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Examining Nitrogen By-Product Management for Microbially-Induced Calcite Precipitation via Stimulated Microbial Ureolysis

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Microbially Induced Calcite Precipitation (MICP), or bio-cementation, has shown significant promise as an environmentally-conscious alternative to traditional geotechnical ground improvement technologies, which oftentimes rely on hazardous grouting chemicals, high mechanical energy, and energy-intensive materials to improve the engineering properties of soils (DeJong et al. 2013). In the urea hydrolysis driven process, soil microorganisms containing urease enzymes catalyze a hydrolysis reaction that degrades urea, producing total ammonium, dissolved inorganic carbon, and hydroxide ions (Stocks-Fisher et al. 1999). In the presence of soluble calcium from treatment solutions or groundwater, the process can supersaturate solutions with respect to calcium carbonate and initiate mineral precipitation on soil particle surfaces and contacts. Bio-cementation can transform the mechanical properties of granular soils through large increases in shear stiffness and strength, with reductions in hydraulic conductivity and porosity (DeJong et al. 2006; Montoya & DeJong 2015; Gomez & DeJong 2017).

Despite many recent advances with respect to MICP, environmental concerns regarding the fate of produced nitrogen by-products have remained largely unaddressed. Although ammonium is a commonly encountered source of inorganic nitrogen in soil systems, high aqueous ammonium concentrations produced following MICP may present serious environmental and human health concerns if left untreated in subsurface soils. In order for MICP to become an environmentally-conscious technology, it is clear that scalable methods to manage, remediate, and/or remove nitrogen by-products following bio-cementation must be investigated.

In this study, a series of soil column experiments were performed to examine the transport, removal, and transformation of nitrogen by-products following MICP treatments. In all columns, bio-stimulation treatment techniques following previous experiments (Gomez et al. 2018) were used to enrich native ureolytic soil microorganisms and enable bio-cementation. Columns were 7.6 cm in diameter, 17.8 cm long, and contained a poorly-graded sand material prepared to an initial porosity of 35%. Prior to all treatments, columns were saturated with de-ionized water and an ammonium bromide solution was applied to investigate the transport of ammonium relative to a passive tracer. Soil columns received identical treatment solution injections over 14 days targeting a final post-treatment calcite content of 4 to 5% by mass. During treatments, non-destructive shear wave (Vs) and compression wave (Vp) velocity measurements were completed to monitor changes in soil skeleton shear stiffness and potential changes in pore fluid compressibility resulting from bio-gas production and carbonate degradation. Aqueous samples were obtained from all columns in time to examine changes in solution chemistry related to microbial urea hydrolysis, calcite precipitation, and ammonium sorption and transport. Following all cementation treatments, soil columns received daily rinse solution injections with differing ionic strengths and pH values to investigate the effect of rinse solution chemistry on by-product removal and the potential for ammonium leaching during solution retention periods. Following all treatments, the effect of rinses on by-product removal and bio-cementation integrity was evaluated. Results will guide efforts to model the transport and removal of ammonium by-products following bio-cementation.

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