TECHNICAL BULLETIN // **UP-FLO™ FILTER**

FIELD EVALUATION OF PHOSPHORUS REMOVAL

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INTRODUCTION

Historically, the main pollutant of concern in stormwater runoff has been total suspended solids (TSS). However, there has been an increasing awareness of the environmental degradation caused by the array of secondary constituents found in stormwater runoff, such as nutrients, metals and organics. The issue of how to control secondary constituents has become a focus within the field of stormwater management. A study by leading stormwater researchers (Morquecho, et al., 2005[1]) showed a strong association between the removal of very fine Total Suspended Solids (TSS) with the removal of a broad range of secondary constituents. These findings were recently confirmed in an Up-Flo™ Filter study conducted by Dr. Robert Pitt's research team at the University of Alabama. The study concluded that the Up Flo™ Filter removed over 80% of TSS including the very fine material. It was also shown that the Up-Flo™ Filter removed 72% of Total Phosphorus by virtue of the association of phosphorus with very fine particle sizes in conformance with the earlier study by Morquecho, *et al.*

ASSOCIATION OF STORMWATER POLLUTANTS WITH DIFFERENT SIZE PARTICULATES

The study by Morquecho et al. (2005) assessed particulate matter found in stormwater runoff for its concentrations of various secondary constituents and found a strong correlation between particulate particle size and secondary constituent concentrations. The very fine particulate fractions were found to have the highest concentrations of particulate and particle-bound phosphorus. The report concluded that a reduction of fine particulate matter will lead to a reduction of Total Phosphorus. Specifically, the study showed that 71% of Phosphate and 68% of Total Phosphorus would be removed if all particles greater than 20 µm in diameter were removed. When considering the removal of all particulates down to 5 µm, removals of 78% of Phosphate and 82% of Total Phosphorus were observed.

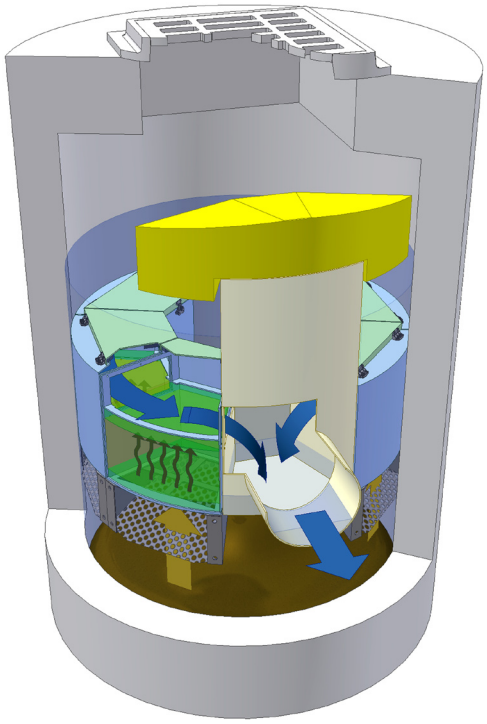

Figure 1: Up-Flo™ Filter Stormwater Treatment System

FIELD EVALUTATION OF THE UP-FLO™ FILTER

An Up-Flo™ Filter unit with CPZ Mix™ Media was installed in a catch basin at the Tuscaloosa City Hall parking lot in Tuscaloosa, Alabama in February 2005. The unit was monitored for Total Suspended Solids (TSS) removal efficiency over a 10-month period from March – November 2005. Sampling at the test site was conducted using two ISCO 6712 automatic samplers, one located in the inlet chamber of the Up-Flo™ Filter and the other located in the outlet pipe of the treatment unit. Two ISCO 4250 area-velocity meters were used to calculate flow rate in the inlet chamber and in the effluent pipe. The rainfall intensity and amount was measured using a standard tipping bucket rain gauge. YSI 6600 water quality sondes were used to measure the real time water quality data (temperature, dissolved oxygen, pH, ORP,

turbidity, conductivity, and water depth) of the influent and the effluent flows at 1-minute intervals during storm flows and at 5-minute intervals during inter-event periods.

A total of 31 rain events were sampled. The samples were divided using a Dekaport/USGS cone splitter and analyzed for Total Suspended Solids concentration using EPA Method 160.3 (SM 2540 D) and particle size distribution using a Coulter Counter/Multi Sizer III. The average influent TSS concentration for all samples taken by the ISCO 6712 automatic sampler was 64.7 mg/L, with a mean particle size of 30 µm. The average effluent TSS concentration for all samples taken by the automatic sampler was 19 mg/L with a mean particle size of 25 µm.

At the conclusion of the monitoring period, all the material captured in the sump was removed and analyzed. Contrary to the average particle size of particulate matter observed in the influent samples taken by the automatic sampler, the sump material contained a large amount of coarser particles. A particle size distribution analysis conducted on the sump material confirmed that the bulk of the material in the sump was coarse (in the 250 – 2000 µm range), as the finer materials were captured and stored within the filtration media. A summary of the particle size analysis of the sump material is shown in **Table 1**.

Particle Size Range (µm)	Particulate in Range	
	(kg)	(% Mass)
< 75	1.1	2.0
75 – 150	1.6	3.0
150 – 250	3.6	6.7
250 – 425	11.5	21.4
425 – 850	17.1	31.8
850 – 2000	10.5	19.6
2000 – 4750	4.8	8.9
>4750	3.5	6.5
Sum	53.7	100

Table 1: Particle size analysis of material captured in the Up-Flo™ Filter sump over the duration of the monitoring period

Figure 2 compares the TSS gradation of the sump material with the TSS gradations observed in the influent samples taken by the automatic samplers. As it is shown, the influent sampler data did not reflect the amount of coarse material captured in the sump.

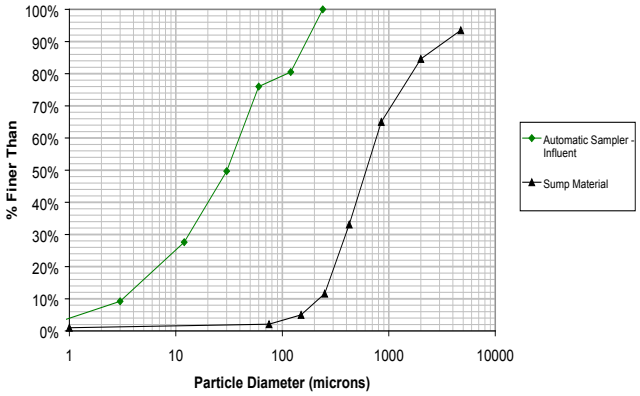

Figure 2: Average particle size distributions of all influent and effluent samples taken with the ISCO 6712 automatic samplers as compared to the particle size distribution of material captured within the sump

The total runoff volume treated by the Up-Flo™ Filter for the 10-month monitoring period was 1,570,000 liters (55,500 ft^3). The average influent and effluent TSS concentrations for all samples were determined to be 64.7 mg/L and 19.2 mg/L, respectively. To determine the total mass of material for the 0.45 – 3 µm, 3-12 µm, 12-30 µm, 30-60 µm, 60-120 µm and 120-240 µm particle size ranges, the average TSS concentrations in the range for the ISCO 6712 influent samples were used. For example, the total mass of material in the influent for the 0.45 - 3 µm range was determined using the following equation:

$$m_{\text{influent: 0.45 - 3 µm}} = 5.9 \text{ mg/L} \times 1.57\text{E}6 \text{ L} \times 1\text{kg}/1\text{E}6 \text{ mg}$$

$$= 9.3 \text{ kg}_{\text{0.45 - 3 µm material}}$$

$$m_{\text{influent: 0.45 - 3 µm}} = 9.3 \text{ kg}_{\text{0.45 - 3 µm material}}$$

Table 2 summarizes the mass of particulate material in the influent and effluent based on the samples collected by the automatic samplers.

Particle Size Range (µm)	Influent		Effluent	
	Avg Concentration of Automatic Sampler Samples (mg/L)	Total Mass in Range over Duration of Monitoring Period (kg)	Avg Concentration of Automatic Sampler Samples (mg/L)	Total Mass in Range over Duration Monitoring Period (kg)
0.45 – 3.0	5.9	9.3	1.8	2.8
3.0 – 12.0	11.9	18.7	4.1	6.4
12.0 – 30	14.3	22.4	4.9	7.7
30 – 60	17.0	26.7	4.3	6.8
60 – 120	2.9	4.6	1.1	1.8
120 – 240	12.6	19.7	2.7	4.3
> 240	0.0	0.0	0.0	0.0
Sum	**64.7**	**101.5**	**19.2**	**29.9**

Table 2:Total mass of particulate material in influent based on average TSS concentrations from automatic samplers for <240-micron particle size ranges

A composite gradation of all influent particulate material is shown in **Table 3**. Table 3 combines the 0 – 240 µm particle size ranges from Table 2 and the 250 – 4750 µm particle size ranges from Table 1. The influent automatic samplers picked up no material greater than 240 µm, yet there was a great deal of material greater than 250 µm in diameter captured within the sump. Thus, in estimating the total influent mass of coarser (>250 µm) particles for

Particle Size Range (µm)	Total Particulate Mass during Monitoring Period (kg)		% Reduction
	Influent	Effluent	
0.45 – 3.0	9.3	2.8	70
3.0 – 12.0	18.7	6.4	66
12.0 – 30	22.4	7.7	66
30 – 60	26.7	6.8	74
60 – 120	4.6	1.8	61
120 – 250	19.7	4.3	78
250 – 425	11.5	--*	100
425 – 850	17.1	--*	100
850 – 2000	10.5	--*	100
2000 – 4750	4.8	--*	100
>4750	3.5	--*	100
Sum	**149.1†**	**29.9**	**80**

Table 3: Mass balance calculation for net suspended solids removed during the monitoring period as reported by the University of Alabama research team

Based on the measured particle size distribution of particulate material in the effluent samplers shown in Figure 3, it is assumed that all material >250 µm is removed by the Up-Flo™ Filter system.

†Of the 149.1 kg total material removed by the Up-Flo™ Filter, Table 1 shows that 53.7 kg of coarse particulate material was removed by the sump. The remainder of the material was the fine fraction, which was removed by filtration within the filter media.

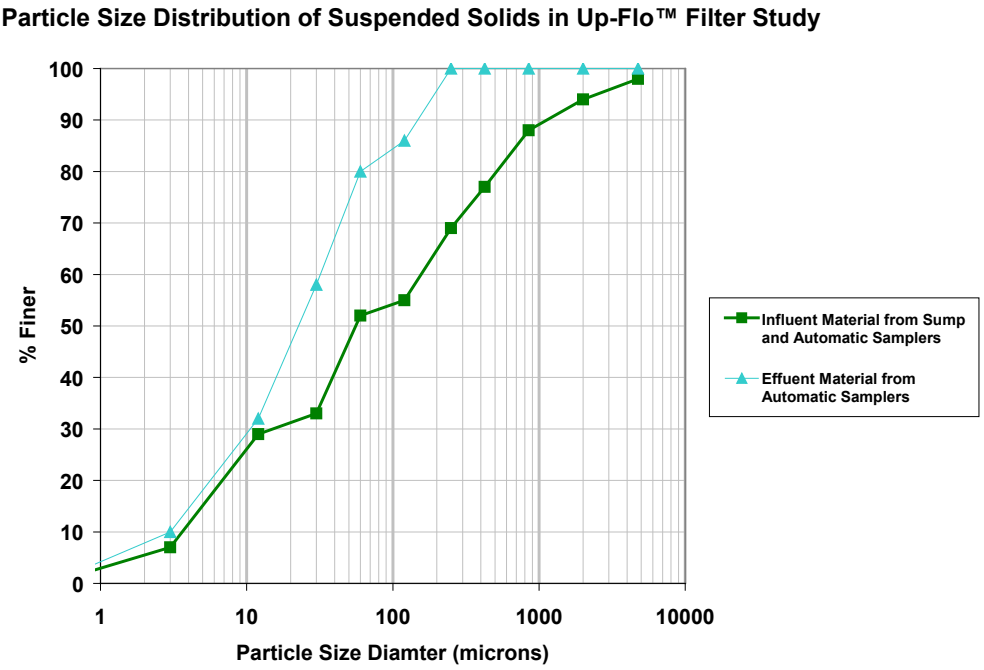

Figure 3: Particle size distributions of influent material considering all samples taken with ISCO 6712 automatic samplers and material captured in the sump

the monitoring period, only the mass of material from the sump collection was considered. The total mass of material for the 250 - 425 µm, 425 – 850 µm, 850 – 2000 µm, 2000 – 4750 µm and >4750 µm particle size ranges was taken directly from Table 1, above.

Based on the observed effluent particle size characterization shown in **Figure 3**, it is implicit that all particles greater than 250 µm in diameter are captured by the Up-Flo™ Filter. The particle size gradation for the composite influent material from Table 3 is shown graphically in Figure 3.

ANALYSIS FOR PHOSPHORUS CAPTURED BY THE UP-FLO™ FILTER

The sediment gradations from the sump analysis were then analyzed for their concentrations of phosphorus using EPA Method 365.2 (SM 4500-P B, 5 and P.E.). The sediment analysis indicated a strong correlation between the removal of very fine particulates and phosphorus removal. As shown in **Table 4**, the highest concentration of phosphorus is associated with the <75 µm particle size range.

Particle Size Range (µm)	Concentration of P (mg/kg)
< 75	3580
75 – 150	1620
150 – 250	511
250 – 425	315
425 – 850	496
850 – 2000	854
2000 – 4750	1400
>4750	1700

Table 4: Measured phosphorus concentrations associated with different gradations of particulate matter collected from the Up-Flo™ Filter sump as reported by the University of Alabama

TOTAL PHOSPHORUS REMOVAL WITH THE UP-FLO™ FILTER

The total mass of phosphorus in the influent and effluent was calculated by applying the phosphorus concentrations for each particle size range shown in Table 4 to the influent and effluent mass of total suspended solids for the influent and effluent given in Table 3 (refer to the example equation on the following page).

$$P_{influent\ 0.45 - 3\ \mu m} = 3580\ mg_P/kg_{Particulate\ Mass\text{-}Influent} \times 9.3\ kg_{Particulate\ Mass\text{-}Influent} \times 1\ gm_P/1000\ mg_P = 33.4\ gm$$

$$P_{Effluent\ 0.45 - 3\ \mu m} = 3580\ mg_P/kg_{Particulate\ Mass\text{-}Enfluent} \times 2.8\ kg_{Particulate\ Mass\text{-}Influent} \times 1\ gm_P/1000\ mg_P = 10.0\ gm$$

$$\%\ Reduction_{P\ 0.45 - 3\ \mu m} = [(33.4\ gm_{P\ influent\ 0.45 - 3\ \mu m} - 10.0\ gm_{P\ Effluent\ 0.45 - 3\ \mu m}) / 33.4\ gm_{P\ Influent\ 0.45 - 3\ \mu m}] \times 100 = 70\%$$

Based on the associations of phosphorus with the specified particle size gradations, the removal of Total Phosphorus for the 10-month monitoring period was determined to be 72%. The phosphorus removal evaluation by mass balance is shown in Table 5.

CONCLUSIONS

The results from Up-Flo™ Filter field study confirm earlier findings that certain secondary constituents, such as Total Phosphorus, can be reduced by reducing the overall concentration of particulate matter. Field monitoring results show that the Up-Flo™ Filter removed 80% of fine Total Suspended Solids from stormwater runoff over a 10-month monitoring program. Analysis of the sediment captured in the sump at the conclusion of the monitoring period showed that phosphorus is strongly associated with particulate in the <75 µm particle size range. The conservative mass balance evaluation shows with a high degree of confidence that the Up-Flo™ Filter removes 72% of Total Phosphorus from stormwater runoff. A full copy of the University of Alabama Field Verification Report for the Up-Flo™ Filter is available upon request.

Particle Size Range (µm)	P (mg/kg)	Influent		Effluent		P Captured in Sump (gm)	% Reduction
		Suspended Solids (kg)	$P_{influent}$ (gm)	Suspended Solids (kg)	$P_{effluent}$ (gm)		
0.45 – 3.0	3580	9.3	33.4	2.8	10.0	23.4	70
3.0 – 12.0	3580	18.7	66.9	6.4	22.9	44.0	66
12.0 – 30	3580	22.4	80.2	7.7	27.6	52.7	66
30 – 60	3580	26.7	95.6	6.8	24.3	71.1	74
60 – 120	1620	4.6	7.5	1.8	2.9	4.6	61
120 – 250	511	19.7	10.1	4.3	2.2	7.9	78
250 – 425	315	11.5	3.6	--	--	3.6	100
425 – 850	496	17.1	8.5	--	--	8.5	100
850 – 2000	854	10.5	9.0	--	--	9.0	100
2000 – 4750	1400	4.8	6.7	--	--	6.7	100
>4750	1700	3.5	6.0	--	--	6.0	100
Sum	**--**	**149.1**	**328.1**	**29.9**	**90.3**	**237.6**	**72**

Table 5: Mass balance calculation for net Phosphorus removed during the monitoring period as reported by the University of Alabama

1. Morquecho, R., R. Pitt, S. Clark. Pollutant Associations with Particulates in Stormwater. World Water & Environmental Resources Contress, ASCE/EWRI. Anchorage, Alaska. May 15 – 19, 2005. January 2005.