Controlling the distribution of microbially induced calcite precipitation in the subsurface

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Microbially induced calcite precipitation (MICP) has gained interest as an environmentally friendly method for a number of subsurface applications, including consolidation of granular materials, modification of permeability, metal and radionuclide immobilization, self-healing of concrete, etc. MICP relies on microorganisms that when provided with appropriate nutrients create chemical conditions conducive to calcite precipitation. A major challenge is controlling and predicting spatial distribution of precipitates, whether the target be uniform or nonuniform (e.g., in specific strata or locations) deposition. The spatial distribution depends on calcite precipitation kinetics, the kinetics of the biological and chemical reactions that generate the required Ca^{2+} and carbonate, locations and phase association of the microbial catalyst, and timing of the arrival of amendments introduced into the medium; the latter depends on hydraulic boundary conditions and medium properties (porosity, permeability).

We present results from a field experiment where we sought to induce uniform precipitation relying only on indigenous microorganisms and calcium within an approximately 3 meter thick saturated zone between two wells located 4 meters apart. We employed a continuous recirculation design; water extracted from the downgradient well was amended with urea and molasses and re-injected into the upgradient well for 12 days and the aqueous chemistry and microbiology was monitored for 419 days. Measurements of substrates and products, and isotopic data for DIC all indicated desired reactions were stimulated within the zone and downstream, during active recirculation and afterward. The results could be reasonably simulated by postulating that the recirculation resulted in homogeneous aqueous geochemistry within the entire zone, that a metabolic lag time persisted during the recirculation period, and that native ureolytic microorganisms were all attached. While alternative scenarios cannot be ruled out, the data and model support that spatial distribution of urolytic calcite precipitation can be manipulated by engineering design, although still constrained by site hydrogeology.