Field Verification of Performance of an Engineered Phosphorus Removal Media Deployed in a Flow Based Stormwater Filter

Gretchen Tellessen[1], Vaikko Allen[2*]
[1] Contech Engineered Solutions, Portland, Oregon.
[2] Contech Engineered Solutions, Ojai, California.
[*]Email: vallen@conteches.com

ABSTRACT

A lightweight phosphorus removal media has been has been demonstrated to remove particulate bound and dissolved phosphorus in laboratory studies and in field studies using the media in a downstream of detention. To investigate the utility of the media in a flow based design without upstream detention or pretreatment, a field evaluation was performed at a medium use road site in ZigZag, Oregon following the Technology Assessment Protocol – Ecology (WADOE, 2011).

A total of 19 qualified runoff events have been sampled, all with detectable influent concentrations of both total phosphorus (TP) and total suspended solids (TSS). For these events the median and mean removal efficiencies for TP were 72% and 66% respectively. The median and mean removal efficiencies for TSS are 92% and 89% respectively. Initial data suggests that the media deployed in a flow based media filter can provide significant phosphorus load reductions.

KEYWORDS: Phosphorus, media filter, activated alumina, perlite, total suspended solids, suspended solids concentration, stormwater, Technology Assessment Protocol – Ecology (TAPE).

INTRODUCTION

Phosphorus is a common cause of impairment in fresh water bodies throughout the United States. In urban watersheds, loads contributed by stormwater runoff can be a dominant source. As a result, phosphorus removal requirements are increasingly common and innovative phosphorus removal technologies are needed that can be integrated into an urban environment.

A lightweight phosphorus removal media comprised of a perlite base with an activated alumina coating has been developed for use in media filtration systems. In addition to providing physical filtration of phosphorus bearing solids, adsorption of dissolved phosphorus has been demonstrated in laboratory based studies using this media. Field studies have previously been conducted using the media in a media filter downstream of detention, resulting in total phosphorus load reductions of 60% or greater. Detention based designs provide several benefits including pretreatment of solids by gravitational separation and peak flow attenuation in the detention system, however they are relatively large and costly compared to flow through designs without detention. To investigate the utility of the media in a flow based design without upstream detention or pretreatment of any kind, a field evaluation was performed at a typical site located in Western Oregon. The project plan for this evaluation was designed to conform to guidelines outlined in the Technical Guidance Manual for Evaluating Emerging Stormwater Treatment

Technology Assessment Protocol – Ecology (TAPE) as written by the Washington State Department of Ecology (TAPE, 2011).

SITE AND SYSTEM

The evaluation site (the Lolo Pass Road evaluation site) is located in Zigzag, Oregon and is situated at the west protruding end of Zigzag Mountain in the foothills of Mt. Hood and sits approximately 425 m (1400 feet) above sea level. The site, located on Lolo Pass Road at Bear Creek Bridge, is a 100% impervious, medium-use road managed by the Clackamas County Department of Transportation and Development. Drainage area of the site is 250 m^2 (2800 ft^2) of bridge deck and is located near the intersection of Lolo Pass Road and US Highway 26 (Lat: 45.34420862, Lon: -121.94275218).

The site is swept periodically, but significant amounts of sediment and organic debris are typically present on site. Sanding, graveling, and de-icing occur on the site as necessary during the winter to control ice accumulation and assist with tire traction. The time of concentration (t_c) on the site is estimated to be 1.4 minutes. A photo of the drainage area can be seen in Figure 1.

Figure 1. View of the drainage area of the stormwater treatment evaluation site located on Lolo Pass Road, ZigZag, Oregon.

The stormwater treatment system evaluated at the Lolo Pass Road evaluation site is a flow based treatment unit which contains one 46 cm (18 inch) tall radial flow filter cartridge. The filter cartridge has an 18 cm (7 inch) inch media bed depth designed to operate at a specific flow rate of 70 L/m/M^2 (1.67 gpm/ft^2) or 47 L/m (12.5 gpm) per cartridge. The media used in this evaluation is lightweight phosphorus removal media comprised of a perlite base with an activated alumina coating. This engineered phosphorus removal media provides stormwater treatment by physical filtration of solids, including phosphorus bearing solids as well as the adsorption of dissolved phosphorus.

DATA COLLECTION METHODS

The equipment and sampling techniques used for this study are in accordance with the 2011 version of the Washington State Department of Ecology TAPE. A full maintenance of the stormwater treatment unit was performed at the beginning of the evaluation period. Maintenance involved the removal of all material within the unit and associated conveyance, removal of the

used media cartridge, and installation of a new media cartridge containing the engineered phosphorus removal media. Immediately following maintenance all monitoring equipment was installed and the sampling period was initiated.

Influent and effluent flows were measured continuously throughout the evaluation period using large 60°V trapezoidal flumes in conjunction with individual ISCO 730 bubbler flow modules. Each flow module was connected to an individual ISCO 6712 Portable Automated Sampler. Precipitation was also analyzed continuously though the evaluation with a 0.023 cm (0.01-inch) resolution Texas Electronics tipping bucket rain gage.

Individual volume-paced influent and effluent samples were collected over the course of each qualified storm event using individual ISCO 6712 Portable Automated Samplers. At the conclusion of each qualified runoff event, individual influent and effluent samples were combined to create influent and effluent bulk composite samples. Event Mean Concentration (EMC) subsamples were then taken from the bulk composite sample and submitted to Apex Laboratories, LLC in Beaverton, Oregon for analysis. Samples were analyzed for total suspended solids (TSS), suspended solids concentration (SSC), total phosphorus (TP), and dissolved phosphorus.

WATER QUALITY RESULTS

A total of 19 qualified runoff events were sampled at the evaluation site between February 2012 and June 2013. Of the 19 events sampled; 1) the total rainfall was greater than 0.38 cm (0.15 in) for all storm events sampled, 2) the minimum event duration was greater than one hour for all events sampled, 3) the minimum inter event (antecedent) period was greater than 6 hours with rainfall < 0.10 cm (0.04 in) for all but two events (events 9 and 11), 4) volume paced composite samples covered a minimum of 60% of the total flow for all storm events sampled, and 5) the minimum influent and effluent aliquots per sample event was 7. All 19 events were determined to be qualified based on data collection guidelines set up for this evaluation and are presented in Table 1.

Table 1. Qualified runoff event data collection requirement results for the 19 storm events sampled at the Lolo Pass Road evaluation site.

Event Date	Total precipitation depth (mm)	Maximum precipitation intensity (mm/hr)	Avgerge precipitation intensity (mm/hr)	Precipitation duration (hours)	Influent coverage (%)	Effluent coverage (%)	Antecedent dry period (hours)	Number of aliquots (inf:eff)
2/20/1012	16	3.0	1.0	17	96	84	21	10:7
2/14/2012	9	1.5	0.5	19	79	76	21	7:7
2/17/2012	34	3.6	1.0	46	94	97	18	40:32
2/20/2012	60	3.6	1.5	44	67	76	14	48:45
2/24/2012	20	3.3	1.8	11	100	91	31	23:17
3/10/2012	15	2.3	0.5	33	100	62	89	20:8
3/12/2012*	11	2.5	1.5	6.5	84	95	28	14:12
3/29/2012	119	8.6	2.8	48	69	75	26	48:45
5/24/2012	12	3.6	2.0	5.5	91	80	4	13:15
6/1/2012	22	3.8	2.8	8.0	98	99	104	32:37
6/4/2012	20	3.3	1.5	13	91	92	5	24:25
6/7/2012	19	3.6	1.3	13	92	89	36	24:25
11/6/2012	12	3.3	1.3	8.3	100	98	>6	13:16
11/11/2012	40	5.8	2.0	19	64	60	>6	32:31
11/23/2012	40	4.6	2.3	19	70	74	>6	48:41
11/30/2012	18	6.6	1.5	18	77	96	>6	27:15
5/17/2013	7	1.8	0.8	10	66	69	13	16:13
5/21/2013	18	4.6	2.5	7.0	97	95	10	35:28
6/25/2013	18	7.1	3.6	5.0	68	75	>6	35:28

*backup rain gage data used for this event due to rain gage equipment issues

All 19 events had detectable influent concentrations for TSS, SSC, and total phosphorus and can be seen in Table 2. Minimum, maximum, median and mean influent and effluent concentrations for these constituents are also presented in Table 2. Samples were also analyzed for dissolved phosphorus using EPA Method 200.7, however only two events had detectable influent concentration of dissolved phosphorus. Both events showed positive removal of dissolved phosphorus but the limited data set is not sufficient to continue with further analysis and discussion.

Table 2. Influent and effluent concentrations for the stormwater treatment unit with engineered phosphorus removal media for the 19 storm events sampled at the Lolo Pass Road evaluation site.

Parameter	TSS (mg/L)		SSC (mg/L)		Total Phosphorus (mg/L)	
Analytical Method	SM 2540D		ASTM D3977		SM 4500PF	
Sample Location	Influent	Effluent	Influent	Effluent	Influent	Effluent
Event 1	182	63	180	68.2	0.141	0.104
Event 2	539	32	404	35.0	0.220	0.0620
Event 3	387	48	414	53.5	0.310	0.0674
Event 4	246	ND	258	12.1	0.163	0.0259
Event 5	512	43	507	52.7	0.424	0.0701
Event 6	360	27	430	ND	0.140	0.0490
Event 7	150	18	220	ND	0.150	0.0370
Event 8	370	47	390	58.0	0.280	0.0810
Event 9	510	43	830	47.0	0.170	0.0700
Event 10	780	16	960	ND	0.200	0.0350
Event 11	580	32	1000	30.0	0.210	0.0043
Event 12	570	120	780	120	0.170	0.140
Event 13	40.0	10	46.0	9.00	0.068	ND
Event 14	100	14	92.0	16.0	0.076	ND
Event 15	110	ND	120	7.60	0.082	ND
Event 16	230	17	230	15.0	0.170	ND
Event 17	94.0	6.0	211	7.59	0.282	0.0300
Event 18	389	24	484	21.4	0.558	0.0498
Event 19	308	21	710	19.0	0.583	0.0452
Min	**40.0**	**6.00**	**46.0**	**7.59**	**0.068**	**0.0043**
Max	**780**	**120**	**1000**	**120**	**0.583**	**0.140**
Median	**360**	**27.0**	**404**	**25.7**	**0.170**	**0.0498**
Mean	**340**	**34.2**	**435**	**35.8**	**0.231**	**0.0580**

PERFORMANCE SUMMARY

Significant reductions in TP, TSS and SSC pollutant loads were observed between influent and effluent sampling locations. Performance was calculated using two different methods, the Efficiency Ratio (ER) method and the Summation of Loads (SOL) efficiency calculation method. The ER method defines the efficiency as the average event mean concentration of pollutants over a given time period.

Equation 2: $$ER = 1 - \frac{mean\ effluent\ EMC}{mean\ influent\ EMC}$$

The ER method assumes; 1) The weight of all storm events is equal regardless of the relative magnitude of the storm event and 2) that if all storm events at the site had been monitored, the average inlet and outlet EMCs would be similar to those that were monitored (URS/ EPA 1999). A summary of ER performance data for TP, TSS and SSC for the 19 sampled events is presented in Table 3.

Table 3. Performance calculated using the Efficiency Ratio (ER) method for the stormwater treatment unit with engineered phosphorus removal media for the 19 events sampled at the Lolo Pass Road evaluation site.

Parameter	TSS (mg/L)		SSC (mg/L)		Total Phosphorus (mg/L)	
Sample Location	Influent	Effluent	Influent	Effluent	Influent	Effluent
Mean	340	34.2	435	35.8	0.231	0.0580
Efficiency Ratio	**90%**		**92%**		**75%**	

Performance was also calculated using the Summation of Loads (SOL) efficiency calculation method. The SOL method defines the efficiency as a percentage based on the ratio of the summation of all influent loads to the summation of all effluent loads.

Equation 2: $$SOL = 1 - \frac{sum\ of\ all\ effluent\ loads}{sum\ of\ all\ influent\ loads}$$

The SOL method assumes; 1) monitoring data accurately represents the actual entire total loads in and out of the BMP for a period long enough to overshadow any temporary storage or export of pollutants and 2) any significant storm events that were not monitored had a ratio of inlet to effluent loads similar to the storms events that were monitored (URS/ EPA 1999). SOL efficiency results for TP, TSS and SSC for the 19 sampled events is presented in Table 4.

Table 4. Summation of Loads (SOL) efficiency calculations for the stormwater treatment unit with engineered phosphorus removal media for the 19 storm events sampled at the Lolo Pass Road evaluation site.

Parameter	TSS (g)		SSC (g)		Total Phosphorus (mg)	
Sample Location	Influent	Effluent	Influent	Effluent	Influent	Effluent
Total	43352	3577	54426	3691	33643	7228
SOL Efficiency	**92%**		**93%**		**79%**	

Particle size distribution information collected during sampled events confirms that the influent solids have a silt loam distribution which is typical for the Pacific Northwest. pH was measured on site at the time of sample collection for all storm events using EPA Method 105.1. Median influent and effluent EMCs were 6.7 and 6.6 respectively.

DISCUSSION AND CONCLUSION

An engineered phosphorus removal media contained in a radial flow filter cartridge, deployed in a flow based stormwater treatment unit without upstream detention or pretreatment of any kind, was tested for the removal of solids and total phosphorus. A total of 19 qualified runoff events were sampled over a 17 month period beginning in February 2012.

Positive removal of total phosphorus was observed for all of the 19 sampled events. Performance calculated using the Efficiency Ratio method and the Summation of Loads efficiency calculation method were 75% and 79% respectively. These results show reductions in total phosphorus above the requirements currently outlined by most regulatory agencies. This engineered phosphorus removal media would be a good choice for stormwater treatment in phosphorus sensitive areas.

Positive removal of solids was also observed for all 19 sampled events. TSS and SSC performance calculated using the Efficiency Ratio method were 90% and 92% respectively. TSS and SSC performance calculated using the Summation of Loads efficiency calculation method were 92% and 93% respectively. Again, these results show reductions above requirements currently outlined by most regulatory agencies. This is significant in that the engineered phosphorus removal media can be used for both solids and phosphorus removal without any additional treatment.

Overall, the data collected during this evaluation suggests that the engineered phosphorus removal media deployed in a flow based media filter can provide significant load reduction for TSS, SSC, and total phosphorus at or above levels dictated by stormwater permitting requirements and TMDL compliance plans. Data also suggests that using this media can provide TSS, SSC, and total phosphorus load reductions without significant upstream flow attenuation or pretreatment.

REFERENCES

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