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Phragmites biochar filtration for nutrient runoff into wetlands

Introduction

In many wetland areas surrounded by residential or agricultural zones, the impact of nutrient-rich and polluted runoff is apparent. This study determined the effectiveness of biochar, made from an invasive species (*Phragmites australis*, common reed grass), biochar as a sustainable solution for removing dissolved phosphorus (P) and nitrogen (N) from runoff. Plants were sourced from an invasive lineage collected in residential wetland areas using a cut-stem approach with comprehensive seed capture to minimize the additional spread of the invasive species.

The collected *Phragmites* material underwent initial processing using a hammer mill, followed by nitrogen gas purging and heating to produce biochar. Subsequent enhancements to the biochar included activation through potassium hydroxide and the introduction of specific metals. The modified biochar, serving as the carbon source in this activated carbon filtration system, was then tested to ascertain its performance as a filtration medium for agricultural runoff. *Phragmites australis* biochar shows potential in removing dissolved phosphorus and nitrogen from runoff. Utilization of this organic material in future filtration products could complement current management practices of the invasive species, potentially providing additional economic incentives.

Materials & Methods

Phragmites australis, commonly known as common reed, obtained from Northeastern Wisconsin, served as the biochar feedstock (Figure 1). Pyrolysis initiation involved subjecting the phragmites to temperatures exceeding 800°C in a furnace for over an hour. Enhancements Biochar involved the incorporation of specific metals (Al, Ca, La, Nb, and Mg) and activation with potassium hydroxide. The treated media underwent blending with a cement mixture to facilitate the formation of 3mm pellet dye.

Figure 1: *Phragmites australis* biochar pellets (left), drinking water treatment residual pellets (center) and flow-through columns (right).

Materials & Methods

(Continued)

Pellets were precisely weighed, and their phosphorus removal potential was assessed through flow-through columns crafted from 19mm PVC pipes (Figure 2). These columns, packed with 76mm of treated media, received water containing potassium phosphate [KH2PO4] at a flow rate of 9mL s-1 to achieve a hydration retention time.

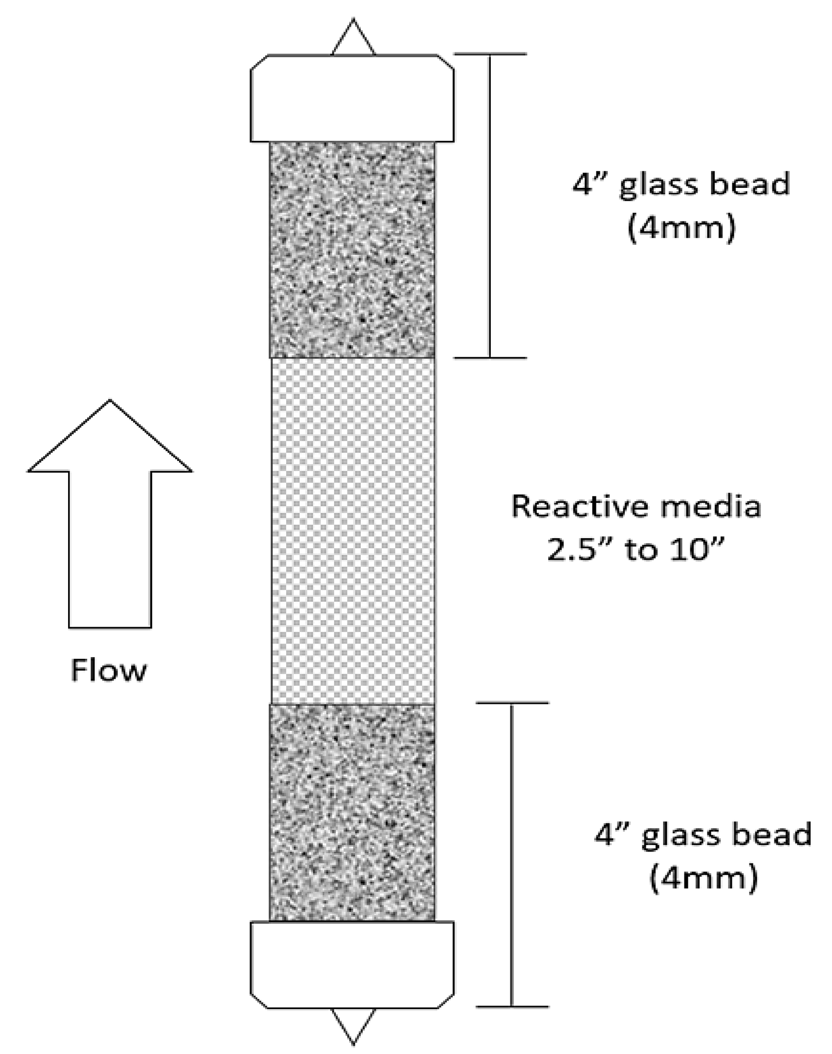

Figure 2: Schematic of lab scale flow through reactor column.

The columns were analyzed in triplicates for each media variant. Influent and effluent samples were systematically collected every 4 hours until exhaustion (<10% Removal) or observed underperformance of the media. Analysis utilized a Seal AQ300 analyzer following U.S. EPA method 365.1. The collected data underwent thorough analysis to compute the percentage of phosphorus removal.

Results

The sorption capacity of the biochar pellets is noteworthy.
Among the biochar pellets, CCC stands out as the top performer (Figure 3), showcasing a sorption capacity that has led to over 70% phosphorus removal after just 25 hours. This signifies its efficacy in phosphorus retention and highlights its potential as a key player in improving wetland environments. Phragmites australis, being an invasive species, is abundant and readily available, minimizing production costs associated with feedstock acquisition. This cost-effectiveness contributes to the economic viability of implementing biochar filters for phosphorus removal in water systems.

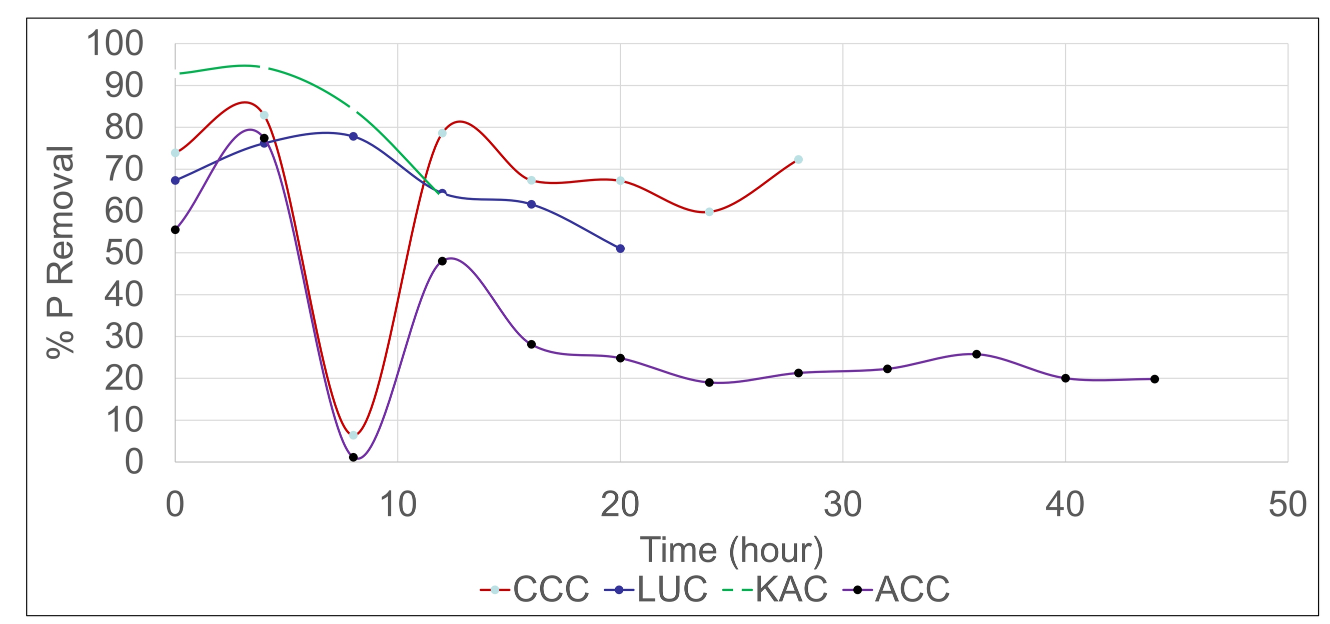

Figure 3: Percent of phosphorus removal over time by biochar-based media.

Table 1: Media evaluated, acronym, treatment, and final pellet composition.

Name	ID	Treatment	Pellet Composition
$AlCl_3$ Biochar	AIC	0.1L of 0.1M $AlCl_3$ per 25g Phragmites prior to the charring process	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 131mL Deionized water.
$MgCl_2$ Biochar	MCC	0.1L of 0.1M $MgCl_2$ per 25g Phragmites prior to the charring process	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 210mL Deionized water.
Unmodified Biochar	UAC	-	1 part Untreated Char, 2 parts sand, 1 part lime, 1 part cement, 220mL Deionized water.
KOH Activated Biochar	ACC	100g biochar soaked in 400mL 2M KOH for 60 mins, filtered then acid washed until neutral then dried at 105°C for 12 hours.	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 130mL Deionized water.
KOH Activated and $AlCl_3$ Biochar	KAC	125g biochar soaked in 500mL 2M KOH for 60 mins, filtered then acid washed until neutral; dried at 105°C for 12 hours; saturated in 0.1L of 0.1M $AlCl_3$ per 25g activated char, then dried again.	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 130mL Deionized water.
Calcium Chloride Treated Char	CCC	0.1L of 0.1M $CaCl_2$ per 25g Phragmites prior to the charring process	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 210mL Deionized water.
KOH Activated and $AlCl_3$ Biochar	KAC	100g biochar soaked in 400mL 2M KOH for 60 mins, filtered then acid washed until neutral then dried at 105°C for 12 hours then 0.1L of 0.1M $AlCl_3$ per 25g char.	1 part Treated Char, 2 parts sand, 1 part lime, 1 part cement, 130mL Deionized water.

Conclusions

Utilizing the invasive species *Phragmites australis* as a biochar in water filtration systems presents a unique opportunity to not only address environmental concerns but also yield economic benefits. Biochar filters placed at the edges of agricultural fields could intercept and treat nutrient runoff at the source mitigating the downstream impact on water bodies. This proactive approach could help farmers by reducing the need for expensive downstream water treatment measures and by safeguarding against potential penalties related to nutrient pollution. The economic benefits extend beyond the agricultural sector, as improved water quality positively influences various industries, including tourism, fisheries, and municipal water treatment.
Additionally, biochar filters could be used to support the nutrient removal capabilities of engineered wetlands, which are constructed environments that mimic natural wetland processes, effectively capturing and transforming nutrients like phosphorus. The economic advantages of engineered wetlands lie in their long-term sustainability and multifunctionality. They not only contribute to nutrient removal but also provide habitat restoration, flood control, and aesthetic benefits. Investing in such ecologically sound solutions not only safeguards water quality but also fosters a harmonious balance between economic development and environmental conservation.

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