Developing Biosolids Based Bioretention Soils for Green Stormwater Infrastructure

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Bioretention systems are increasingly used as alternatives to engineered systems for stormwater management in urban areas. These systems typically consist of sand and compost and are designed to allow for rapid infiltration and filtering of stormwater. In some cases, these systems drain directly into streams. In other cases, the water percolates through the subsoil into groundwater. The systems are also designed for a wide range of settings including curbside systems, systems in parking lots and systems alongside buildings. The contaminants of concern in the stormwater include nutrients (N and P), metals (primarily Cu, Pb and Zn), organics (primarily PAHs) sediment and pathogens. Recent work has shown that untreated stormwater is toxic to fish and that filtering stormwater through a sand, compost and bark mixture was sufficient to eliminate any negative impacts (McIntyre et al., 2016). The current regulations on bioretention systems for green stormwater infrastructure in WA State specify that the compost used not include municipal biosolids or animal manures. The rational for this guidance is that biosolids and manures are considered to have higher nutrient and metal concentrations than yard waste or food scraps. The current guidance does not take into account that composts can have widely different characteristics based on feedstock blends and different ratios of each component of the mixture. Previous work demonstrated that feedstocks were not a significant predictor of performance for bioretention systems (Brown et al., 2016). In contrast, the phosphorus saturation index (PSI), a test to estimate the potential for phosphorus leaching, was shown to be highly predictive of efficacy of the different mixtures for both nutrients and metals.

<u>Methods</u>

We conducted a replicated field trial to test a range of different bioretention soil mixtures (BSM) for their ability to remove metals and nutrients from stormwater. The study included 40% food yard waste compost and 60% sand by volume, the current recommended mixture in WA State and a 100% sand as control treatments. Other treatments included biosolids: yard waste compost produced by King County added at different rates with sand, and +/- Fe based water treatment residuals, and high Fe biosolids from DC Water, used both directly and following composting. A list of the treatments used in the study is shown below. The control treatments and the treatments that include biosolids from DC Water are shown in bold.

1. **Yard/food compost: sand 40:60**
2. Biosolids compost sand 40:60
3. Biosolids compost: WTR: sand 35:5:60- to same PSI as #2
4. Biosolids compost: sand 80:20 (2x compost volume from #2)
5. Biosolids compost: WTR: sand 70:10:20 – to same PSI as #4

6. Biosolids compost: sand 20:80 (0.5 compost volume from #2)
7. Biosolids compost: WTR: sand 17.5:2.5:80 – to same PSI as #6
8. **100% sand**
9. Biosolids compost: sawdust: sand 15:5:80
10. Biosolids compost: oyster shells: sand 15:5:80
11. **Sand: loamy clay: DC Water Biosolids 80:12:8**
12. **Sand: DC Water Biosolids 80:20**
13. **Sand: DC Biosolids compost 80:20**
14. **Sand: Sawdust: DC Water Biosolids:Mineral Fines 15:40:40:5**
15. **Sand: Sawdust: DC Water Biosolids 25:25:50**

A total of 12 leachings were conducted. The first 8 were done with synthetic stormwater at both high and low metal levels with the last 4 done with stormwater collected from highway runoff in Seattle, WA. The effluents from the columns were collected and analyzed for total and dissolved metals and P and total N and nitrate. Concentrations of nitrogen, phosphorus and copper in stormwater are shown in Table 1.

Table 1. Concentrations of total nitrogen, phosphorus and copper in stormwater used for the replicated greenhouse trial.

	Total Nitrogen	Copper	Phosphorus
	mg/L	ug/ L	
Synthetic high metal	0.92 ± 0.04	2792 ± 1153	1443 ± 125
Synthetic low metal	1.1 ± 0.04	525 ± 132	2009 ± 80
Actual stormwater	1.8 ± 1.0	39.8 ± 19.1	80.8 ± 32.8

<u>Results- metals</u>

In general, all treatments removed metals from the stormwater with effluent concentrations significantly lower than influent concentrations. The rates of removal were high for all metals measured (Cd, Cr, Cu, Pb, Zn). Of all of the treatments tested, the high Fe biosolids based BSM were the most effective at metal removal showing full removal for the synthetic stormwater treatments and very high removal rates from the actual stormwater. The percentage removal rate of metals for two high Fe biosolids treatments are shown in Table 2. These results are similar to those seen in an earlier trial where both biosolids: yard waste and food:yard waste composts showed high removal of Cu and Zn from synthetic stormwater (Brown et al., 2016). These results suggest that biosolids based bioretention soil mixtures can be used to remove metals from stormwater. It is important to note that the biosolids that were most effective had Fe added during wastewater treatment. The Fe can form highly adsorptive oxides and remove metals from solution. In a previous study high Fe compost from the same treatment plant was as effective as high rates of P addition for reducing the bioaccessibility of Pb in a smelter impacted soil (Brown et al., 2004). These results also suggest that properties other than feedstocks can be more effective at predicting BSM performance.

Table 2. Portion of total metal removed from stormwater by the bioretention soil mixtures containing high Fe biosolids or biosolids compost from DC Water. A removal rate of 1 means that all metal added in the influent was removed by the mixtures and metal concentrations in the effluent were below detection limits.

	Biosolids: sand		Biosolids compost: sand	
	Actual	Synthetic	Actual	Synthetic
Cd	1	1	1	1
Cr	0.92 ± .22	0.99 ± .01	0.92 ± .32	0.99 ± .01
Cu	0.86 ± .14	0.99 ± .02	0.83 ± .22	0.99 ± .01
Pb*	---	0.98 ± .02	---	0.99 ± .02
Zn	0.92 ± .07	0.99 ±.02	0.91 ± .10	0.99 ± .01

* Concentrations were below detection limits in stormwater so removal rates could not be calculated.

Results- nutrients

All mixtures were sources of N and P for the duration of the trial. Over time, concentrations of N decreased significantly. The decrease in total N for all treatments across the duration of the trial is shown in Figure 1. Unlike engineered systems, the performance of systems that rely on natural processes are likely to vary over time. A question that needs to be addressed with the use of these systems is what level of variability is acceptable and also what time frame is acceptable for the systems to come into equilibrium. For example the concentrations of N in the leachate from the first event and the final event for select treatments is shown in Figure 2. The purpose of this figure is two fold. Each of the treatments shown in the figure contain the high Fe biosolids, either as compost or as biosolids. Certain of these treatments had the highest initial N concentrations in the leachate for the first leaching events. By the end of the trial, the total N in these treatments was significantly reduced and was similar to many other treatments. Secondly, treatment #14 Sand: Sawdust: DC Water Biosolids:Mineral Fines 15:40:40:5 had consistently low N in the leachate. Here we mixed sawdust with the biosolids at a 1:1 dry weight ratio. This increased the C:N ratio of the mixture. The higher C:N ratio was a more significant factor in predicting N movement than the presence of biosolids in the BSM. The added C was sufficient to tie up the N and essentially eliminate N movement through the columns. Again, this is an example of variables other than feedstocks as being more important for predicting system performance. The trial was conducted without plants. Rye grass was seeded into the columns only after the 12 leachings had been completed. This was done to measure plant response. Previous work has shown that plants will significantly decrease nutrient concentrations in the effluent from these mixtures (Brown et al., 2016).

Figure 1. Total nitrogen in leachate across all treatments for the duration of the study. The decrease in total N over time is clear.

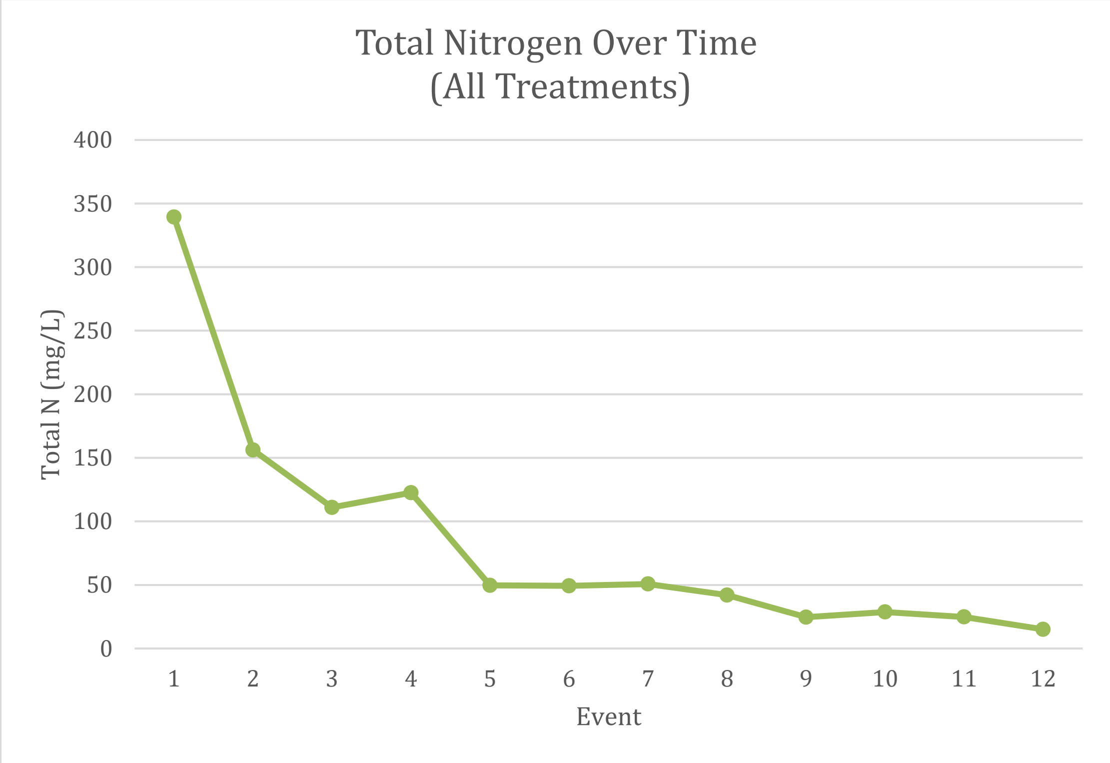
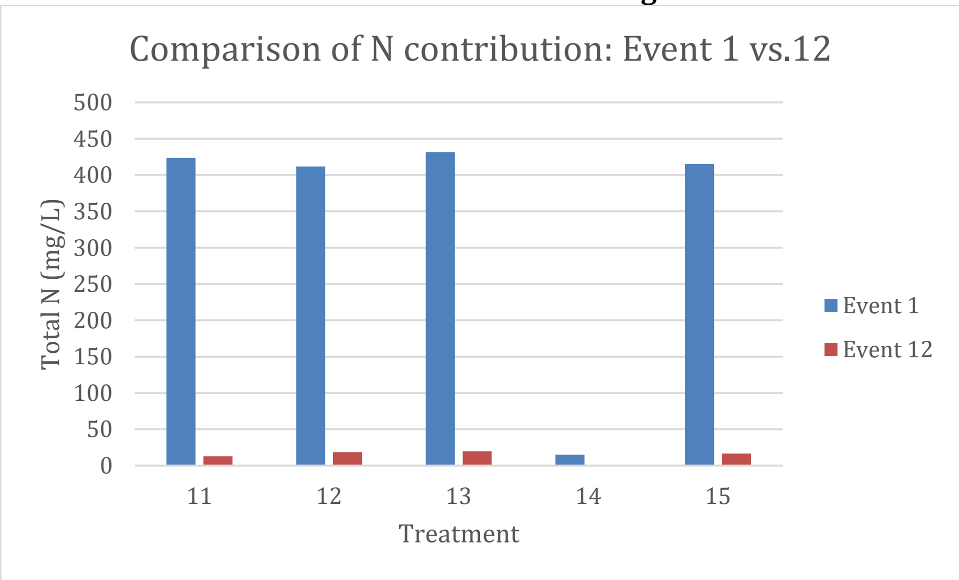


Figure 2. A comparison of total N in the DC Water biosolids treatments from the first leaching event and the last leaching event. A decrease in N in the leachate is clear for treatments 11,12, 13 and 15. Treatment 14 had high rates of sawdust added and showed minimal N movement throughout the trial.



Conclusions

The results of this study indicate that biosolids products can be effective in bioretention soil mixtures. However, not all materials will be equally effective. It is critical to determine what predictive measures can be used to evaluate system performance so that different feedstocks can be reliably used for these systems. Developing standards that can reliably be tested and are effective for predicting performance of bioretention systems will allow use of boutique blends for these systems, but it will also allow for use of readily and locally available materials if they are able to perform. This will in turn allow for more reliable systems and more widespread use of green stormwater infrastructure.

References

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