UNC CHARLOTTE

Linking Small Businesses to Academic and Community Resources

EAO

Environmental Assistance Office

Final Report – Stalite Phase II

Submitted to:
Carolina Stalite Company

By
Environmental Assistance Office (EAO)
Infrastructure, Design, Environment, and Sustainability (IDEAS) Center
UNC Charlotte

March 4, 2013

UNC CHARLOTTE

Infrastructure, Design, Environment
and Sustainability (IDEAS) Center

Final Report – Stalite Phase II

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With Assistance of:

Emily Chien and X. Liu

March 04, 2013

Acknowledgment

The research described in this report was conducted by Emily Chien and X. Liu. Funding for this project from Carolina Stalite Company is gratefully acknowledged.

1. Experimental Setup

Four bench-scale columns were fabricated and packed with filter media per proposal requirements, as summarized in Table 1 and Figure 1.

Table1. Details of Column Setup

	Column 1	Column 2	Column 3	Column 4
Inside Diameter, in	6	6	6	6
Filter Material	80% M16 + 20% Pine Bark	100% M16	100% M16	NCDENR Soil Mix
Filter Height, ft	1	1	1	1
Weight, lbs	13.8 + 1.0	15.6	15.6	~18
Bottom Gravel, in	3	3	3	3
Mode of Operation	Batch*	Batch*	Flow Through**	Flow Through**

*1000 mL of synthetic feed was added to top of the filter medium while the bottom drain valve was closed. The synthetic feed gradually moved downward and saturated the filter medium. After 12 hours of contact between the filter medium and the feed solution, the drain valve was then open to release effluent sample for collection and analysis.

**1000 mL of synthetic feed solution was added to top of the filter medium with the bottom drain valve being closed. Feed solution remained on top of the filter medium for 30 minutes. The bottom drain valve was then open to allow the feed solution to flow through the filter medium for collection,

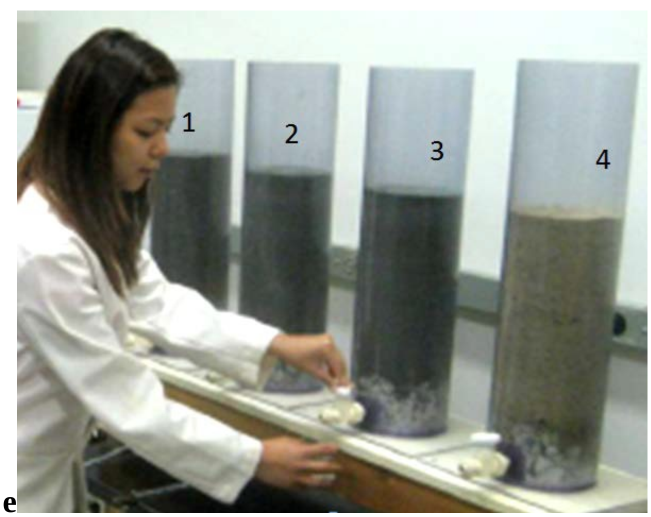

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Figure 1. Bench-Scale Experimental Columns

2. Experimental Results

2.1 Initial Leaching Test Runs

All test runs were conducted as batch fed operation. Each column was saturated with DI water to leach out NO_3-N and PO_4-P originally present in the filter medium. After a contact time of 24 hours, effluent from each column was drained and collected for the analysis of NO_3-N and PO_4-P. This part of research was carried out in the months of September and October of 2012; see Figure 2 for leaching test results. We have encountered the following operation difficulties at the startup phase of the research.

The initial filter height in column 2 was gradually lowered by about one inch due to settlement of M16 into the gravel layer of the column. Column 3 (duplicate of column 2) has encountered the same problem and was repacked to restore its original height. A ½-inch sand layer was added to the bottom to prevent entrapment of M16 into the gravel layer.

Column 4 was packed with the NCDENR soil mix. With the bottom drain-valve closed, DI water tended to accumulate on top of the column with little downward flow. We had to slightly open the drain valve (to release the back pressure at the column bottom) in order to allow water to slowly flow downward in about 6 hours. We then recycled the effluent water back to the top of the column and kept recycling the effluent water within the test period.

Nonetheless, effluent NO_3-N concentrations from all four columns reduced to zero in about 10 days. Effluent PO_4-P from column 1 continuously remained at an average of 0.35 mg/L while the other three columns were at <0.1 mg/L. We decided that this low-level of effluent PO_4-P justified the introduction of synthetic feed containing a PO_4-P level of 3.33 mg/L and started the next stage of research as described in the next section of this report.

2.2 Test Runs with Synthetic Stormwater

The synthetic stormwater was made of 1000 mL DI water enriched with 1 mg/L NO_3-N and 3.33 mg/L PO_4-P. This stage of research covered the period of November 4, 2012 through March 15, 2013. Columns 1 and 2 were run on a batch fed mode as explained in Table 1. Columns 3 and 4 were initially fed with the synthetic stormwater while the drain valve was closed. After 30 minutes, the drain valve was open to allow the feed solution to flow through the filter medium and effluent from each column bottom was collected for chemical analysis.

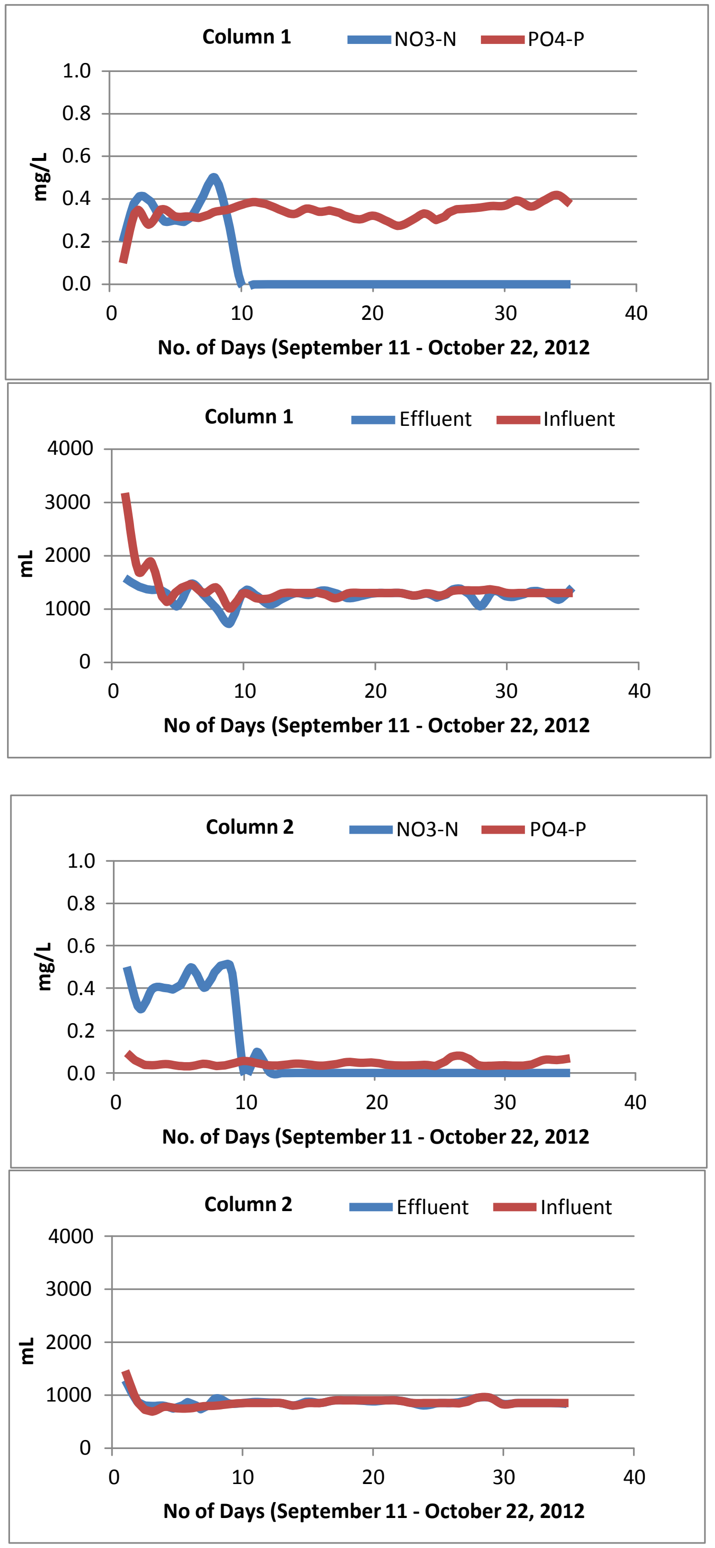


Figure 2. Results of DI Water Leaching Test Runs

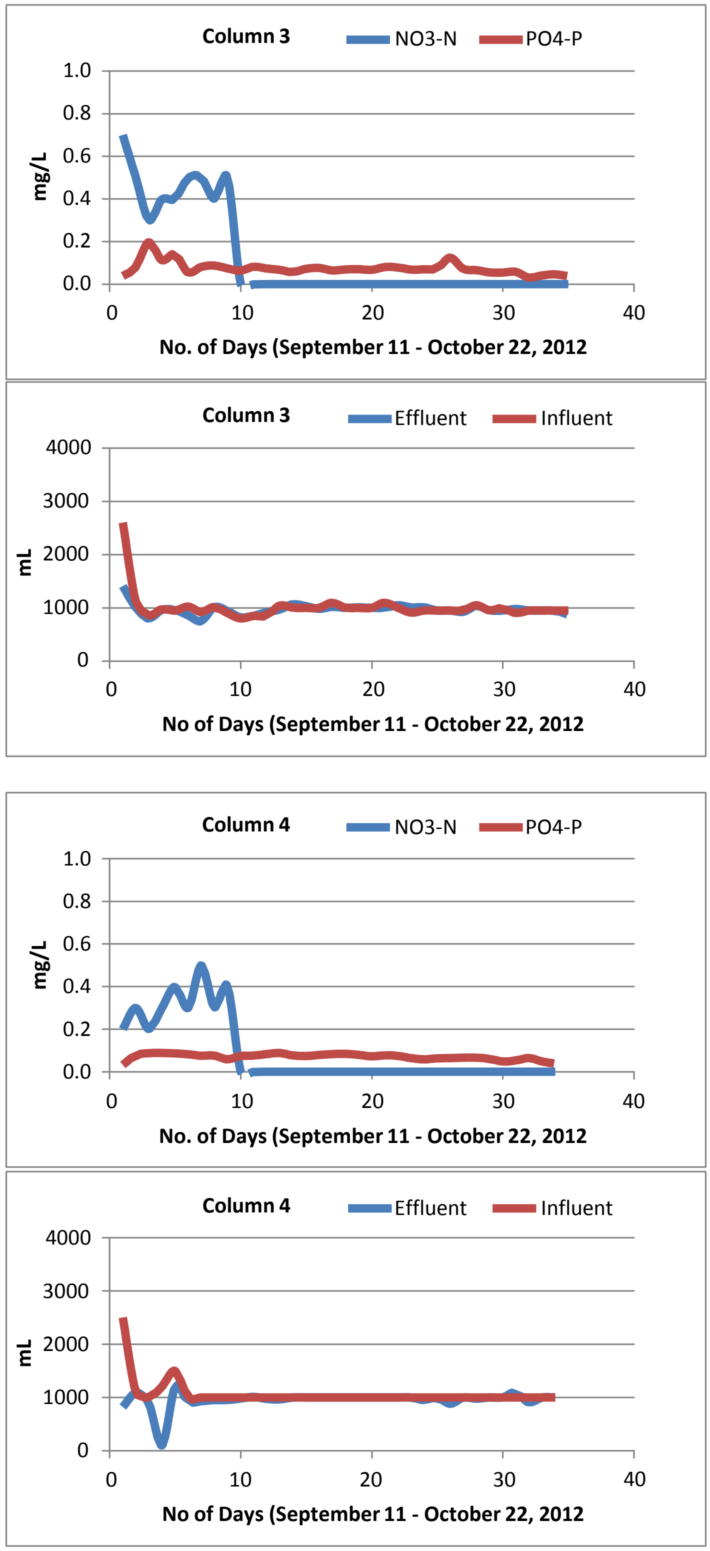


Figure 2. Results of DI Water Leaching Test Runs (cont'd)

Upon introduction of the synthetic feed, all four columns exhibited some fluctuation in effluent PO_4-P concentration but gradually reached a steady trend after 60 days. Test data starting November 2012 are included in Appendix A. Figure 3 displays only the effluent PO_4-P concentration for each column during the steady trend periods starting January of 2013. The following observations with regard to effluent concentrations are provided for column performance during the steady trend period.

- Column 1 (M16 + Pine Bark, batch fed) – attaining an average effluent PO_4-P of 0.60 mg/L with no obvious rising trend of the effluent concentration. Effluent NO_3-N was at 0.3-0.4 mg/L.
- Column 2 (M16, batch fed) – exhibiting a small rising trend of effluent PO_4-P concentration. The effluent PO_4-P concentration was 0.15 mg/L after 130 days of the test period. It may increase to reach the influent concentration of 3.33 mg/L PO_4-P for at least 5-6 years if this rising trend continues. Effluent NO_3-N was around 1.0 mg/L.
- Column 3 (M16, flow through) – showing a rising trend of effluent PO_4-P concentration that is about 3 times faster than that of column 2, based on comparing slopes of the respective trend lines. The effluent PO_4-P concentration was 0.28 mg/L at the end of the test period. Effluent NO_3-N was about 1.0 mg/L.
- Column 4 (NCDENR soil mix, flow through) – showing a rising trend of effluent PO_4-P concentration that is about 4.9 times faster than that of column 3. The effluent PO_4-P concentration was 1.4 mg/L at the end the test period. Effluent NO_3-N was about 0.3 mg/L.

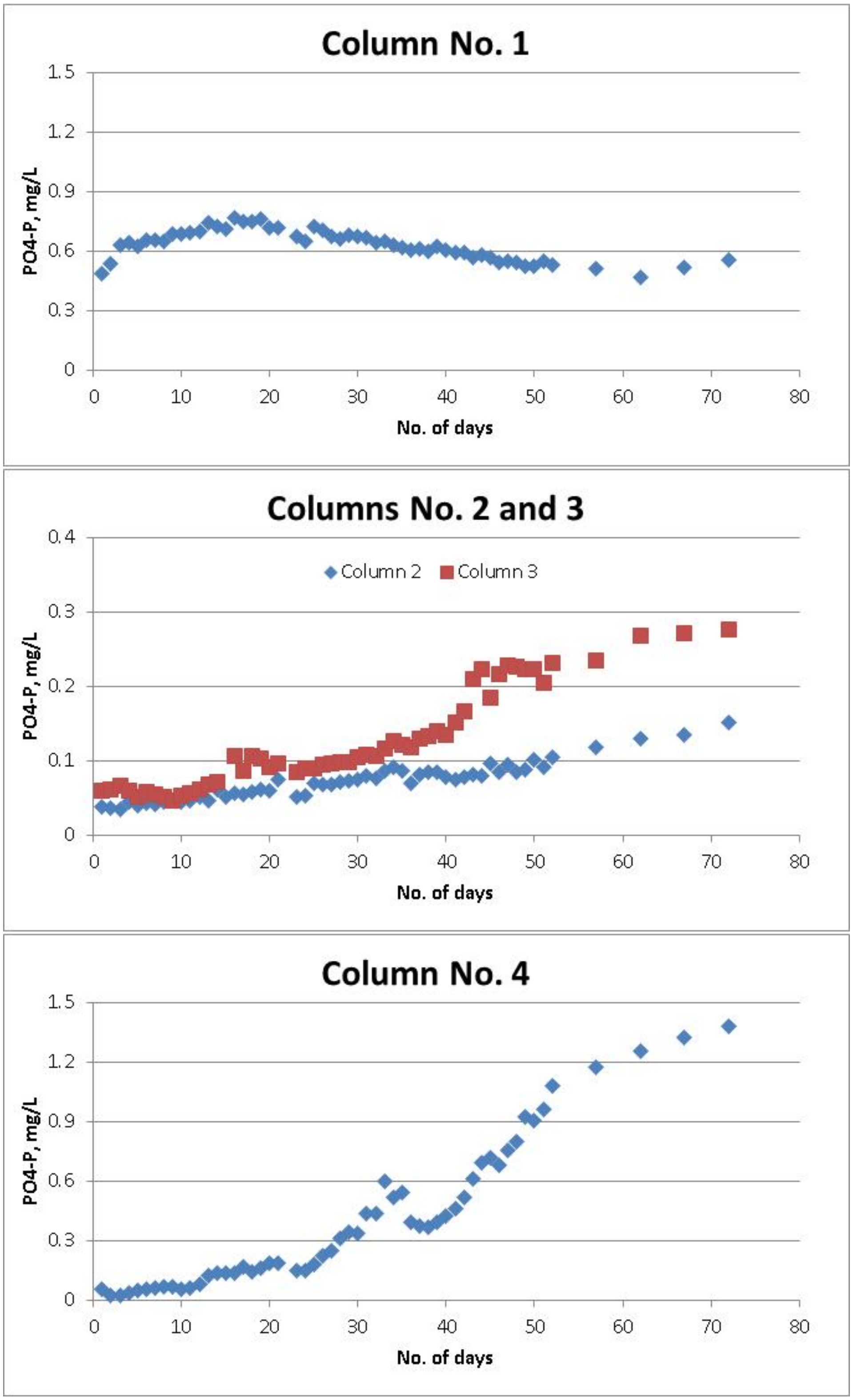


Figure 3. Effluent PO_4-P Concentrations for Experimental Columns 1-4 (starting 1/12/13)

2.3 Flow-Through Volumetric Rates for Column 3 and 4

Figure 4 displays a set of flow data for columns 3 and 4 that was collected on December 13, 2012. Column 3 (M16) exhibited a volumetric flow through that is at least 8 time faster than column 4 (NCDENR soil mix) at 80% of the cumulative flow-through volume. The effluent PO_4-P concentration of column 3 was about 5 time lower than that of column 4, implying column 3 packed with M16 was capable of not only delivering a higher hydraulic flow through rate but also a better PO_4-P removal performance than column 4.

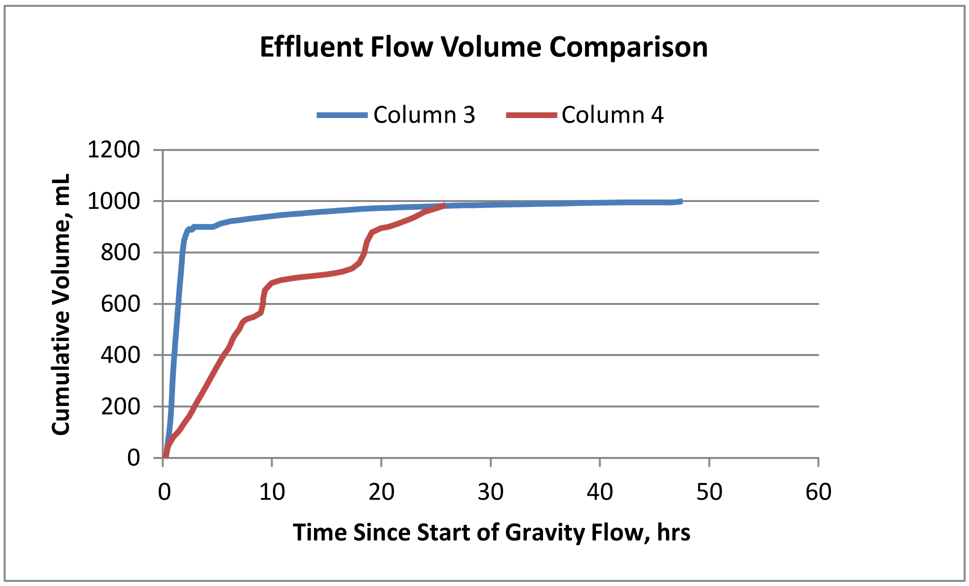


Figure 4. Flow-Through Volumetric Measurements for Columns 3 and 4 (Dec 13, 2012)

Appendix A

		PO4-P, mg/L, Infflュent 3.33mg/L				NO3-N, mg/L, inffluent 1mg/L			
No.	Date	Column 1	Column 2	Column 3	Column 4	Column 1	Column 2	Column 3	Column 4
1	01/12/13	0.485	0.038	0.060	0.058	0.4	1.1	0.9	0.3
2	01/13/13	0.538	0.037	0.061	0.027	0.4	0.9	1.0	0.2
3	01/14/13	0.63	0.034	0.066	0.026	0.4	1.0	1.1	0.2
4	01/15/13	0.644	0.045	0.059	0.036	0.4	1.1	1.0	0.3
5	01/16/13	0.626	0.039	0.051	0.05	0.4	0.9	0.9	0.3
6	01/17/13	0.657	0.043	0.058	0.056	0.4	0.9	0.9	0.3
7	01/18/13	0.655	0.042	0.054	0.063	0.4	1.0	1.0	0.3
8	01/19/13	0.646	0.045	0.051	0.066	0.4	1.0	2.0	0.3
9	01/20/13	0.686	0.046	0.047	0.068	0.3	0.8	0.9	0.3
10	01/21/13	0.688	0.045	0.053	0.056	0.4	0.8	1.0	0.3
11	01/22/13	0.691	0.047	0.057	0.059	0.4	0.9	1.0	0.3
12	01/23/13	0.699	0.052	0.062	0.083	0.3	0.8	1.0	0.3
13	01/24/13	0.742	0.047	0.068	0.124	0.3	1.0	1.0	0.3
14	01/25/13	0.724	0.061	0.071	0.135	0.4	0.7	1.0	0.3
15	01/26/13	0.714	0.051	na	0.134	0.3	0.7	na	0.2
16	01/27/13	0.768	0.057	0.107	0.138				
17	01/28/13	0.751	0.054	0.086	0.166				
18	01/29/13	0.747	0.058	0.106	0.141				
19	01/30/13	0.761	0.061	0.103	0.162				
20	01/31/13	0.718	0.059	0.092	0.188				
21	02/01/13	0.718	0.075	0.096	0.188	0.4	1	1	0.3
22	02/02/13								
23	02/03/13	0.671	0.052	0.085	0.152	0.3	0.8	1	0.3
24	02/04/13	0.648	0.053	0.089	0.151	0.3	0.9	1	0.3
25	02/05/13	0.724	0.07	0.089	0.183	0.3	0.9	1	0.2
26	02/06/13	0.708	0.068	0.095	0.224	0.3	0.9	1	0.3
27	02/07/13	0.672	0.068	0.096	0.248	0.3	0.9	1	0.3
28	02/08/13	0.660	0.071	0.098	0.310	0.3	0.9	1	0.3
29	02/09/13	0.682	0.073	0.098	0.340	0.3	0.9	1	0.3
30	02/10/13	0.671	0.075	0.104	0.335	0.3	1	1	0.3
31	02/11/13	0.668	0.079	0.108	0.436	0.3	1	1	0.3
32	02/12/13	0.641	0.077	0.106	0.438	0.3	1	1	0.3
33	02/13/13	0.648	0.087	0.116	0.597	0.3	1	1	0.3
34	02/14/13	0.631	0.092	0.126	0.519	0.3	1	1	0.3
35	02/15/13	0.62	0.087	0.121	0.543	0.3	1	1	0.3
36	02/16/13	0.606	0.069	0.118	0.391	0.3	1	1	0.3
37	02/17/13	0.61	0.082	0.129	0.375	0.3	1	1	0.3
38	02/18/13	0.596	0.085	0.133	0.365	0.3	1	1	0.3
39	02/19/13	0.622	0.085	0.139	0.395	0.3	1	1	0.3
40	02/20/13	0.606	0.078	0.135	0.421	0.3	1	1	0.3
41	02/21/13	0.595	0.075	0.151	0.461	0.4	1	1	0.3
42	02/22/13	0.593	0.078	0.166	0.52	0.4	1	1	0.3
43	02/23/13	0.567	0.082	0.209	0.609	0.4	1	1	0.3
44	02/24/13	0.579	0.079	0.223	0.692	0.4	1	1	0.3
45	02/25/13	0.566	0.096	0.185	0.716	0.4	1	1	0.3
46	02/26/13	0.543	0.084	0.216	0.681	0.4	1	1	0.3
47	02/27/13	0.546	0.095	0.228	0.753	0.4	1	1	0.3
48	02/28/13	0.541	0.085	0.227	0.801	0.4	1	1	0.3
49	03/01/13	0.527	0.088	0.223	0.923	0.4	1	1	0.3
50	03/02/13	0.527	0.101	0.223	0.904	0.4	1	1	0.3
51	03/03/13	0.547	0.091	0.204	0.959	0.4	1	1	0.3
52	03/04/13	0.528	0.105	0.231	1.08	0.4	1	1	0.3
53	03/05/13								
54	03/06/13								
55	03/07/13								
56	03/08/13								
57	03/09/13	0.514	0.118	0.234	1.174	0.4	1	1	0.3
58	03/10/13								
59	03/11/13								
60	03/12/13								
61	03/13/13								
62	03/14/13	0.465	0.129	0.268	1.252	0.4	1	1	0.3
63	03/15/13								
64	03/16/13								
65	03/17/13								
66	03/18/13								
67	03/19/13	0.52	0.135	0.272	1.32	0.4	1	1	0.3
68	03/20/13								
69	03/21/13								
70	03/22/13								
71	03/23/13								
72	03/24/13	0.553	0.151	0.277	1.382	0.4	1	1	0.3

Appendix A

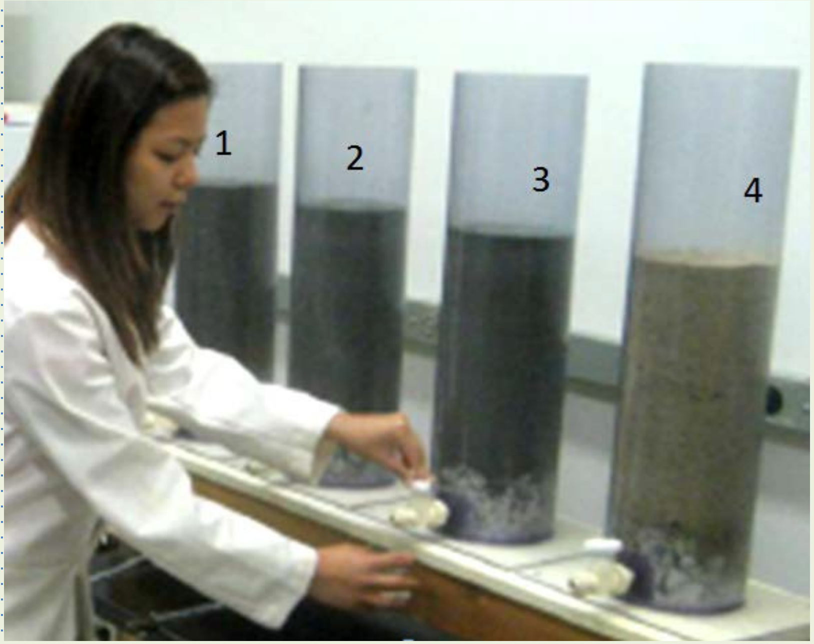
Run no.	Date	Column 1 Effluent		Column 2 Effluent		Column 3 Effluent		Column 4 Effluent	
		NO_3-N	PO_4-P	NO_3-N	PO_4-P	NO_3-N	PO_4-P	NO_3-N	PO_4-P
		(mg/L)		(mg/L)		(mg/L)		(mg/L)	
1	11/4/2012	0.0	0.316	0	0.034			0.0	0.040
2	11/5/2012	0.0	0.313	0.4	0.036			0.0	0.026
3	11/6/2012	0.0	0.302	0.8	0.037				
4	11/7/2012	0.0	0.298	0.4	0.035			0.0	0.024
5	11/8/2012	0.0	0.29	0	0.074			0.0	0.029
6	11/9/2012	0.0	0.285	0	0.07			0.0	0.032
7	11/10/2012	0.0	0.312	0	0.064			0.0	0.036
8	11/11/2012	0.0	0.302	0	0.068				
9	11/12/2012	0.0	0.336	0	0.07			0.0	0.034
10	11/13/2012	0.0	0.408	0	0.082	0.0	0.026	0.0	0.040
11	11/14/2012	0.0	0.42	0	0.091	0.0	0.023		
12	11/15/2012	0.0	0.431	0	0.089	0.0	0.035	0.0	0.038
13	11/16/2012	0.0	0.422	0	0.092	0.0	0.030	0.0	0.040
14	11/17/2012	0.0	0.45	0	0.094	0.0	0.037		
15	11/18/2012	0.0	0.468	0	0.08	0.0	0.039	0.0	0.042
16	11/19/2012	0.0	0.474	0	0.098	0.0	0.035	0.0	0.044
17	11/20/2012	0.0	0.482	0	0.104	0.0	0.040		
18	11/21/2012	0.0	0.49	0	0.113	0.0	0.046	0.0	0.048
19	11/22/2012	0.0	0.494	0	0.122	0.0	0.058	0.0	0.046
20	11/23/2012	0.0	0.512	0	0.092	0.0	0.072	0.0	0.048
21	11/24/2012	0.0	0.513	0	0.130	0.0	0.098		
22	11/25/2012	0.0	0.55	0	0.145	0.0	0.038	0.0	0.059
23	11/27/2012	0.0	0.489	0.0	0.037	0.0	0.065	0.0	0.018
24	11/28/2012	0.0	0.553	0.0	0.021	0.0	0.083	0.0	0.003
25	11/29/2012	0.0	0.645	0.0	0.038	0.0	0.048	0.0	0.000
26	11/30/2012	0.0	0.668	0.0	0.046	0.0	0.070	0.0	0.009
27	12/1/2012	0.0	0.754	0.0	0.062	0.0	0.083	0.0	0.107
28	12/2/2012	0.0	0.909	0.0	0.088	0.0	0.143	0.0	0.032
29	12/3/2012	0.0	0.909	0.0	0.091	0.0	0.061	0.0	0.021
30	12/4/2012	0.0	0.978	0.0	0.087	0.0	0.072	0.0	0.008
31	12/5/2012	0.0	1.115	0.0	0.071	0.1	0.070	0.0	0.000
32	12/6/2012	0.0	1.100	0.0	0.102	0.1	0.095	0.0	0.000
33	12/7/2012	0.0	0.974	0.1	0.072	0.1	0.071	0.0	0.015
34	12/8/2012	0.0	0.962	0.3	0.015	0.3	0.043	0.0	0.018
35	12/9/2012	0.0	0.952	0.6	0.041	0.5	0.069	0.0	0.026
36	12/10/2012	0.0	0.905	0.7	0.087	0.6	0.083	0.0	0.040
37	12/11/2012	0.0	1.144	0.7	0.171	0.7	0.073	0.0	0.012
38	12/12/2012	0.0	0.870	0.7	0.018	0.6	0.052	0.0	0.019
39	12/13/2012	0.0	0.788	0.7	0.042	0.4	0.039	0.1	0.003
40	12/14/2012	0.0	0.716	0.6	0.000	0.6	0.038	0.0	0.000
41	12/15/2012	0.0	0.644	0.7	0.166	0.4	0.015	0.0	0.026
42	12/16/2012	0.0	0.717	0.6	0.080	0.6	0.059	0.0	0.018
43	12/17/2012	0.0	0.750	0.7	0.037	0.6	0.053	0.0	0.019
44	12/18/2012	0.0	0.708	0.6	0.021	0.6	0.040	0.0	0.030
45	12/19/2012	0.0	0.734	0.6	0.020	0.6	0.057	0.0	0.032
46	12/20/2012	0.0	0.708	0.6	0.077	0.6	0.071	0.0	0.054
47	12/21/2012	0.1	0.654	0.7	0.048	0.7	0.025	0.0	0.040
48	12/22/2012	0.0	0.677	0.3	0.014	0.6	0.047	0.0	0.029
49	12/23/2012	0.0							
50	12/25/2012	0.0	0.853	0.7		0.5	0.055	0.0	0.011
51	12/26/2012	0.0	0.844	0.5		0.7	0.077	0.0	0.022
52	12/27/2012	0.0	0.805	0.4		0.4	0.012	0.0	0.035
53	12/28/2012	0.0	0.816	0.6	0.019	0.7	0.037	0.0	0.041
54	12/29/2012	0.0	0.818	0.5	0.034	0.6	0.034	0.0	0.067
55	12/30/2012	0.0	0.841	0.7	0.014	0.7	0.035	0.0	0.067
56	12/31/2012	0.0	0.805	0.7	0.009	0.5	0.036	0.0	0.061
	Average	0.002	0.649	0.271	0.066	0.278	0.054	0.002	0.031

Appendix B

Stalite Phase II
Bench Scale Column Study

Final Report

April 2013



	Column 1	Column 2	Column 3	Column 4
Inside Diameter, in	6	6	6	6
Filter Material	80% M16 + 20% Pine Bark	100% M16	100% M16	NCDENR Soil Mix
Filter Height, ft	1	1	1	1
Weight, lbs	13.8 + 1.0	15.6	15.6	~18
Bottom Gravel, in	3	3	3	3
Mode of Operation	Batch*	Batch*	Flow Through**	Flow Through**

DI Water Leaching Tests

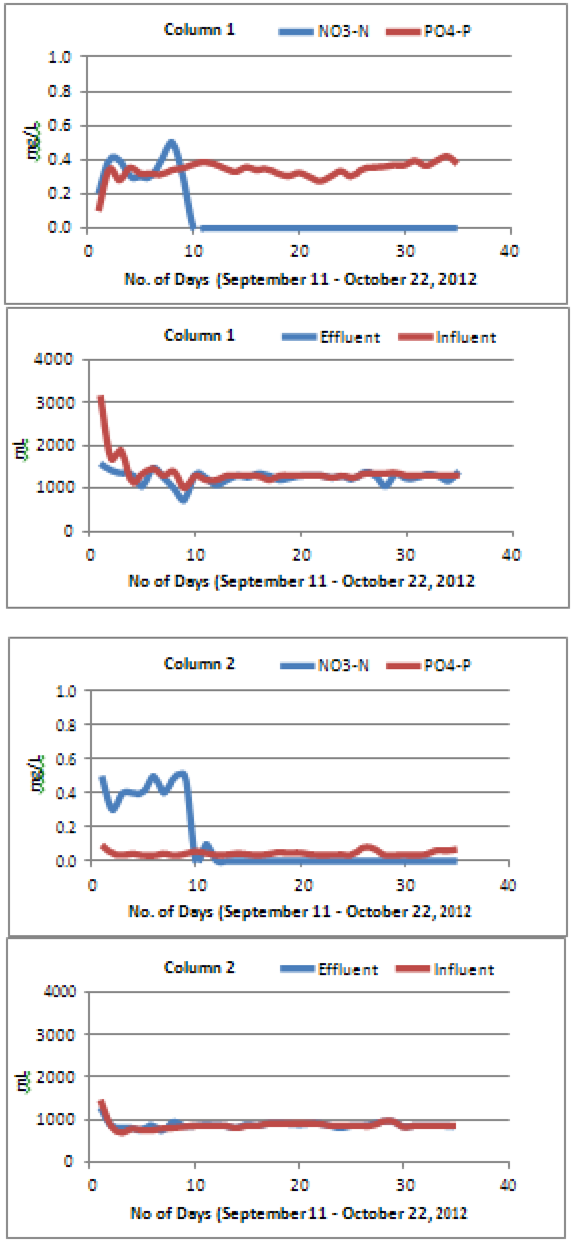


Figure 2. Results of DI Water Leaching Test

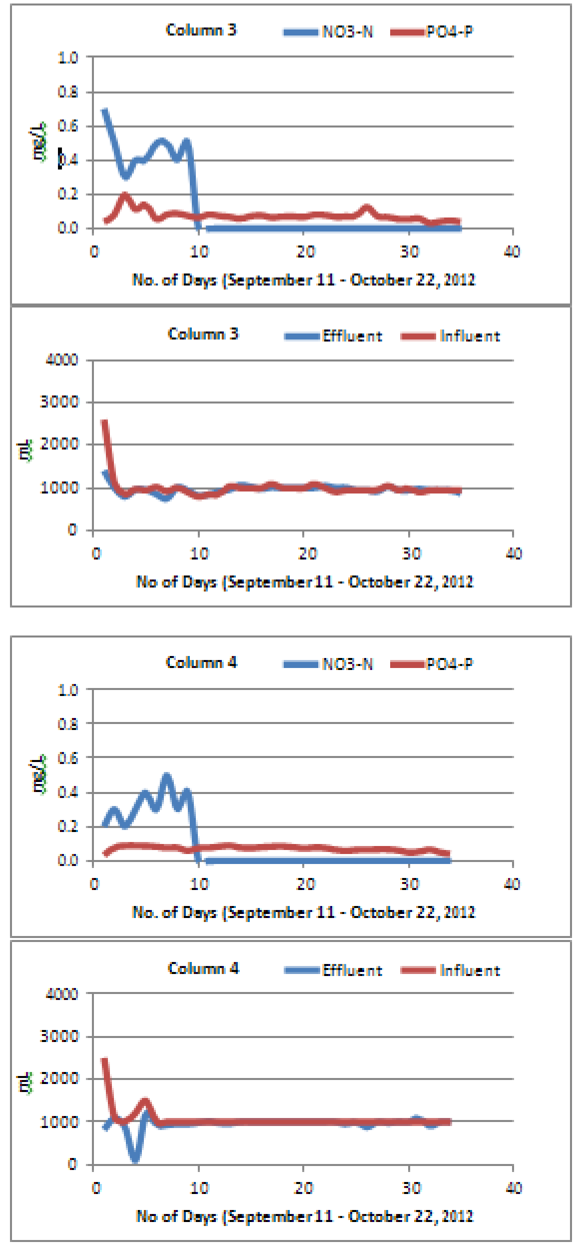
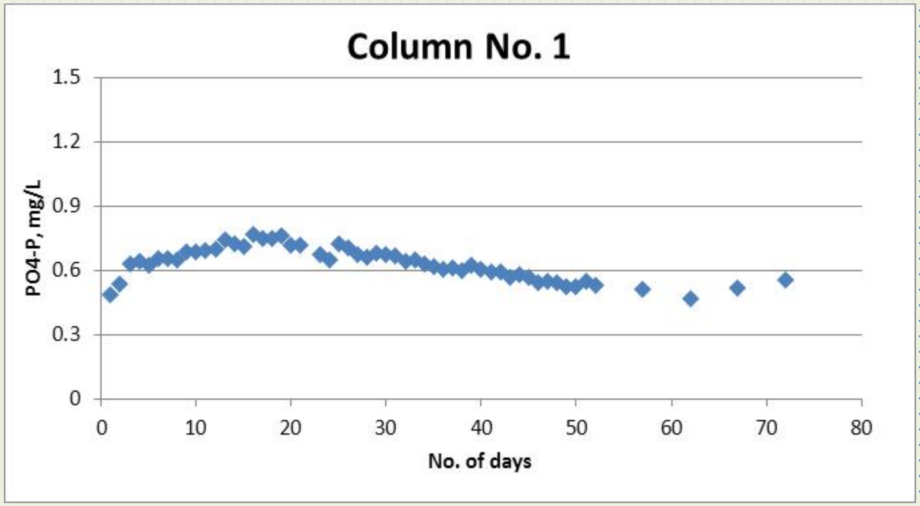


Figure 2. Results of DI Water Leaching Test (cont'd)

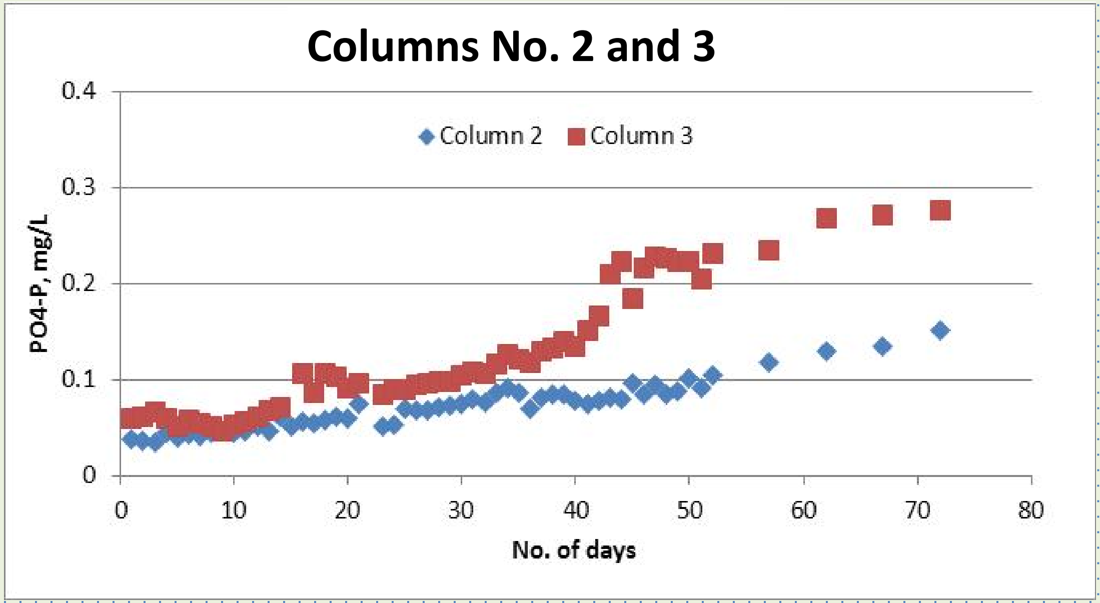
Synthetic Stormwater Tests



Column 1 (M16 + Pine Bark, batch fed) :

- Attaining an average effluent PO_4-P of 0.60 mg/L with no obvious rising trend of the effluent concentration.
- Effluent NO_3-N was at 0.3-0.4 mg/L.

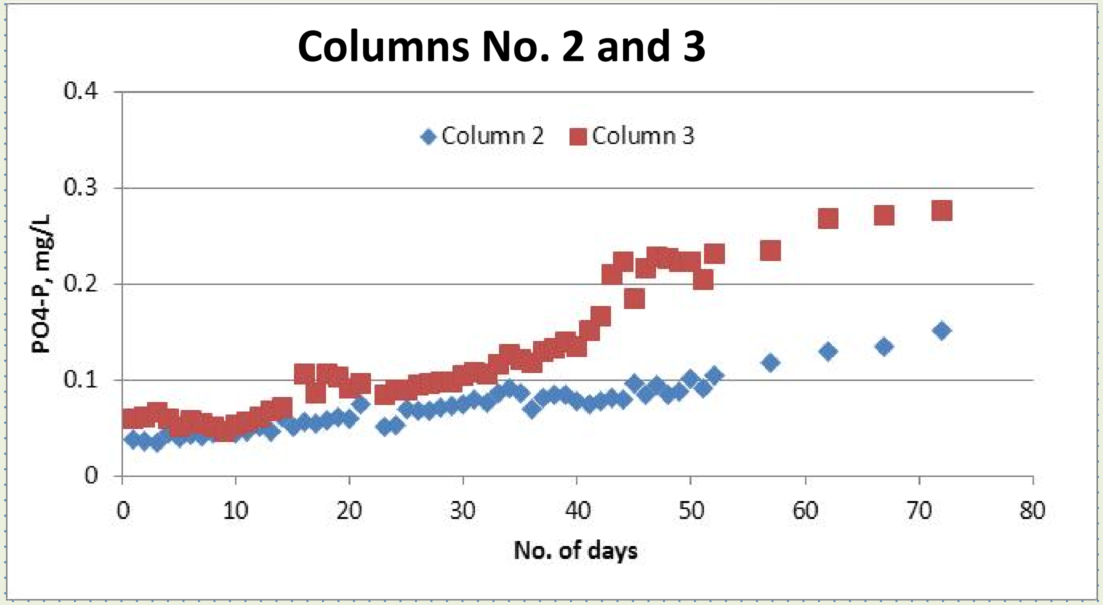
Synthetic Stormwater Tests



Column 2 (M16, batch fed):

- Showing a small rising trend of effluent PO_4-P concentration; PO_4-P was 0.1 mg/L at the end the test period.
- Effluent PO_4-P concentration may increase to approach the influent concentration of 3.33 mg/L for at least 5-6 years if the rising trend hcontinues.
- Effluent NO_3-N was around 1.0 mg/L

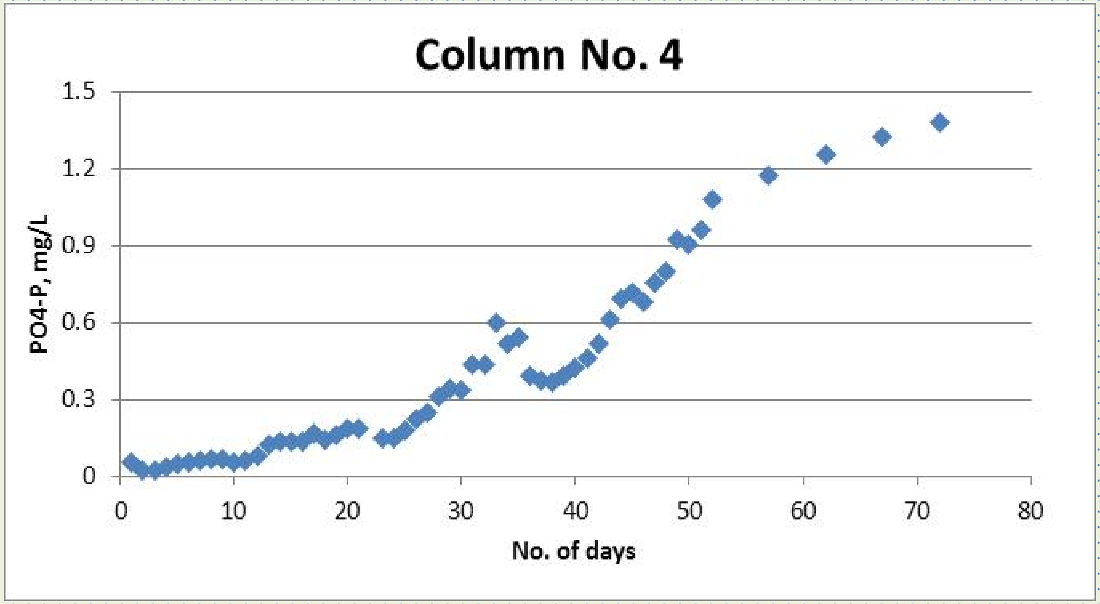
Synthetic Stormwater Tests



Column 3 (M16, flow through) :

- showing a rising trend of effluent PO_4-P concentration that is about 3 times faster than that of column 2, based on comparing slopes of the respective trend lines.
- Effluent PO_4-P concentration was 0.28 mg/L at the end of the test period.
- Effluent NO_3-N was about 1.0 mg/L.

Synthetic Stormwater Tests



Column 4 (NCDENR soil mix, flow through):

- Showing a rising trend of effluent PO_4-P concentration that is about 4.9 times faster than that of column 3.
- Effluent PO_4-P concentration was 1.4 mg/L at the end the test period.
- Effluent NO_3-N was about 0.3 mg/L.

Hydraulic Flow Through Test for Columns 3 and 4

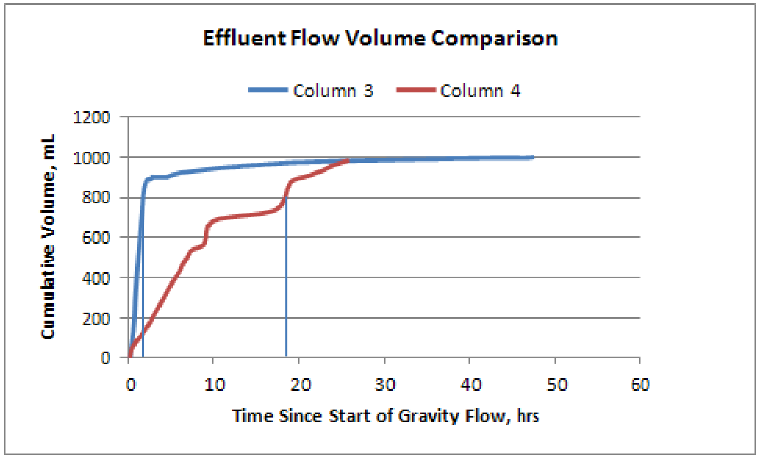


Figure 4. Flow-Through Volumetric Measurements for Columns 3 and 4 (Dec 13, 2012)

- Column 3 (M16) exhibited a volumetric flow through that is at least 8 time faster than column 4 (NCDENR soil mix) at 80% of the cumulative flow-through volume. The effluent PO_4-P concentration of column 3 was about 5 time lower than that of column.

Conclusion

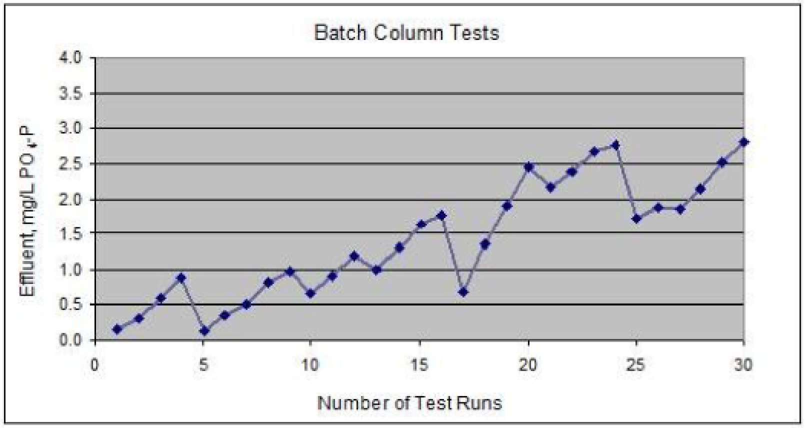
Column 3 packed with M16 was capable of not only delivering a higher hydraulic flow through rate but also a better PO_4-P removal performance than column 4 (NCDENR soil mix).

Stalite Phase I

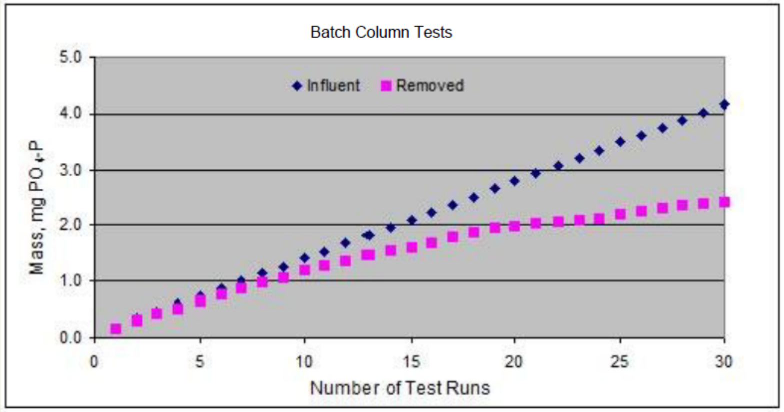
Small Column Study

Phase I
Small Column Tests

The cumulative removal was 2.42 mg as compared to an inflow cumulative mass of 4.18 mg;



Experimental Data for Small Column Tests



overall removal of 58%

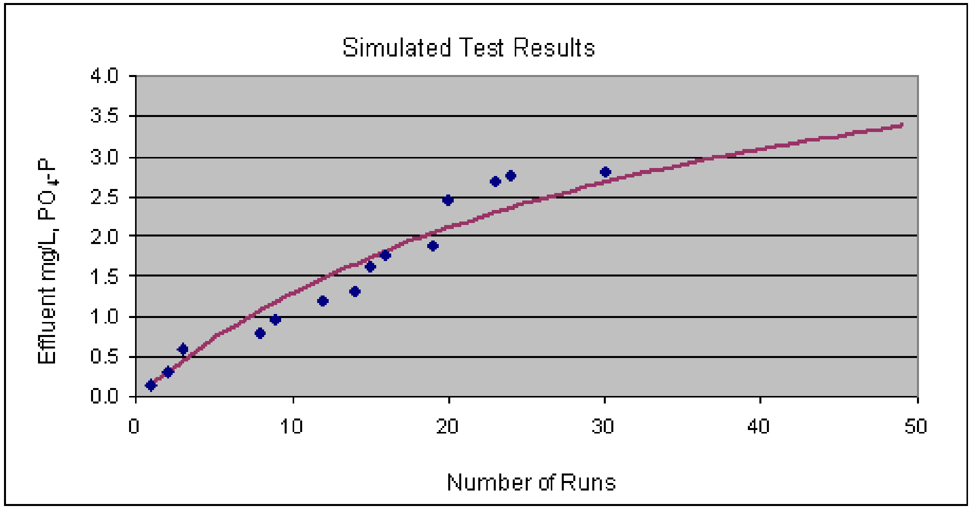


Figure 3. Projected Breakthrough Volumes at Effluent Concentration of 3.33 mg/L PO_4-P

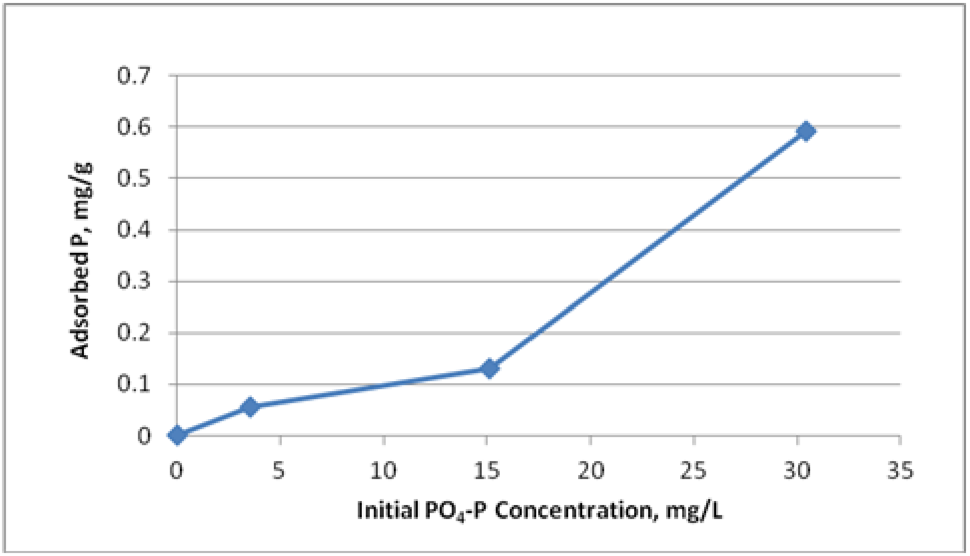


Figure 4. Concentration versus Adsorbed Phosphorus in mg/g of Agitation Results

Table 1. Characteristics of Selected Adsorption Media

Media	Nominal size (mm)	Bulk density (Kg/m^3)	Effective bed porosity (%)	Specific surface area (m^2/g)	Adsorption capacity* (mg P/g)	Adsorption Capacity** (mg P/g)
Perlite	2.36-9.50	105-135	62	6.6	Negligible	0.01
Zeolite	1.40-4.75	700-770	47	1.4	<0.01	0.13
GAC	2.36-4.75	450-500	65	863.0	0.33	1.16
PhosphoSorb™	1.40-2.36	320-400	75	28.8	0.74	7.82
SortiveMedia[3]	0.80-5.00	740	-	75-100	0.40	-
Sand	-	-	-	-	0.0013	-

*Based on adsorption break-through testing[2] **Based in Langmuir adsorption isotherms[2]