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Transport of Sporosarcina Pasteurii in porous saturated sands and applications on soil improvement

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Microbial-induced calcite precipitation (MICP) has been regarded as a promising bio-grouting technique for soil stabilization, remediation of concrete and subsurface rocks, wellbore sealing, among others. One of the most extensively utilized bacteria for MICP is Sporoscarcina pasteurii (S. pasteurii), which enables to catalyze the hydrolysis of urea to carbonate and ammonia via the production of urease enzyme, resulting in an increase in pH and precipitation of calcite if calcium is available. Understanding of the transport of S. pasteurii in porous sands is fundamental to delineate its fate and distribution, so as to provide clues to optimize the treatment strategy for soil improvement.
The study attempts to elucidate the transport and retention mechanisms of S. Pasteurii in saturated sands based on a series of column breakthrough experiments under different physical-chemical-biological conditions including ionic strengths (ISs), flow velocity, bacterial optical density, column length. A two-site kinetic model, defining (1) physicochemical attachment on grain surfaces, and (2) straining at the crevices and constrictions, is applied to fit the column breakthrough curves. The experimental and modelling results show that bacterial breakthrough declines from 88% to 5.4% with IS increasing from 0.5mM (tap water) to 1M (NaCl), resulting from that higher ionic strength tends to weaken the electrostatic repulsion between negatively-charged bacteria and sands, and hence to enhance both physicochemical attachment and straining (due to flocculation). Besides, lower flow velocity, lower bacterial density, and longer column correspond to a higher bacterial retention. Under physicochemical perturbations, the injection of 0.5M $CaCl_2$ with stronger IS stabilizes the pre-attached and pre-strained bacteria while the elution of deionized water with lower IS causes the bacterial release.
In addition, a radial flow cell (diameter: 1 m, thickness: 0.15 m) is constructed for MICP treatment in two types of sands, one well-graded and the other less well-graded. After 9 cycles of MICP treatment, the unconfined compressive strength of the treated sands (initially loose) is achieved up to several MPa. The permeability of the well-graded sands drops by one order of magnitude from 2.0×10-12 m2 to 2.5×10-13 m2, while the permeability of the less well-graded sands shows a minor drop from 1.3×10-11 m2 to 7.9×10-12 m2. The post-treated well-graded sands also show greater spatial heterogeneity in permeability, calcite distribution and strength due to the migration of fine particles and induced preferential flow paths. Our study shows the viability of MICP application in soil improvement as well as some opportunities and challenges for upscaling and optimizing MICP soil improvement in the field.

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References

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Participation

Unsure

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