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

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BACKGROUND

The increase in impervious surface that accompanies urbanization leads to:
1) greater volumes of stormwater runoff;
2) greater contaminant loads discharged to urban streams.

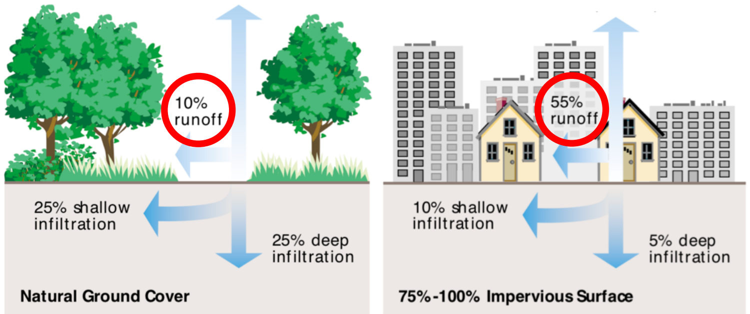

Figure 1. Relationship between impervious cover and surface runoff (adapted from FISRWG, 1998).

- Contaminants of concern that pose threats to human and aquatic health include pathogens, nutrients, organic compounds, and heavy metals (Grebel et al., 2013).
- ReNUWIt is currently developing a low-impact development (LID) technology referred to as BEST, or Biohydrochemical Enhancements for Streamwater Treatment (Herzog et al., 2016), which enhances stream hydraulics to promote the removal of contaminants from stormwater.

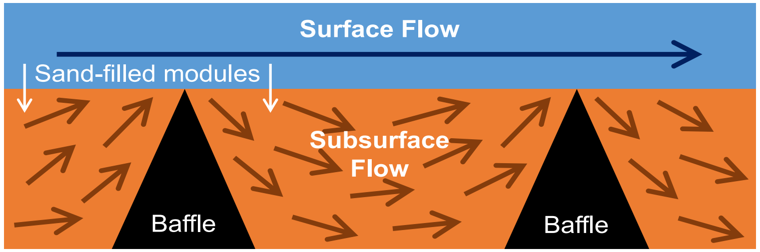

Figure 2. The BEST System (Adapted from City of Golden, CO).

RESEARCH GOALS

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. The specific research goals were as follows:

- Determine if the geomedia leached dissolved organic carbon (DOC).
- Determine if the geomedia leached heavy metals.
- Determine if the the geomedia effectively removed heavy metals.
- Consider the ease and practicality of acquiring, working with, and applying these geomedia to LID stormwater treatment mechanisms.

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**.

- Geomedia were minimally processed before use so results most accurately inform applications in real-world LID systems.
- Geomedia were kept in contact with synthetic stormwater (SSW)—with or without spikes of heavy metals—for 24 hours.
- SSW samples were collected for pH, DOC, and ICP-MS analysis before and after 24-hour period of solid-water contact.
- Percent removal of each heavy metal by each geomedia was calculated.

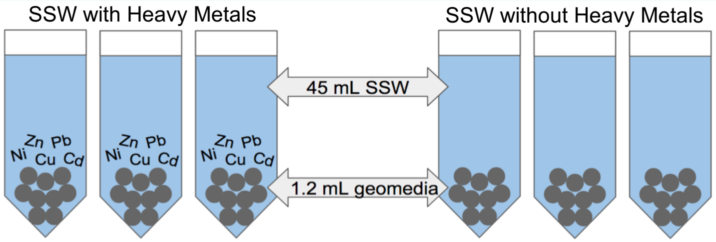

Figure 3. Experimental Setup.

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*Table 1. Target Concentrations of Constituents in Synthetic Stormwater**

Constituent	Target Concentration
Ca^{2+}	0.75 mM
Mg^{2+}	0.075 mM
Na^{+}	1.75 mM
NH_4^{+}	0.072 mM
SO_4^{2-}	0.33 mM
HCO_3^{-}	1 mM
Cl^{-}	1.7 mM
NO_3^{-}	0.072 mM
$H_2PO_4^{-}$	0.016 mM
DOC	10 mg-C/L
Cadmium**	3 µg/L
Copper**	20 µg/L
Nickel**	20 µg/L
Lead**	10 µg/L
Zinc**	100 µg/L

*Adapted from Grebel et al., 2013; Grebel et al., 2016; & Göbel et al., 2007.
**Only added to synthetic stormwater with heavy metals.*

Table 2. Average (n=3) 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%**

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

RESULTS & CONCLUSIONS

- 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, with percent removals of at least 87% and 65% respectively.
- DOC leaching was not a cause of concern with any of the geomedia that were tested.
- The leaching of metals, specifically copper and zinc, was more common than expected.
- Lead was most effectively removed, in comparison to the other metals, with at least 90% removal by all geomedia.

FUTURE WORK

- 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

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