Geomedia Amendments for Low-Impact Development (LID) Systems to Remove Heavy Metals from Urban Stormwater Runoff

Claire Shillington[1,2], Brittnee Halpin[2], Andrea Portmann[2], John E. McCray[2], Christopher P. Higgins[2]
[1]Hampshire College, [2]Colorado School of Mines, Department of Civil and Environmental Engineering

Introduction

The depletion of our surface and groundwater reservoirs threatens water scarcity on a global scale. As such, finding alternative ways to preserve and sustain the freshwater left in circulation on this planet is important. One solution is to improve the quality of urban stormwater runoff, which creates possibilities for surface and groundwater recharge and stormwater use.

The increase in impervious surface that accompanies urbanization increases the amount of urban runoff that must be managed because rainfall is unable to infiltrate (Figure 1). This runoff is instead rerouted, via pipes and channels, to the nearest surface water body or wastewater treatment plant to prevent flooding. Along the way, urban runoff has potential to pick up contaminants that may be harmful to human and aquatic health, such as pathogens, nutrients, organic compounds, and heavy metals (Grebel et al., 2013).

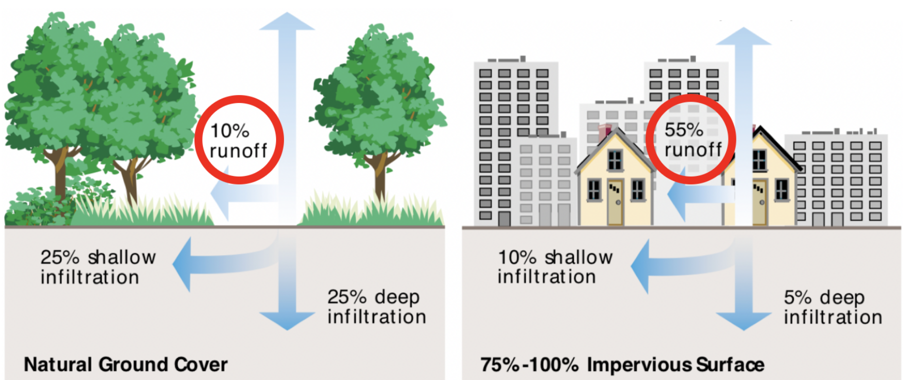

Figure 1. Relationship between impervious cover and surface runoff (adapted from FISRWG, 1998).

Low-impact development (LID) technologies can be designed not only to store and slowly infiltrate water to recharge groundwater reservoirs, but to improve stormwater quality. ReNUWIt is currently developing a LID technology referred to as BEST, or Biohydrochemical Enhancements for Streamwater Treatment (Herzog et al., 2016). BEST enhances stream hydraulics to promote the removal of contaminants from stormwater. This project examined the sorption capacity of seven geomedia for five heavy metals commonly found in urban stormwater runoff. These geomedia were studied as possible amendments to BEST.

Methods

To determine which reactive geomedia, or stormwater filtration media, were most effective at removing a suite of heavy metals commonly found in stormwater—cadmium, copper, nickel, lead, and zinc—seven geomedia were studied: mason sand, zeolite, manganese oxide-coated sands, mulch, iron aggregates, and two types of biochar. The geomedia were minimally processed before use, so the results could most accurately inform applications in real-world LID systems. Batch tests were performed in 45 mL Falcon™ tubes, in which each geomedium was kept in contact with synthetic stormwater (recipe from Grebel et al., 2016)—

with or without spikes of heavy metals—for 24 hours. The target concentrations of heavy metals are shown in Table 1 and were selected to be representative of concentrations typical of stormwater runoff (Grebel et al., 2013). Samples of the synthetic stormwater solution were collected for inductively coupled plasma mass spectrometry (ICP-MS), dissolved organic carbon (DOC), and pH analyses before and after the 24-hour period of solid-water contact. The percent of each heavy metal removed by each geomedia was then calculated.

Table 1. Target Concentrations of Metals in Synthetic Stormwater.

Metal	Target Concentration (µg/L)
Cadmium	3
Copper	20
Nickel	20
Lead	10
Zinc	100

This experimental design was implemented to determine if 1) the geomedia leached DOC; 2) the geomedia leached heavy metals; and 3) the geomedia effectively removed heavy metals. Also taken into consideration were the ease and practicality of acquiring, working with, and applying these geomedia to LID stormwater treatment systems.

Results

The results of this study indicate that Biochar B and iron aggregates were the most effective geomedia at removing the suite of heavy metals that was tested. DOC leaching was not a cause of concern for any of the geomedia tested. However, the leaching of metals, specifically copper and zinc, was more common than expected (Table 2). Even so, all of the geomedia removed at least some of the heavy metals from synthetic stormwater.

Overall, Biochar B and iron aggregates most effectively removed the suite of heavy metals studied, with percent removals of at least 87% and 65% respectively (Table 2). Across all studied geomedia, lead was most effectively removed, in comparison to the other metals, with at least 90% removal by all materials.

Table 2. Average Percent Removal of Heavy Metals from Various Geomedia.

Metal	Sand	Zeolite	MOCS	Biochar A	Biochar B	Mulch	Iron Aggregate
Cadmium	49%	82%	89%	29%	>99%**	60%	94%
Copper	PLO*	PLO*	PLO*	24%	94%	53%	83%
Nickel	30%	30%	41%	19%	87%	32%	65%
Lead	>98%**	>98%**	>98%**	>98%**	>98%**	90%	~100%**
Zinc	PLO*	79%	PLO*	PLO*	>94%**	57%	>99%**

Lowest % removal — Highest % removal

**PLO: Possible leaching observed. These geomedia contributed metals, rather than removing them.*
***Indicates censored data. Minimum percent removal was calculated assuming the concentration of metal in synthetic stormwater after 24 hours equaled the ICP-MS limit of quantitation.*

Conclusions and Future Work

Biochar B and iron aggregates were the most effective geomedia for removing cadmium, copper, nickel, lead, and zinc from synthetic stormwater in this screening experiment. This experiment was part of a larger study that aims to amend the sand modules in BEST with a geomedium capable of removing heavy metals and other contaminants of concern. Future work will characterize the most effective geomedia from this experiment and continue to study their ability to remove heavy metals in additional kinetic and equilibrium batch tests. Tests like these will ensure that the most environmentally sustainable and cost-effective technologies are put to use in the improvement of urban stormwater quality.

Acknowledgements

The authors of this work would like to thank the various geomedia suppliers for their contributions to this study. The suppliers' names have been omitted given the screening-level nature of this work.

References

FISRWG. (1998). *Stream Corridor Restoration: Principles, Processes, and Practices*. *Bridges*.

Grebel, J. E., Charbonnet, J. A., & Sedlak, D. L. (2016). Oxidation of organic contaminants by manganese oxide geomedia for passive urban stormwater treatment systems. *Water Research*.

Grebel, J. E., Mohanty, S. K., Torkelson, A. A., Boehm, A. B., Higgins, C. P., Maxwell, R. M., Nelson, K. L., & Sedlak, D. L. (2013). Engineered Infiltration Systems for Urban Stormwater Reclamation. *Environmental Engineering Science*, *30*(8), 437–454.

Herzog, S. P., Higgins, C. P., & McCray, J. E. (2016). Engineered Streambeds for Induced Hyporheic Flow: Enhanced Removal of Nutrients, Pathogens, and Metals from Urban Streams. *Journal of Environmental Engineering*.