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# ABSTRACT

## CLOSING THE PHOSPHORUS LOOP WITH GREEN INFRASTRUCTURE: REMOVAL AND RECOVERY USING AMENDED SOILS AND 3D-PRINTED MATERIAL

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Phosphorus (P) is a life-essential element contributing to the deterioration of water quality. Eutrophication and hypoxia in waterbodies result from excessive P loading from stormwater runoff. Green infrastructure (GI) is implemented to solve stormwater runoff pollution, but the P removal performance of these systems is variable. Moreover, P is arguably being unsustainably mined, with the majority being converted into fertilizers and animal feedstock to support demand for farming products due to increasing global populations.

This dissertation explored completing the circular P economy utilizing 3D-printed structures and GI soil amendments to remove P from stormwater runoff and provide a means to recover removed P. Laboratory-scale batch experimentation was used to gather data for all objectives. First, the P removal and recovery potential of a 3D-printed iron-embedded polylactic acid composite representative unit cell (RUC) was investigated. The RUC's maximum P adsorption capacity ($q_{max}$) was 1.90, 1.57, and 1.83 mg-P g-media$^{-1}$ from solution at pH 5, 7, and 9, respectively. Furthermore, the $q_{max}$ was 2.24., 1.57, and 1.85 mg-P g-media$^{-1}$ at temperatures 15, 23, and 36 °C, respectively. The $q_{max}$ was reduced by 48% in solution with competing ions. In bioretention effluent, the RUC removed 94% of P within 48 hrs. A solution with pH 12.3 facilitated recovery of 69% of adsorbed P.

Second, P recovery from GI soils was explored. Desorption solutions at pH 12.3 and 2 resulted in the recovery of 43% and 98% of the P mass (mg-P g-media$^{-1}$) originally removed using iron- and slag-amended soils, respectively. When testing media reuse for P recovery, the mass of P recovered (mg-P g-media$^{-1}$) decreased from 60% to 18% and 230% to 0 % from cycles 1 to 5 for iron- and slag-amended soils, respectively.

Lastly, native adsorbed P (NAP)-adjusted isotherm equations were used to model the P adsorption data from iron- and slag-amended soils. When desorption of P from soil was observed, NAP-adjusted models fit the data better than traditional isotherm equations. Additionally, the NAP-adjusted model resulted in higher parameter estimates than traditional models, indicating that traditional models may underestimate the soil's P adsorption capacity and affinity.