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Investigating Treatment Techniques for Stimulated Ureolytic Microbially-Induced Calcite Precipitation at Field Scale Treatment Depths

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Microbially Induced Calcite Precipitation (MICP) is a bio-mediated soil improvement process that can improve the engineering properties of granular soils through the precipitation of calcium carbonate on soil particle surfaces and contacts. Although bio-cementation has been investigated extensively in laboratory experiments (DeJong et al. 2006, Martinez et al. 2013, and others) and successfully up-scaled in several meter-scale applications (van Paassen 2011; Gomez et al. 2015), most studies have relied on the injection of laboratory-cultured bacterial strains, or bio-augmentation, to enable the bio-cementation process. Bio-stimulation offers the transformative ability to use selective environmental conditions and substrates to enrich native microbial populations in-situ to obtain desired metabolic and enzymatic capabilities. The enrichment of native ureolytic bacteria for bio-cementation may enable significant reductions in process treatment financial costs and detrimental environmental impacts.

Although past studies have shown that ureolytic stimulation is feasible in surficial soils and groundwater samples (Fujita et al. 2000; Tobler et al. 2011; Burbank et al. 2011; Gat et al. 2014; Gomez et al. 2014; 2016), many engineering applications may require stimulation of native ureolytic microorganisms at much greater treatment depths near 15 meters. At the same time, microbial abundances and activities are anticipated to decrease with increasing soil depth due to reductions in nutrient availability, soil temperature, and changes in other environmental factors (Fierer et al. 2003; Eilers et al. 2012). If bio-cementation via stimulated microbial ureolysis is to be used for deeper subsurface applications, the effect of soil depth on ureolytic enrichment in natural soils must be better understood.

In this study, batch and soil column experiments were performed using alluvial sand and gravel samples obtained aseptically from a recently exposed cut slope and geotechnical boring at a field site (Gomez et al. 2018) at depths up to 12 meters. Experiments were completed to investigate the effect of soil depth on the enrichment of native ureolytic microorganisms, the bio-cementation process, and the performance of several different stimulation solution techniques. During tests, solution samples were obtained over time to monitor changes in aqueous cell densities, urea degradation, and solution pH occurring during stimulation and bio-cementation treatment phases.

Results suggest that significant biological differences may exist between soil samples with increasing soil depth and that different stimulation techniques than previously used on surficial soils may be required to achieve successful bio-cementation in deeper materials. Despite most specimens achieving similar cell growth and solution pH increases over time, significant differences in urea degradation were observed, suggesting that solution pH monitoring alone may not be an effective indicator of urea hydrolysis and that total cell counts may omit important information about differences in enriched microbial populations. Increases in stimulation solution yeast extract and ammonium chloride concentrations and adjustment of solution pH to more alkaline values was shown to improve ureolytic enrichment through both increases in obtained total cell densities and increased selective pressure for alkaliphilic ammonium-tolerant microorganisms. The achieved results suggest that stimulated ureolytic MICP is possible in deeper subsurface locations at treatment depths near 12 meters.

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