

Microbially induced calcium carbonate precipitation: A bioremediation technology for heavy metal immobilization

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Microbially induced calcium carbonate precipitation (MICP), a bacteria-induced bio-mineralization process, has been investigated extensively in civil, environmental and infrastructure engineering applications. The urea hydrolysis by indigenous or exotic urease-producing bacteria is one of the most common pathways for bio-mediated calcium carbonate precipitation. The MICP process via ureolysis involves several stages: synthesis of enzyme through bacteria metabolic activities; catalysis of ureolytic reactions by enzyme and massive production of ammonia and dissolved inorganic carbon; alkalinity accumulation at the proximity of bacteria cells and formation of calcium carbonate precipitation on nucleation sites (i.e., bacteria cell surfaces) in the presence of available calcium source. Among these processes, production of ammonia and dissolved inorganic carbon can raise the pH of soil pore fluid. Precipitated calcium carbonate can provide extra specific surface area, which improves absorption capacity of soil. Calcium and carbonate may also entrap other metal ions in soil pore fluid to form co-precipitation. These features of MICP are in favor of heavy metal immobilization in contaminated soils. In this study, firstly, a series of rigid-wall column leaching test was conducted to investigate the immobilization effect of MICP treatment on several heavy metal species (Pb, Zn, Ni, and Cu). Base soil was composed of sand and kaolin clay at a ratio of 9:1 (w/w). Binary mixture was prepared in rigid-wall columns using the dry tamping method to maintain uniformity. After saturated by de-aired water, nitrate solution of heavy metals was injected into the column specimen at a rate of 1.0 PV/h (pore volume per hour) for a total volume of 1.5 PV. Soil samples were left alone for 24 hours, before bacteria (*Sporosarcina pasteurii*) solution and urea-CaCl₂ solution were injected in sequence to trigger calcium carbonate precipitation. In some cases, urea-CaCl₂ solution was injected several times to improve precipitation content. After final injection, MICP treated heavy metal contaminated soil samples were held for 20 hours, which allowed calcium carbonate precipitation to grow and form sufficient cementations in soil matrix. As a comparison, control samples without MICP treatment were prepared as well. Finally, the column leaching test was conducted by percolating distilled water downwards. Hydraulic conductivity of soil and pH, EC and heavy metal concentrations of the leachate were measured during the leaching procedure. Results have demonstrated that MICP contributes to better immobilization of most heavy metals investigated in this study. There were only marginal discrepancies in hydraulic conductivity between untreated and MICP treated samples.

In order to understand the interactions between the bacteria solution and heavy metals, a follow-up laboratory batch test was conducted. The interactions were examined under aqueous condition by mixing nitrate solution of heavy metals and the bacteria solution. It was found that the interactions between the bacteria solution and heavy metals were predominantly pH-dependent. In the cases of Zn, Pb and Cu, ionized heavy metals were directly precipitated when mixed with the bacteria solution.

In addition, the efficacy of MICP for heavy metal immobilization was further examined via chemical equilibrium simulation using MINTEQA2. It was found that the aqueous condition in favor of calcium carbonate precipitation also facilitate heavy metal immobilization, mainly through precipitation.

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