Efficacy of California Native Drought-tolerant Plants at Heavy Metal Removal from Urban Stormwater in Biofiltration Systems

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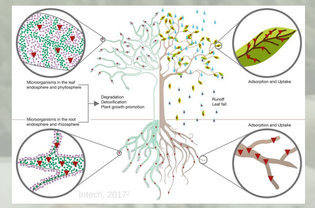
Introduction: Urban Storm Runoff and Biofiltration

Issues with Urban Storm Runoff

- Rain collects heavy metals, such as copper, lead, nickel, and zinc, from roofs, roads and other paved surfaces.
- Runoff flows into local streams, negatively impacting aquatic ecosystems.

Impact of Metal Contamination[1]

- Lead - Reduced plant growth and survival, impaired reproduction, death of aquatic species & birds
- Nickel & Zinc – Plant growth decline, plant damage, increased cancer rates in animals
- Copper - Interferes with salmonid sensory systems, juvenile growth, migratory success



Intech, 2017[2]

Biofiltration

- A popular low impact development best management practice for remediation[3]
- Composed of soil media, plants and microbial communities[4]
- Phytoremediaton - plants immobilize contaminants through uptake and degradation processes

Objectives

Having an effective design and long-term maintenance plan for biofiltration systems is a cost-efficient and practical solution to pollutants in urban stormwater, positively impacting aquatic health and drinking water quality of local watersheds.[3]

This study assesses **i) whether California native, drought-tolerant plants improve the filtration of trace heavy metals in biofiltration systems** and, if so, **ii) which plants are most effective at filtering particular metals.** If plants do improve filtration**, iii) do trace heavy metals accumulate in plant roots or shoots?**

Methods

Experimental Design

- Triplicate PVC columns layered with pebbles, sand, soil and mulch
- Planted with five drought-tolerant, native plants[5] (with a control):
  - Deer grass (*Muhlenbergia rigens)* MURI
  - Spreading rush *(Juncus patens)* JUPA
  - Basket sedge (*Carex barbarae)* CABA
  - California rose (*Rosa Californica)* ROCA
  - Blue sage (*Salvia clevelandii)* SACL
- Three applications of synthetic stormwater of known metal concentrations applied in one month period
- Concentration of heavy metals (Cu, Ni, Pb, Zn) measured in water before and after filtration using flame ionization atomic absorption spectrometry at CSU Chico
- Metal concentrations measured in roots and shoots of plants before and after watering regime using inductively coupled plasma optical emission spectrometry ICP-OES at University of Riverside
- Samples for dissolved metal analysis were filtered with 0.45 µm cellulose acetate membrane filters.

Analysis

- ANOVA and Tukey's Honest Significant Difference tests were used to assess significant statistical variation between results with 95% confidence ($p<0.05$)

Results

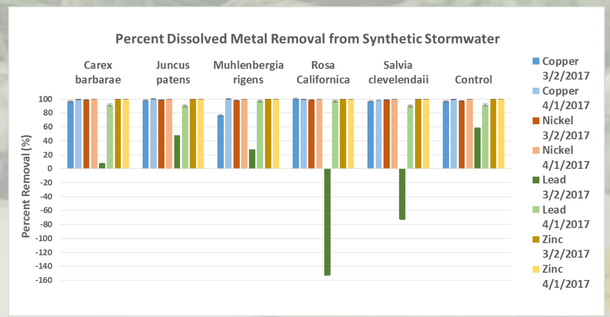


Figure 1: Removal percent of dissolved copper, lead, nickel, and zinc in stormwater applied to biofilters on March 2nd, 2017 and April 1st, 2017.

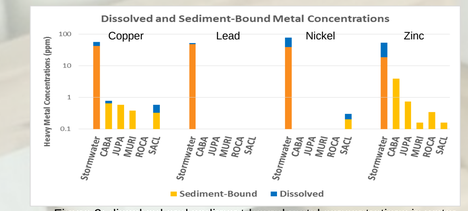


Figure 2: dissolved and sediment-bound metal concentrations in water before and after biofiltration.

Dissolved Metals

With the exception of lead, all dissolved metals (copper, nickel, zinc) were successfully removed from synthetic stormwater (77 - 100% removal)

- Planted biofilters did not display significantly different performance than control biofilters
- Aside from lead, filtration of dissolved metals did not change significantly over time
- *Rosa Californica* and *Salvia clevelendaii* leached a statistically significant proportion of lead on the first watering (73 – 153% leaching)

Sediment-bound Metals

- Sediment-bound zinc and copper were not completely removed from stormwater by biofiltration (0.9 – 5.7% remained)
- Sediment-bound and dissolved nickel was completely removed from biofiltered water in all columns but *Salvia clevelendaii*.
- Sediment-bound lead was completely removed by biofiltration
- Ignoring stormwater concentrations, sediment-bound metal concentrations were not statistically different between plants

Trends

Sediment-bound lead was retained in filters, while some dissolved lead was leached. Copper and zinc that were not immobilized in biofilters were mainly bound to sediment. Nickel (dissolved + sediment-bound) was the most retained metal in biofilters

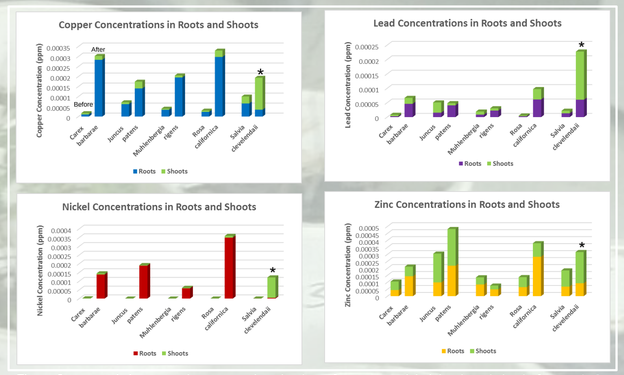


Figure 3: root and shoot metal concentrations in plants for copper, nickel, lead, and zinc before and after three applications of synthetic stormwater.
* *Salvia clevelendaii* died early in the study, which may influence results for root/shoot metal concentrations.

Heavy Metal Uptake in Roots and Shoots

In general, heavy metal concentrations increased in plant roots and shoots after three stormwater applications.

- Copper, lead and nickel in plants were statistically higher after stormwater applications, with copper concentrations increasing the most over time (4x increase)
- Lead concentration increased the least in plant roots and shoots over time (3.5x increase)
- Copper accumulated significantly more in roots than shoots

Trends

Plants displayed statistically different metal accumulation patterns between roots and shoots. Plant uptake did not appear to reach its peak for copper, lead and nickel.

Conclusions

Metals were successfully removed from synthetic stormwater in all planted biofilters and the control, with the exception of lead which leached in the first stormwater application.
Over time, biofiltration was either maintained, or improved. This may be due to plant growth and metal uptake, as supported by the general increase in metal concentration in roots and shoots
Biofiltration may not be a solution to lead contamination, but this study shows that biofiltration is effective for copper, nickel, and zinc remediation.
Although plants did not significantly improve metal remediation compared to controls, other benefits to planting a biofiltration system with these five, California native plants include erosion control, hydrologic improvement, and nutrient removal.[6]

Management Recommendations

Whether metals deposit in roots or shoots can inform best management practices. This study suggests that plant type is not as important a factor in management as the type of metal to be remediated. Plants in nickel- and copper-saturated soils may need to be replaced over time, as metals accumulate in roots. On the other hand, plants in zinc- and lead-saturated soils should be pruned, and leaf litter disposed of properly.

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