Capturing chloride in roadside bioswales on the Illinois Tollway using woody biochar

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Introduction

Bioswales along the Illinois Tollway (IT) remove excess pollutants from stormflows and snowmelt, but possess chloride ion (Cl^-) and heavy metal (cadmium, arsenic, chromium, and lead) levels that surpass the Illinois Environmental Protection Agency's surface water quality standards[1,2]. High salt and heavy metal levels promote the spread of salt-tolerant invasive species, such as *Phragmites australis* (common reed grass) and *Typha* × *glauca* (hybrid cattail)[3,4]. Harvesting invasive biomass reduces regrowth and removes excess nutrients from the system but fails to address the nutrient inputs that drive invasion[5]. Preliminary research suggests applying biochar (a negatively-charged, high-carbon soil amendment) post-harvest decreases plant-available Cl^- and heavy metals by adsorbing these materials to its surface[5]. To investigate these assumptions, we conducted a fully factorial field experiment that included 2 biochar treatments (no biochar, 40 T/ha biochar) and 2 harvest treatments (no harvest, harvest) replicated across four bioswales.

H1: ***Adding 20 Ton/hectare woody biochar to harvested IT bioswales will decrease heavy metal and plant-available nutrient concentrations in the soil.***

H2: ***Harvesting the aboveground plant biomass, primarily Typha × glauca, will decrease the amount of Cl^- available in the system.***

Rationale: Biochar's high porosity and highly charged surface will directly adsorb Na^+ ions, heavy metals, and Cl^- containing compounds. Biochar will reduce plant Na^+ stress, increasing growth and uptake of Cl^- into plant tissues, which is then removed with harvesting.

Methods

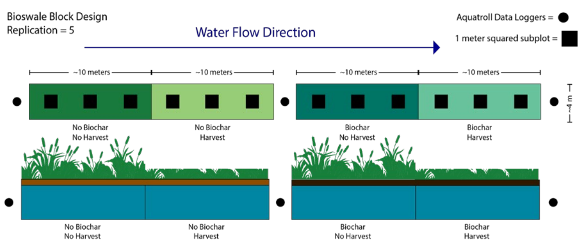

Figure 1. Placement and methodology of water quality probes and subplots at each bioswale.

We placed water quality probes at the ends and center points of each bioswale. We collected soil and plant tissues and surveyed vegetation metrics in fall and spring 2022 and 2023 before harvesting with sickle bar harvesters and removing biomass. Ion chromatography analysis was conducted on living and dead plant matter and soil samples. Heavy metal analysis was conducted on soil samples. We also placed biochar in flow-through mesh bags at the upstream end of the appropriate blocks to conduct a time series analysis of the adsorption of ions to the surface of the biochar.

Results

Chloride concentration in living *Typha* × *glauca* tissue

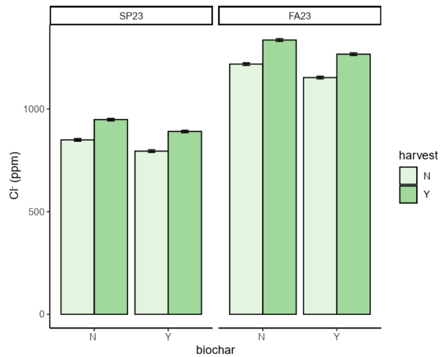

Figure 2. Chloride concentration in the living plant tissue collected in the IT bioswales across treatments and years. The p value of the contrast from Fall 2023 to Spring 2023 was 0.0055.

Chloride concentration in soil

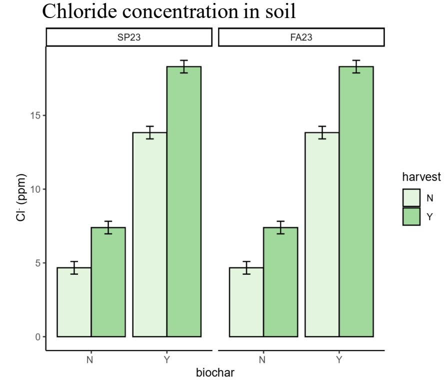

Figure 3. Chloride concentration in the soil samples collected in the IT bioswales across treatments and years. The p value between fall and spring was 1.000, however the p value for the harvest treatments were <.0001 and .4046 for the biochar treatments.

Interpretation

The average concentration of chloride ions (Cl^-) in the soil was significantly lower in plots without biochar, indicating that biochar retains Cl^- in the soil. This supports the hypothesis that biochar application to the IT may increase the capture of Cl^- in bioswales.

Harvesting the aboveground plant biomass resulted in higher Cl^- concentration in the soils, indicating that the plant biomass is absorbing significant amounts of Cl^-. As a result, we reject the hypothesis that removing invasive biomass will decrease soil Cl^- concentration. The invasive and native plants growing in the bioswales are important for nutrient retention and limiting downstream plant available nutrients.

Soil heavy metal and water specific conductivity analyses will be completed in fall 2024.

Future Directions

Figure 4. Harvest treatment of an IT bioswale.

Figure 5. Biochar bag in IT bioswale.

Groundwater contamination from traffic and road salt application has long been a concern in the Illinois Tollway system. Our findings suggest that biochar application in the bioswales of Illinois Tollways may be a useful tool to improve heavy metal and chloride ion retention. Harvesting the invasive biomass is a time consuming and laborious practice. These results suggest that harvesting is unnecessary to improve the functioning of the Illinois Tollway system.

Preventing the spread of pollution from road runoff can improve downstream wetlands, their hydrology, and support biodiversity. We suggest a land management approach of annual biochar application to the upstream points of IT bioswales in the fall to ensure that the biochar is present for Cl^- and heavy metal retention throughout the snowmelt and storm season.

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