Lab and field testing of urban stormwater pollutant removal using biochar and iron materials

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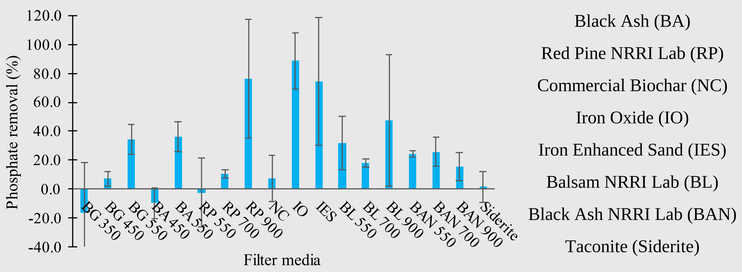
INTRODUCTION

Biofiltration is frequently employed as a stormwater treatment system to reduce phosphorus pollution and prevent eutrophication. Biochar is expected to have excellent potential given its large surface area and microporous structure. These characteristics are dependent on the biochar feedstock and pyrolysis temperature. This study, a collaboration between the Natural Resources Research Institute (NRRI), The University of Minnesota (UMN), and the Mississippi Watershed Management Organization (MWMO), investigates the efficiency of biochars produced from different feedstocks and pyrolysis temperatures along with iron-based filter media at the batch, pilot, column, and field scale. Experiments are tested against nutrients, metals, organics, *E.* coli, and general water quality parameters. Preliminary results were used to inform testing at the field and column scale. Biochar produced at NRRI, in combination with sand was placed in demonstration treatment cells for removal of a comprehensive suite of stormwater contaminants from parking lot run off. Results of this study will provide critical field-scale testing for technology application and inform the selection of feedstock and pyrolysis temperature to tailor biochar production for enhanced stormwater treatment efficiency.

PRELIMINARY TESTING

NRRI produced 14 biochars from different feedstocks and pyrolysis temperatures from 350 to 900°C to determine the biochar production conditions best suited to stormwater treatment. The biochars, a commercial char, and iron-based media were screened in batch tests for simultaneous removal of PO_4^{3-}, NO_3^{1-}, and DOC. Sorption efficiency was shown to be dependent on both pyrolysis temperature and feedstock. High temperature biochars showed promising PO_4^{3-}, NO_3^{1-}, and DOC removal while low temperature biochars had limited removal or release of nutrients and DOC. Release of nutrients may be attributed to biochar volatile matter and acid functional group density. Iron materials showed removal of both nutrients and DOC. Therefor, mixing or layering biochar and iron-based media may effectively remove nutrients and DOC simultaneously.

Figure 1: Batch Screening Test for Phosphate



Balsam Grand (BG)
Black Ash (BA)
Red Pine NRRI Lab (RP)
Commercial Biochar (NC)
Iron Oxide (IO)
Iron Enhanced Sand (IES)
Balsam NRRI Lab (BL)
Black Ash NRRI Lab (BAN)
Taconite (Siderite)

PRELIMINARY TESTING cont.

To inform the final filter design, two mesocosm scale filter boxes were constructed. These pilot boxes contained two chambers with varied layers of sand, iron enhanced sand, and a commercial biochar mixture. The boxes were run from 09/2020 to 01/2021 for *E. coli* removal. Results from Tischer Creek are shown below.

Figure 2: Pilot Treatment Cell Construction

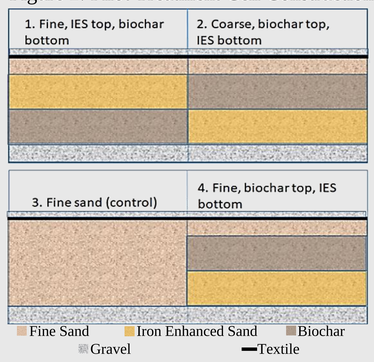
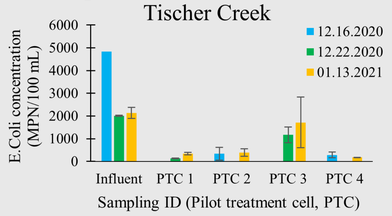


Figure 3: E. coli Removal from Tischer Creek



PRODUCTION AND INSTALLATION

Based on preliminary testing and laboratory constraints, Minnesota-sourced red pine biochar produced at 550°C was chosen for field and column testing. Over 1500lbs of wood chips were used to custom produce the large-scale batch of biochar, 350-lbs, in the rotary kiln at the NRRI Coleraine Biomass Conversion Lab

Figure 4: Rotary Kiln at NRRI

Figure 5: MWMO Filter Test Beds

A large portion of the biochar was installed at the MWMO Filter Media Test Lab on May 13th and 14th for comprehensive contaminant removal from parking lot runoff. The half-pipe filters are 4-ft in diameter and approximately 20-ft in length. Three filter test beds were installed- one with iron enhanced sand (filter P), one with sand and the red pine biochar at a 20% amendment (filter M), and one with a control sand (filter B). Field seasons run from April to October. Water samples collected from the parking lot and filter effluent are tested against general water quality parameters, *E. coli*, nutrients, trace metals, and trace organics. After each field season the aged media will be tested and bioaugmentation analyzed.

PRODUCTION AND INSTALLATION

The remaining biochar was used for large-scale column testing at NRRI. Column tests were conducted in duplicates using PVC pipe with an inner diameter of 2-in and a length of 24-in designed to hold 14-in of media. Synthetic stormwater intermittently dosed columns twice a week to mimic stormwater runoff. Effluent samples were collected at the end of each dosing period, filtered through 0.22 um nylon syringe filter, and analyzed by IC.

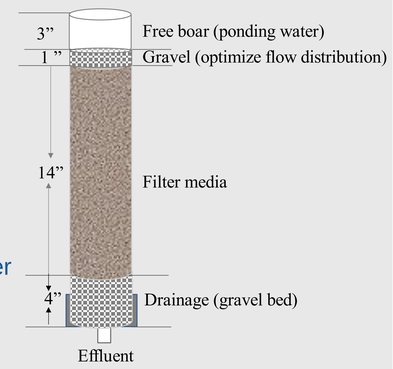
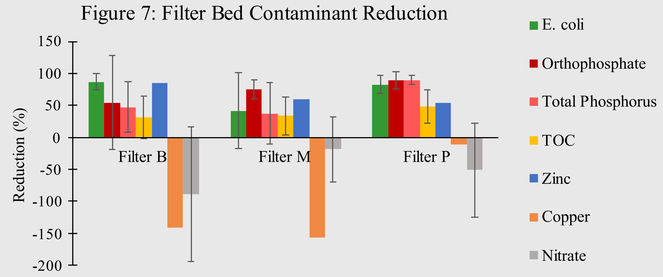


Figure 6: Column Construction

MONITORING

Preliminary data for filter tests beds shows all filters have an affinity for *E.* coli, phosphorus, TOC, and zinc and release copper and nitrate. Filter M (biochar/sand) contaminant reduction is greatest for orthophosphate (75%) and zinc (60%), is least for copper (-157%) and nitrate (-19%), and similar reduction for *E. coli*, total phosphorus, and TOC (38-42%). Analysis is ongoing.

Figure 7: Filter Bed Contaminant Reduction



For column experiments, the extent of nutrient removal depends on the composition of the filter media mixture. Siderite-biochar mixture was found to be most effective for the removal of both phosphate and nitrate, maintained good hydraulic performance throughout the stormwater dosing. Analysis is ongoing.

Figure 8: Effluent Concentration After Intermittent Dosing