CONFERENCE ON STORMWATER AND URBAN WATER SYSTEMS MODELING

Full-Scale Up-Flo® Filter Field Verification Tests

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Presenter Introduction

- **Name**: Yezhao Cai
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- **Education**:
1) Bachelor of Engineering in Environmental Engineering, July 2010. Zhongkai University of Agriculture and Engineering, Guangzhou, China.
2) Master of Science in Environmental Engineering, August 2013. The University of Alabama, Tuscaloosa, AL, USA.

- **Current Position**: Graduate Research Assistant under Dr. Robert E. Pitt, from January, 2012 to present, The University of Alabama, Tuscaloosa, AL, USA

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Research Background

I. Hydraulic Challenges.

As urbanization occurs in developing areas, the amount of impervious surfaces increases. These impervious surfaces, such as asphalt roads and concrete pavements, cause stormwater runoff to flow through the landscape and drainage systems rapidly instead of being absorbed by soil and plants. This results in increased flooding and erosion of the hydraulic infrastructure.

II. Water Quality Issues.

Along with the runoff, pollutants from source areas, including solids, nutrients, metals, bacteria and hazardous organic compounds, enter the receiving streams and rivers. These substances can affect the water and sediment quality of the receiving water and destroy aquatic life habitat.

- ❑ Therefore, under these combined stresses, it is important to use advanced stormwater runoff treatment methods that are able to treat multiple pollutants with a relatively large treatment flowrate to protect both surface and groundwater resources.

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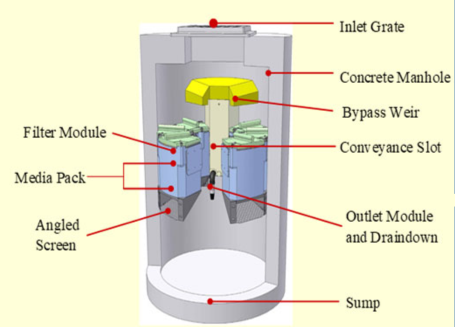
Overview of Up-Flo® Filter



Up-Flo® Filter Components

Features:
- Adjustable number of Filter Modules
- Significantly decreases clogging problems compared to conventional downflow treatment devices,
- High treatment flowrate capacity with reduced maintenance costs.

Development History:

I. EPA Small Business Innovative Research Phases I and II; with commercialization option
II. Hydro International Laboratory Testing;
III. Environmental Technology Verification (ETV) Testing
IV. Actual Storms Monitoring of Full-Scale Filter (Current Research)

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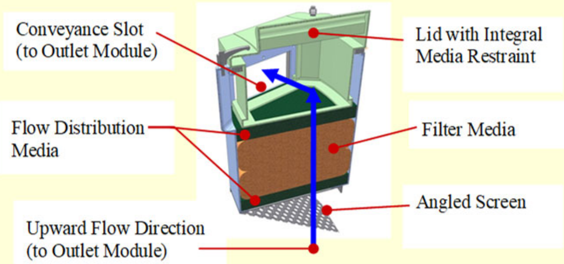
Overview of Up-Flo® Filter



- The flow rises and passes through the screens below the filter module to trap the large debris and floatables. The distribution metalla material distributes the flow evenly across the filter media bags (usually containing a mixture of activated carbon, manganese-coated zeolite, and peat) which trap the finer particles and associated pollutants.
- Runoff treatment during high flow rates is accomplished by controlled fluidization of filter media in the media bags so that fine particulates are captured throughout the depth of the media bags

Test Location And Landscape Profile

- Located at Bama Belle parking deck beside the Black Warrior River in Tuscaloosa, Alabama.

- Total contributing drainage area is about 0.9 acres

Land Use	Area (ft^2)	Area (acres)	Percentage of Land Uses (%)
Landscaped park area	12,400	0.29	32
Asphalt parking	11,800	0.27	31
Asphalt entrance road	10,990	0.25	28
Concrete sidewalks	2,100	0.05	5.4
Small roof area	1,300	0.03	3.4
Total drainage area	38,610	0.89	100
Impervious area	26,190	0.60	68
pervious area	12,400	0.29	32

Test Methodology

Based on a combination of

I. New Jersey Department of Environmental Protection (NJDEP) Protocol and;

II. Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practice Demonstrations,

An eligible storm event for this research should meet the criteria listed below:

1) Have a minimum rain depth of 0.1 inch;
2) Minimum duration of dry period between individual storm events is 6 hours;
3) Use automatic samplers to collect samples, except for constituents that require manual grab samples;
4) Flow-weighted composite samples covering at least 70% of the total storm flow, including as much of the first 20% of the storm as possible;
5) Rainfall monitoring interval should be 15 minutes or shorter period;
6) Quality Control (QC) should be performed on at least 10% of the analyzed samples;
7) At least 10 aliquots (6 aliquots) are needed for each flow-weighted composite sample for the event which the duration is greater (or shorter) than one hour.

Test Methodology

I. Hydrological Monitoring:

- ISCO 4250 area-velocity flow sensors and flow meters
- ISCO 674 tipping bucket rain gage

II. Water Quality Monitoring:

- ISCO 6712 portable automatic samplers (with 15 Liter HDPE Containers)
- YSI 6600 water quality sondes

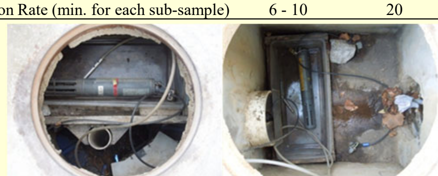
III. Sump Sediment Monitoring:

- USGS load-cell scour sensor
- Manual Measurement of Sediment Depth
- Sediment Sump Samples at the End of Monitoring Period

Test Methodology

Automatic Sampler Programming for Different Sized Rain Events

	Small Size Rain Event	Moderate Size Rain Event	Large Size Rain Event
Precipitation (in)	0.1 - 0.5	0.4 - 2	1.5 - 8
Duration (hr)	2 - 6	4 - 20	> 15
Runoff Volume (gal)	1,440 - 7,190	4,310 - 28,800	21,600 - 115,000
Average Rain Intensity (in/hr)	0.05 - 0.08	0.08 - 0.1	0.19 - 0.33
Average Runoff Rate (GPM)	46 - 76	68 - 91	171 - 304
Programmed Subsample Volume (mL)	250	250	250
Runoff Volume per Subsample (gal / L)	120 / 450	480 / 1820	2,000 / 7570
Estimated Number of Subsamples	12 - 60	12 - 60	11 - 58
Sample Volume per Event (L)	3.0 - 15	3.0 - 15	2.7 - 14
Filling Percentage of 15 L Capacity (%)	20 - 100	20 - 100	18 - 96
Subsample Collection Rate (min. for each sub-sample)	6 - 10	20	25 - 45



Pre-Storm Field Setup and Cleaning of Influent and Effluent Sampling Locations Showing Sampling Trays for Cascading Flows

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Performance Discussion

- Total of 40 storms monitored with full-scale Up-Flo® Filter at Bama Belle site.

Summary of Runoff Characteristics of 40 Monitored Events

	Average	Min.	Max.	COV
Rain Depth (in)	0.73	0.09	2.24	0.69
Runoff Volume (gallon)	13,100	830	47,830	0.82
Volumetric Runoff Coefficient (Rv)	0.73	0.20	1.00	0.38
Average Runoff Rate (GPM)	54	3	240	0.93
Peak Runoff Rate (GPM)	338	18	1023	0.93
Percent treated flow (%)	87.7	49.4	100.0	0.20

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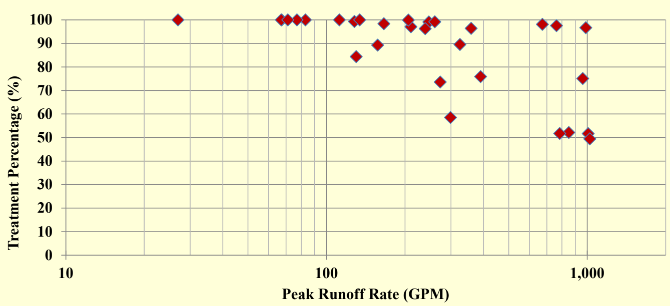
Performance Discussion



- Decreasing percentage of total flow treated by media with increasing peak runoff rate (total flows always treated by sump and siphon overflow for gross solids and floatables).
- At least 90% of the runoff flows received total treatment for events which had up to about 150 GPM peak runoff. Totally treated at least 50% of runoff flows even at 1,000 GPM flow rates.

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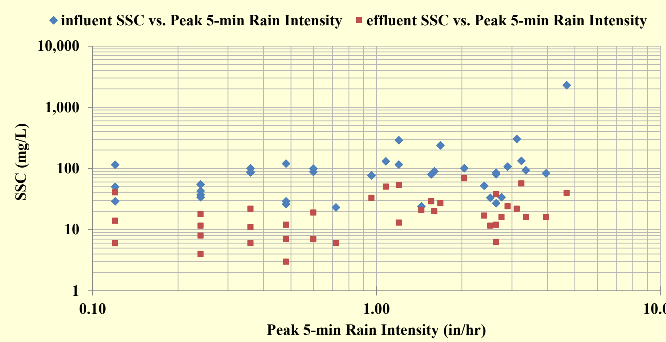
Performance Discussion



- Apparent increasing influent SSC concentrations with increasing peak rain intensities.
- Slightly increasing effluent SSC concentrations with increasing peak rain intensities.

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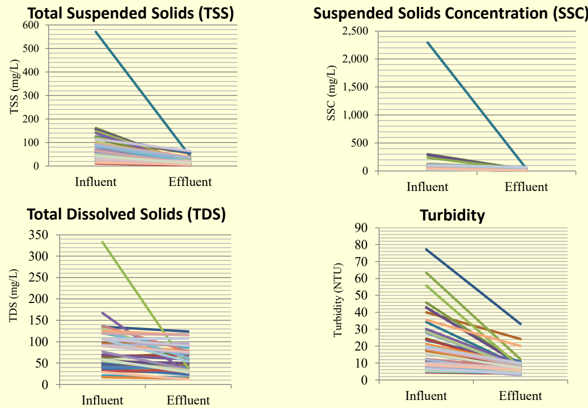
Performance Discussion



- ❑ Standard Method 2540D (Magnetic stir bar and pipetting) was used during this research for TSS analyses. Found to result in higher and more consistent recoveries of particulate solids compared to “shake and pour” EPA method.
- ❑ ASTM D3977-97B (less variations.

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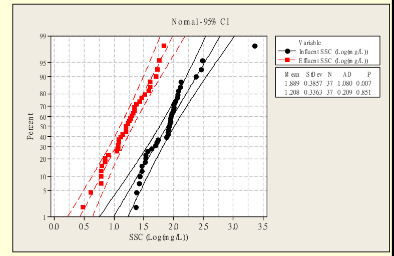
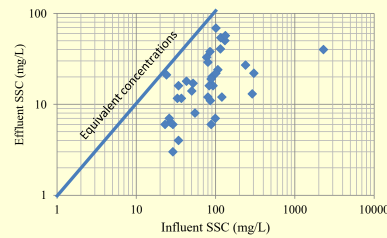
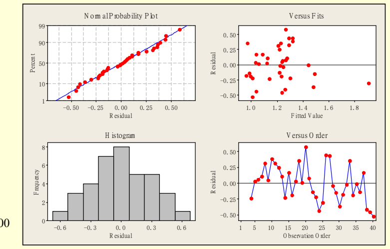
Performance Discussion







Statistical Analyses of SSC Performance

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Performance Discussion

Summary of Particle Size Distribution of 40 Monitored Storms

Particle Size (µm)	Average Mass Percentage (%)		Average solids concentration in the size range (mg/L)		Average Percentage Reduction by Concentration
	Influent	Effluent	Influent	Effluent	
0.45 to 3	0.8	1.9	0.6	0.4	34%
3 to 12	7.6	12.4	9.2	2.5	72%
12 to 30	17.1	25.5	14.7	5.2	65%
30 to 60	14.8	18.0	12.6	4.1	67%
60 to 120	11.7	12.0	9.7	2.7	72%
120 to 250	3.6	1.5	3.2	0.4	89%
250 to 1180	26.6	25.4	57.6	4.7	92%
>1180	18.0	3.3	38.3	0.7	98%
Total	100	100	146	20.6	86%

- ❑ Performance during actual storms reflects the actual particle size and specific gravity of the particulates. Tests using ground silica provide valuable information, but reflect higher levels of performance than occur during actual rain events due to increased specific gravity.

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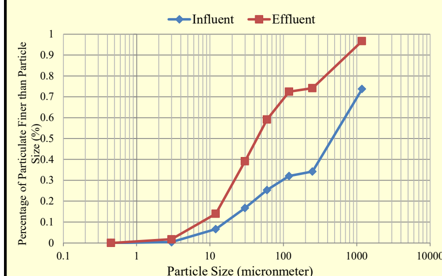
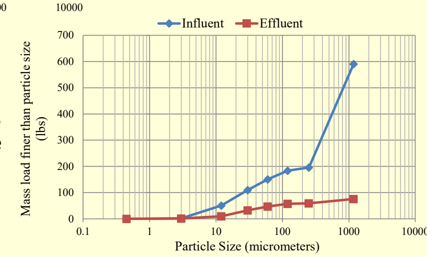
Performance Discussion



Accumulative Percentage Distribution by Particle Size

- ❑ Median particle size (D50) is about 460 µm for the influent samples while reduced to about 45 µm for the effluent samples.
- ❑ The influent D50 is relatively large (in contrast to outfall observations) as this monitoring was at a source area parking lot, and not at an outfall.

- ❑ Best removal for large particles
- ❑ A total of about 815 lbs of solids entered the Up-Flo filter, with about 78 lbs accounted for in the effluent for the 40 monitored storms.
- ❑ There will be more material captured in the device as not all events were monitored, requiring proration for the final mass balance calculations.



Accumulative Calculated Mass Distribution by Particle Size

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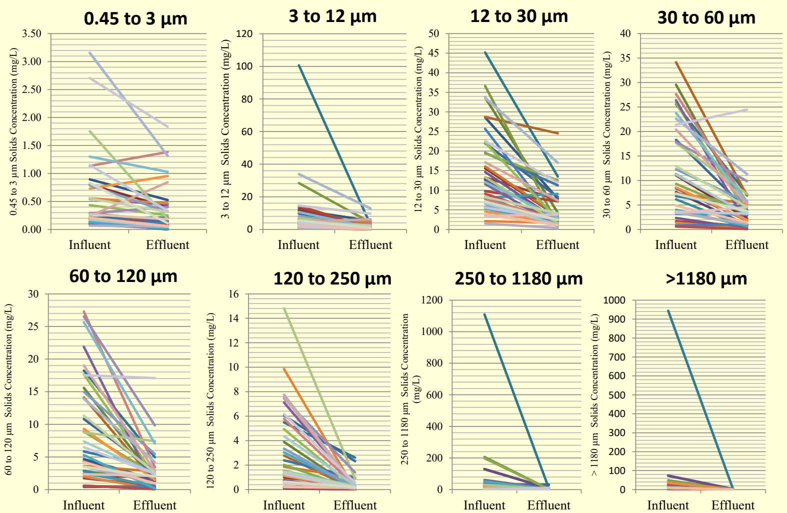
Performance Discussion



Performance Discussion

All units are in mg/L except pH, Bacteria in MPN/100 mL, Turbidity in NTU, Conductivity in µS/cm and Temperature in °C
Wilcoxon Signed Rank Test (non-parametric) is used for hypothesis test; "S" represents for "Significant" while "N" represents for "Not Significant"

Constituent	Influent Average (COV)	Effluent Average (COV)	Flow-weighted Percent Reduction	P-value (Significant or Not)	MDL
TSS	86 (1.0)	19 (0.8)	81.9%	<0.001 (S)	1 mg/L
SSC	149 (2.5)	21 (0.8)	89.9%	<0.001 (S)	1 mg/L
TDS	82 (0.7)	58 (0.5)	33.1%	<0.001 (S)	1 mg/L
VSS	32 (0.9)	8 (0.8)	77.7%	<0.001 (S)	1 mg/L
Total N as N	2.2 (0.7)	1.3 (0.6)	36.7%	<0.001 (S)	0.1 mg/L
Dissolved N as N	1.4 (0.6)	0.8 (0.6)	37.7%	<0.001 (S)	0.1 mg/L
Nitrate as N	0.6 (0.9)	0.4 (0.7)	33%	<0.001 (S)	0.02 mg/L
Total P as P	1.1 (0.5)	0.9 (0.6)	17.0%	<0.001 (S)	0.02 mg/L
Dissolved P as P	0.7 (0.6)	0.5 (0.6)	15%	<0.001 (S)	0.02 mg/L
Total Zn	0.101 (2.4)	0.022 (0.8)	78.5% to 83.2%	<0.001 (S)	0.005 mg/L
E. Coli	7,300(1.7)	4,000 (2.0)	53.5%	<0.001 (S)	<1
Enterococci	6,700 (0.9)	3,000 (1.3)	57.3%	<0.001 (S)	<1
Turbidity	22.2 (0.8)	8.2 (0.7)	61.3%	<0.001 (S)	0 NTU

Performance Discussion

Constituent	Influent Average (COV)	Effluent Average (COV)	Flow-weighted Percent Reduction	P-value (Significant or Not)	MDL
Ammonia as N	BDL (NA)	BDL (NA)	NA	NA	0.1 mg/L
Total Orthophosphate as P	0.37 (0.6)	0.36 (0.6)	2.6%	0.88 (N)	0.02 mg/L
Dissolved Orthophosphate as P	0.36 (0.4)	0.32 (0.4)	1.3%	0.64 (N)	0.02 mg/L
Total Cd	0.048 (1.1)	BDL (NA)	91.9% to 100%	0.125 (N)	0.005 mg/L
Dissolved Cd	0.038 (0.9)	BDL (NA)	87.6% to 100%	0.250 (N)	0.005 mg/L
Total Cr	0.008 (0.3)	BDL (NA)	38.9% to 100%	0.125 (N)	0.005 mg/L
Dissolved Cr	BDL (NA)	BDL (NA)	NA	NA	0.005 mg/L
Total Cu	0.032 (1.7)	0.026 (0.9)	53.6% to 75.7%	0.125 (N)	0.005 mg/L
Dissolved Cu	0.033 (0.9)	0.028 (1.1)	41.8% to 78.6%	0.500 (N)	0.005 mg/L
Total Pb	0.017 (0.9)	0.006 (NA)	67.2% to 98.3%	1.000 (N)	0.005 mg/L
Dissolved Pb	BDL (NA)	BDL (NA)	NA	NA	0.005 mg/L
Dissolved Zn	0.081 (2.5)	0.011 (0.7)	88.8% to 90.8%	0.250 (N)	0.005 mg/L

Conclusions

- ❖ Excellent hydraulic loading endurance and capacity for a wide range of precipitation conditions (treated an average of about 86% of the total flow volume, with partial treatment of the remaining flows, for peak rain intensities of up to 5 in/hr).
- ❖ Excellent removal for solids:
  - ❖ flow-weighted average TSS removal was 82%, and
  - ❖ flow-weighted average SSC removal was 90%.
- ❖ The ability to remove several types of pollutants in stormwater, including:
  - ❖ nutrients (low to moderate removals: 17 to 38%),
  - ❖ metals (moderate to high removals: 39 to 91%), and
  - ❖ bacteria (moderate removals: 54 to 61%).

After the sampling is completed, the sediment in the sump will be collected and analyzed to verify the mass balance of solids for the overall performance of the filter system. The filter media bags will also be changed out and weighed as part of the mass balance calculations.

Reference

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