Heavy metals and phosphorus compounds filtration of stormwater runoff using bioretention systems at UVM Bioretention Laboratory

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Introduction

Lake Champlain is affected by climate change and water discharge from land uses in Vermont (Pealer & Dunnington 2011). Stormwater discharge from urban areas carries pollutants such as: phosphorus (P) compounds and heavy metals particulates (Lintern et al. 2011, Hunt 2006). Bioretention systems, called "rain gardens", are a green infrastructure and type of best management practice (BMP), composed of soil and plant that collect runoff from impervious surfaces in urban areas and provide water quality improvements (Davis et al. 2009, Dietz 2007). Bioretention reduces surface stormwater runoffs, retains pollutants and increases infiltration and groundwater recharge (Debusk & Wynn 2011). The percentage removal from stormwater by bioretention system is reported to be above 80% for zinc, copper and lead (Hunt et al. 2006). Total phosphorus (TP) removal is variable in the literature, ranging from negative percentage (exportation) to 96% removal, depending of the type of soil (Lucas & Greenway & Lintern et al. 2011). Eight bioretention systems were constructed at UVM in 2012 and have three types of treatments: (1) vegetation type, (2) variation in precipitation and (3) Phosphorus Sorbtive Media additive to soil (figure 1).

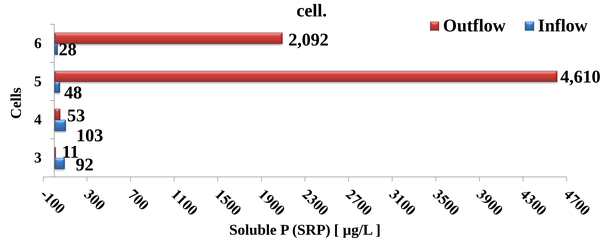
Specific objectives:

- Compare percentage removal or exported of soluble reactive P (SRP), total P (TP), dissolved heavy metals and non-dissolved heavy metals (Cu, Zn, Cd, Pb, Fe, Mn, Al and As) by individual cell and treatment.
- Compare the inflow (stormwater entering the cell) and outflow (stormwater exiting the cell) concentrations of TP, SRP, and heavy metals by each cell, to examine whether the differences varied across treatments.

Figure 1. Study Site

Results

Graph 1. Inflow and Outflow concentrations of soluble P (SRP) by cell.



Graph 2. Inflow and Outflow concentrations of TP by cell.

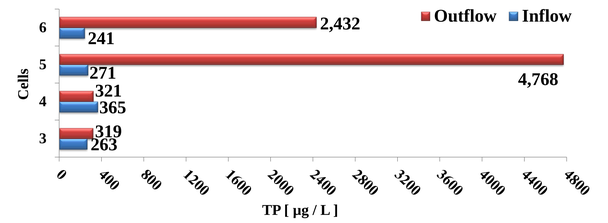
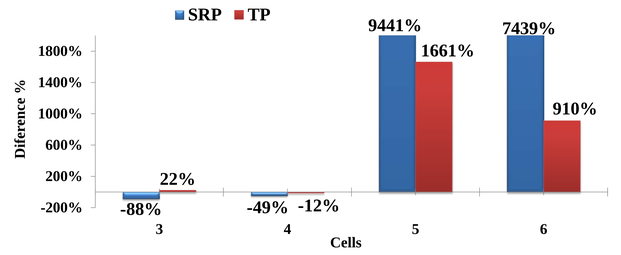


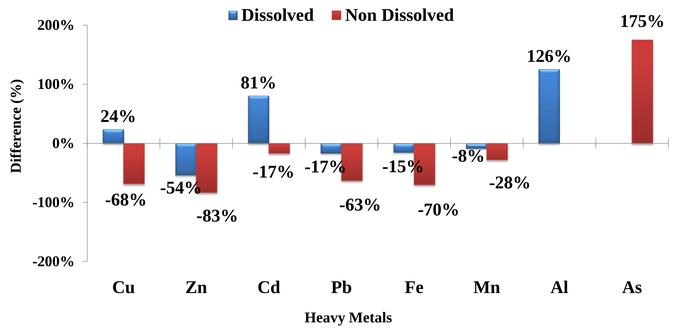
Table 1. TP and SRP t test (p-value) statistic difference.
* p-value < 0.05. Data with no normal distribution, no statistical significance.

Cell	SRP µg P/L	TP µg P/L
3	< .0001*	0.4688
4	0.0006*	0.5085
5	<.0001*	<.0001
6	<.0001*	<.0001*

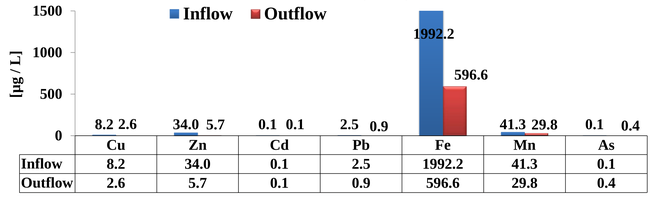
Graph 3. Percentage removal or exported of SRP and TP by cell.



Graph 4. Percentage removal or exportation of dissolved and non-dissolved metals in general soil Media treatment (cell 6).



Graph 5. Inflow and Outflow concentrations of non-dissolved metals in general soil Media treatment (cell 6).



	Cu	Zn	Cd	Pb	Fe	Mn	As
Inflow	8.2	34.0	0.1	2.5	1992.2	41.3	0.1
Outflow	2.6	5.7	0.1	0.9	596.6	29.8	0.4

Table 2. Heavy Metals t test (p-value).
* p-value < 0.05. Data with no normal distribution, no statistical significance

	Cell	Cu	Zn	Cd	Pb	Fe	Mn	Al	As
Dissolved	6	0.1153	0.4587	0.0095*	0.2261	0.694	0.7596	0.0016*	
Non Dissolved		0.0239*	0.0113*	0.7895	0.1104	0.0246*	0.2642		0.5578

Discussion

- Inflow and outflow concentrations has statistical differences ($p < 0.05$) in cells 3, 4, 5 and 6 for SRP, cells 5 and 6 for TP. No statistical difference were found in cells 3 and 4 for TP (Table 1).
- Cells 3 (Additional layer of P sorbtive media with added precipitation treatment) and 4 (Additional layer of P Sorbtive Media treatment) removed SRP concentrations because the inflow concentrations were higher than outflow concentrations. Cells 5 (General soil Media with added precipitation treatment) and 6 (General soil Media treatment) exported SRP concentrations (Graph 1).
- Cells 3 and 4 removed TP concentrations; but, cells 5 and 6 exported TP concentrations (Graph 2 & table 2). Cell 3 removed SRP (88%) and exported TP (22%). Cell 4 removed SRP (49%) and TP (12%). Cells 5 and 6 exported more than 100% for SRP and TP (Graph 3).
- Statistical difference ($p < 0.05$) in concentrations for Cd and Al, but not any difference for Cu, Zn, Pb, Fe and Mn on cell 6 (Table 2).
- No-dissolved heavy metals in cell 6 showed statistical difference ($p < 0.05$) for Cu, Zn and Fe, but any for Cd, Pb, Mn and As (Table 2).
- No-dissolved metals in cell 6 show removal for Cu (68%), Zn (83%), Cd (17%), Pb (63%), Fe (70%) and Mn (28%); but, As (175%) was exported. Dissolved heavy metals in cell 6 removed Zn (54%), Pb (17%), Fe (15%) and Mn (8%), but were exported Cu (24%), Cd (81%) and Al (126%), (Graph 4 & 5).
- The percentages removal in cells 3 and 4 for SRP and cell 3 for TP could were attributed to the additional layer of P Sorbtive Media soil. SRP is the way in which the P reactive is available to be used by plants directly for the photosynthesis processes. The percentage exported in cell 3 for TP could be attributed to the added precipitation treatment (60% more rain).
- SRP and TP exportation could be attributed to the general soil media without the additional layer of P sorbtive media.
- Percentages removal of dissolved heavy metals for Zn, Pb, Fe, Mn and non-dissolved heavy metals for Cu, Zn, Cd, Pb, Fe, Mn could be attributed to the uptake of plants for growth and biological functions. The high diversity (7 species plants mix) that characterized each cell could be influenced the pollutants removal.

Methodology

Samples Collection

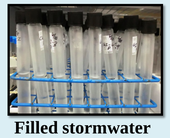
Each storm event

ISCO Bottles are collected

Laboratory analysis

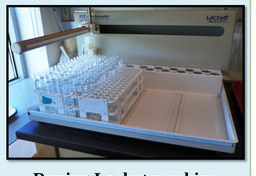
TP

1 Pipetting stormwater



2 Filled stormwater in digestion tubes

3 Acid and cooker pressure for digestion by 3 hours



4 Runing Lachat machine for SRP and TP analysis

SRP

1 Taked stormwater with shiringe from samples

2 Filtrate with 0.45 µm Nylon filter

3

Heavy Metals (Dissolved)

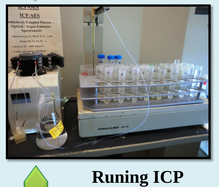
Pipetting stormwater

1 Stormwater composite in a beaker

2 Filtration into two nalgene bottles with 0.45 µm Nylon filter

3 Filled few drops of HCl

4 Runing ICP machine for heavy metals analysis

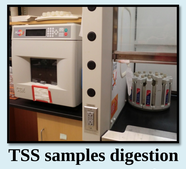


Heavy Metals (non-dissolved)

1 Filtering 3 replicate by section

2 Weigh glass fiber filter with mg balance

3 TSS samples digestion in the microwave for at 100° C



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Literature Cited

- Debusk, K. M. & Wynn, T. M., 2011. Storm-Water Bioretention for Runoff. *JOURNAL OF ENVIRONMENTAL ENGINEERING*, Volume 137, pp. 800-808.
- Hunt, W. F., Jarrett, A. R., Smith, J. T. & Sharkey, L. J., 2006. Evaluating Bioretention Hydrology and Nutrient Removal. *JOURNAL OF IRRIGATION AND DRAINAGE ENGINEERING*, Volume 132, pp. 600-608.
- Lintern, A. et al., 2011. *Key design characteristics that influence the performance of.* Porto Alegre, Brasil, 12th International Conference on Urban Drainage.

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