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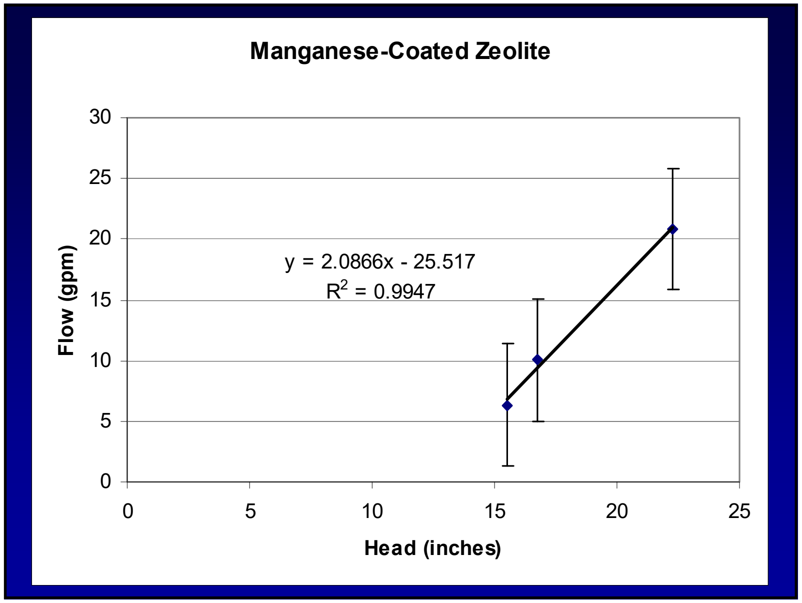
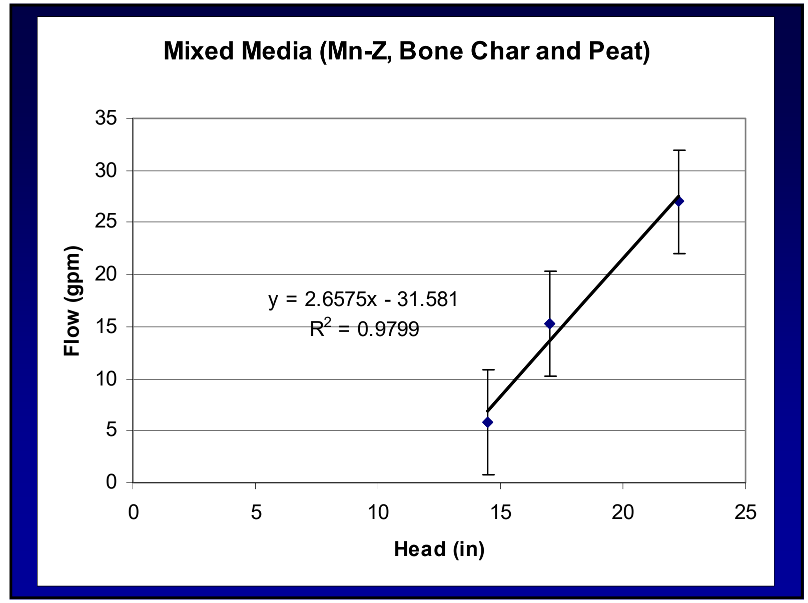

Manganese-Coated Zeolite
y = 2.0866x - 25.517
R2 = 0.9947
Flow (gpm)
Head (inches)
0
5
10
15
20
25
30

21


Mixed Media (Mn-Z, Bone Char and Peat)
y = 2.6575x - 31.581
R2 = 0.9799
Flow (gpm)
Head (in)
0
5
10
15
20
25
30
35

22


EPA-funded SBIR2 Field Test Setup,
Tuscaloosa, AL

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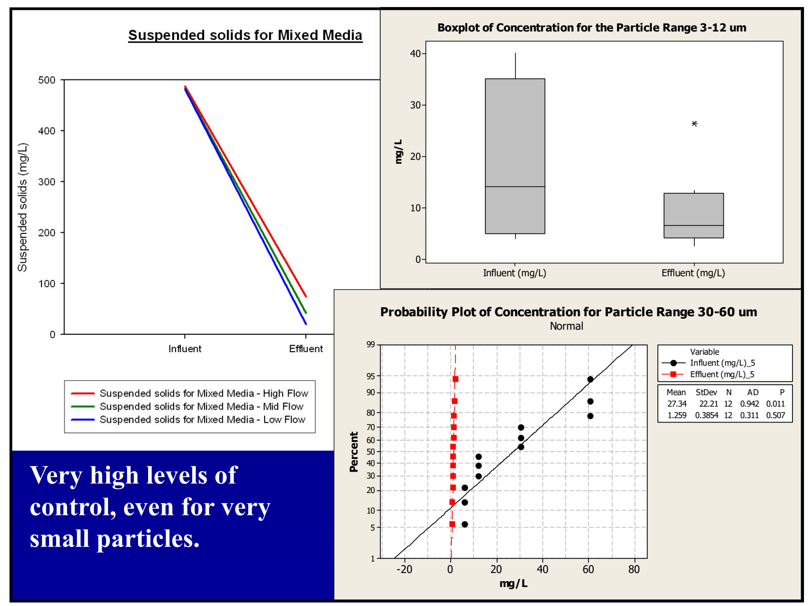
Suspended solids for Mixed Media
Suspended solids (mg/L)
Influent
Effluent
Suspended solids for Mixed Media - High Flow
Suspended solids for Mixed Media - Mid Flow
Suspended solids for Mixed Media - Low Flow
Boxplot of Concentration for the Particle Range 3-12 um
mg/L
Influent (mg/L)
Effluent (mg/L)
Probability Plot of Concentration for Particle Range 30-60 um
Normal
Percent
mg/L
Variable
Influent (mg/L)_5
Effluent (mg/L)_5
Mean StDev N AD P
27.34 22.21 12 0.942 0.011
1.259 0.3854 12 0.311 0.507
Very high levels of control, even for very small particles.

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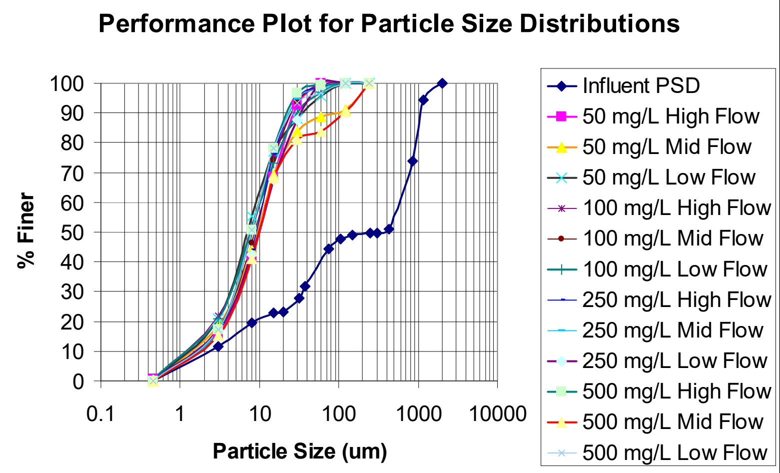
Upflow Filter Mixed Media Tests (Mn-coated Zeolite, Bone Char, Peat Moss)



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concentration in particle size range (mg/L):	6 gpm/ft² or less)	13 gpm/ft²	20 gpm/ft² (to overflow)
0 to 0.45 µm (TDS)			
69 (and smaller)	0	0	0
70	0	0	0
80	0	0	0
93 (and larger)	0	0	0
0.45 to 3 µm			
2.1 (and smaller)	0	0	0
4.2	0	0	0
10.4	80	42	26
20.8 (and larger)	80	62	34
3 to 12 µm			
4 (and smaller)	6	0	0
8	22	22	22
20.1	80	36	35
40.2 (and larger)	80	67	35

26

12 to 30 µm			
2.1 (and smaller)	35	0	0
4.2	35	0	0
10.6	80	42	17
21.2 (and larger)	80	68	31
30 to 60 µm			
6.1 (and smaller)	86	86	86
12.2	90	90	90
30.4	96	96	95
60.8 (and larger)	98	98	97
60 to 120 µm			
4.4 (and smaller)	95	95	95
8.9	97	97	97
22.2	98	97	97
44.4 (and larger)	98	98	98

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120 to 240 µm			
0.8 (and smaller)	100	100	100
1.6	100	100	100
4	100	100	100
8 (and larger)	100	100	100
>240 µm			
25.2 (and smaller)	100	100	100
50.3	100	100	100
126	100	100	100
252 (and larger)	100	100	100

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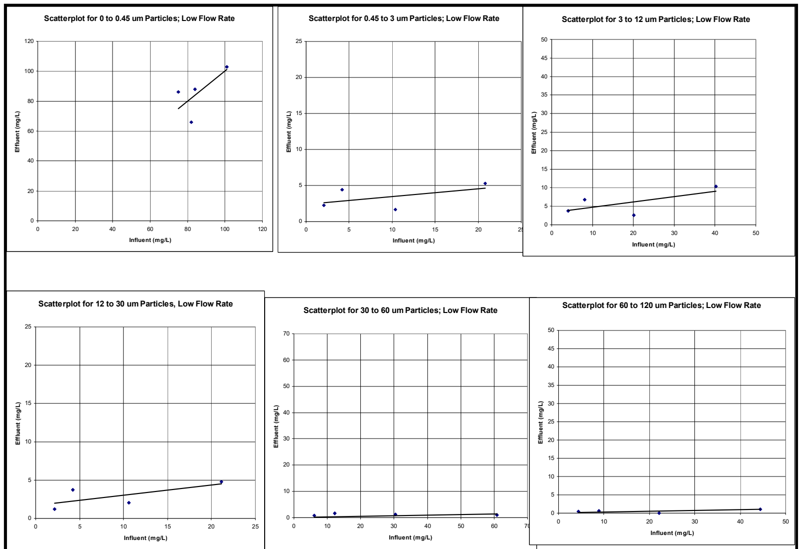

Particle Removal under Low Flow Conditions

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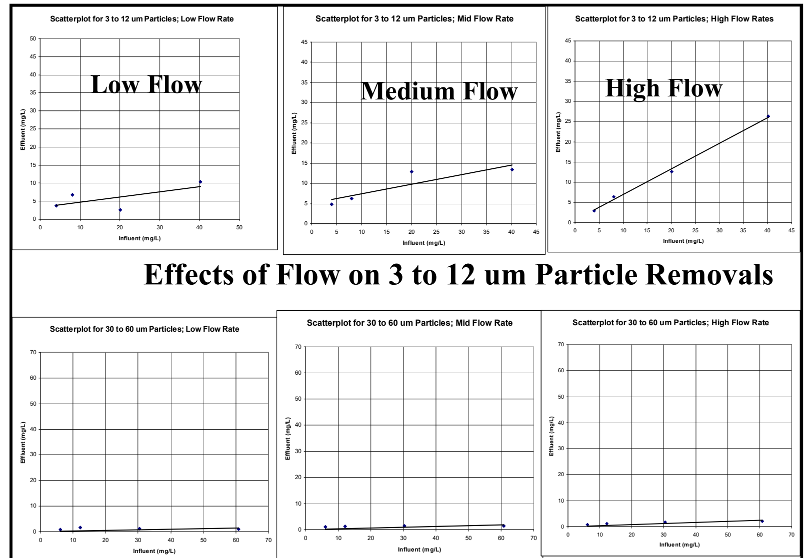

Effects of Flow on 30 to 60 um Particle Removals

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Low Flow Rate (6 gpm/ft^2 or less)

Size Range (µm)	removal rate equation (y = effluent concentration; x = influent concentration, both in mg/L of particulate solids in designated size range)	Approx. irreducible concentration
0.0 to 0.45 (TDS)	y = x	0
0.45 to 3	y = 0.1088x + 2.3895	2.7
3 to 12	y = 0.1438x + 3.2771	3.8
12 to 30	y = 0.1345x + 1.6574	1.9
30 to 60	y = 0.0245x	0
60 to 120	y = 0.0217x	0
120 to 240	y = 0	0
>240	y = 0	0

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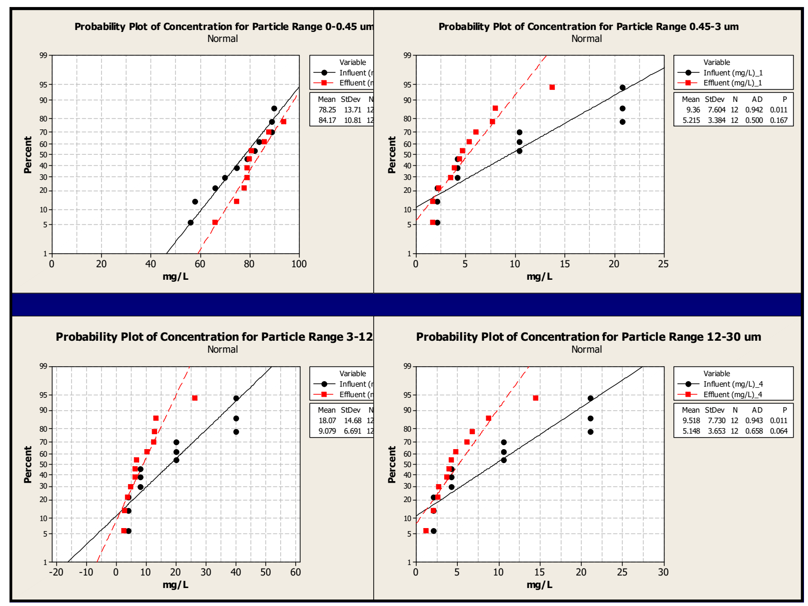

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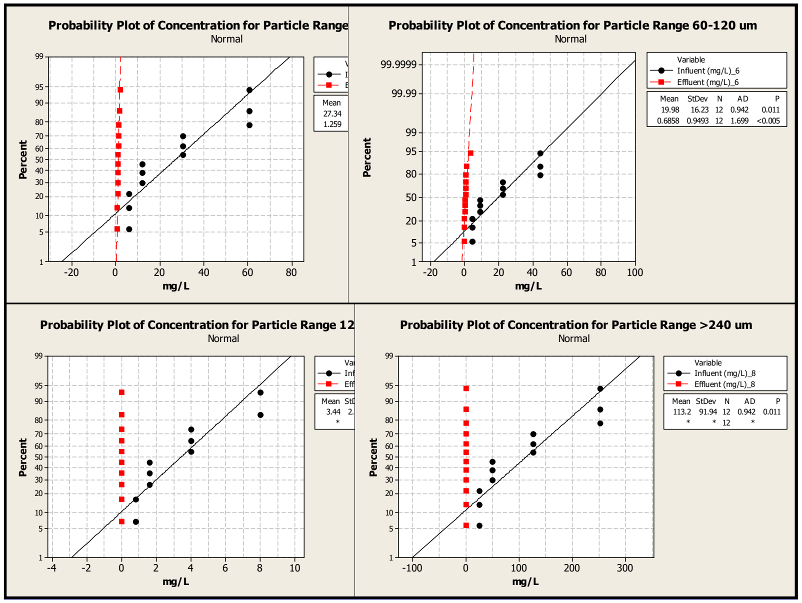

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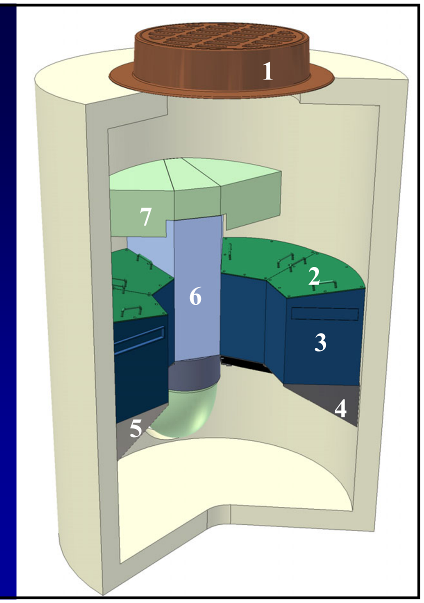
Commercial UpFlo Filter™

Components:

1. Access Port
2. Filter Module Cap
3. Filter Module
4. Module Support
5. Coarse Screen
6. Outlet Module
7. Floatables Baffle/Bypass

Hydro International, Ltd.



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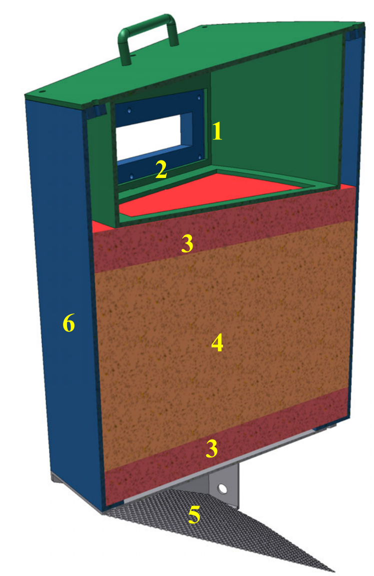
UpFlo Filter™ Components

1. Module Cap/Media Restraint and Upper Flow Collection Chamber
2. Conveyance Slot
3. Flow-distributing Media
4. Filter Media
5. Coarse Screen
6. Filter Module

Hydro International, Ltd.



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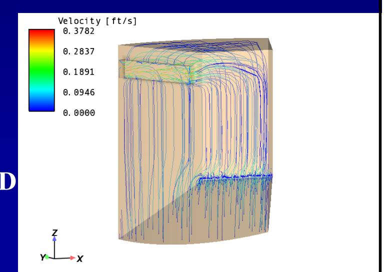
Hydraulic Characterization

Assembling UpFlo Filter™ modules for lab tests

High flow tests



Initial CFD Model Results

Hydro International, Ltd.

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Conclusions

- Setting the initial flow rate using the hydraulic residence time (HRT) predicted from batch studies is not accurate for long-term field applications. Particulate solids loading and clogging in traditional downflow filters will quickly control hydraulic residence times.

- Batch study predictions of rate constants and capacities unlikely to be valid in the field. Laboratory-scale breakthrough curve studies using multi-component and representative concentrations in actual stormwater provide better predictions of kinetics and capacity.

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Conclusions (cont.)

- It is desirable to develop stormwater controls that provide treatment train approach. Available research reports describe stormwater characteristics for critical source areas and treatability requirements.

- Upflow filtration with a sump and interevent drainage provided the best combination of pre-treatment options and high flow capacity, along with sustained high contaminant removal rates.

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Selected References

- Johnson, P., R. Pitt, S. Clark, M. Urritta, and R. Durrans. *Innovative Metal Removal for Stormwater Treatment*. Water Environment Research Foundation. 2003.
- Pitt, R., R. Raghavan, and Clark, S. *Upflow Filters for the Rapid and Effective Treatment of Stormwater at Critical Source Areas*. SBIR Phase 1 report. U.S. EPA, Edison, NJ. 2003.
- Pitt, R., R. Raghavan, S. Clark, M. Pratap, U. Khambhammettu. *Upflow Filters for the Rapid and Effective Treatment of Stormwater at Critical Source Areas*. SBIR Phase 2 report. U.S. EPA, Edison, NJ. 2005.
- Khambhammettu, U. *Evaluation of Upflow Filtration for the Treatment of Stormwater at Critical Source Areas*. MSCE thesis. Dept. of Civil and Envir. Eng., the University of Alabama. Tuscaloosa, AL 2006.

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