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Calcined Eggshell-Woodchip Reactive Material for Phosphorus and Nitrogen Removal

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Phosphorus (P) and nitrogen (N) fluxes from greenhouse agricultural goods production systems represent a persistent source of nutrient loading to the Lake Erie basin [1]. Passive bioreactor systems using calcium-rich reactive materials have been proposed as a low-cost strategy to attenuate nutrient runoff; however, the geochemical controls on phosphate immobilization and the coupled redox processes governing nitrate removal remain insufficiently constrained under laboratory and field conditions [2].

This study evaluates nutrient removal mechanisms in reactive material of calcined eggshells and woodchips through integrated research conducted in a greenhouse-dominated watershed near Leamington, Ontario. Calcination of eggshell-derived $CaCO_3$ produces CaO, generating elevated pH and dissolved Ca^{2+} upon hydration. Batch kinetic experiments were performed to quantify phosphate removal rates and retention capacity across environmentally relevant pH, temperature, and phosphate concentrations. Calcined eggshell solids were characterized using X-ray diffraction (XRD) and scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDX). Calcinated eggshells have been subjected to high temperatures thermally decompose calcium carbonate ($CaCO_3$) within the shells to calcium oxide (CaO), then can react with water and precipitate phosphate through the following reactions (Eqs. 1-4):

(1) $CaCO_3 \rightarrow CaO + CO_2$

(2) $CaO(s) + H_2O \rightarrow Ca(OH)_{2(s)}$

(3) $Ca(OH)_{2(s)} \leftrightarrow Ca^{2+} + 2OH^-$

(4) $10Ca^{2+} + 6PO_4^{3-} + 2OH^- \rightarrow Ca_{10}(PO_4)_6(OH)_2$

Field performance was evaluated using passive flow-through bioreactor installed along greenhouse drainage channel. Monitoring of soluble reactive phosphorus, total phosphorus, nitrogen species, and major ions was combined with periodic media sampling to assess nutrient removal efficiency of leachate under variable hydraulic loading and seasonal conditions.

Linking laboratory kinetics with field observations provides constraints on Ca–P precipitation dynamics, carbon-driven nitrate reduction, and reactive media transformation. These results support optimization of eggshell-derived reactive material for passive nutrient interception and contribute to scalable strategies for reducing nutrient inflow into the Great Lake Erie basin.

References:

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