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Bimetallic Fe/Cu nanoparticles for groundwater remediation: optimized injection strategies via transport modelling in porous media

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ABSTRACT

A field-scale remediation of a contaminated aquifer by means of nanoscale zero valent iron (NZVI) requires an accurate assessment of the mobility of such particles in saturated porous media. Thanks to their reduced size, such particles can be effectively injected in the form of concentrated colloidal dispersions into the subsurface to target contaminated zones and sources. However, NZVI slurries faced critical problems for applications in porous media due to colloidal instability. NZVI aggregation is caused by strong particle-particle attraction, and results in short travel distances and pore plugging, especially when NZVI is injected at high concentrations [1]. More stable suspensions of NZVI can be obtained by adding polymeric surface modifiers or anionic surface chargers or directly modifying the particle surface during synthesis by addition of noble metals. Bimetallic NZVI showed much higher degradation rates towards all contaminants traditionally treated by millimetric iron [2-3].

Several studies investigated the effects of several factors (eg. particle stabilization methods, groundwater ionic strength, particle size and composition, etc.) on the transport and retention of NZVI in well-controlled lab-scale columns. Conversely, few studies have been devoted to understand the role of the injection strategy (flow rate, NZVI concentration, injection duration and alternation with flushing) on NZVI mobility. In this study, a quantitative analysis is presented on how the management of the injection of NZVI water-based slurries can optimize the mobility of the particles. In particular, the impact of injected NZVI concentration, flow rate, and number, duration, and alternation of injection and flushing periods is considered. NZVI transport simulations in 1D domains were performed using E-MNM1D [4] for bimetallic nano-Fe/Cu particles, whose transport was previously assessed by the authors in laboratory column tests [3]. Several injection scenarios were considered, including single-step injections (injection followed by flushing), and multi-steps injections (repetition of injection+flushing steps) with constant and variable particle concentration. The performance of each scenario was quantified in terms of travel distance, changes in porous medium porosity, permeability, and overpressure during injection. The results of this study indicate that, when injecting under conditions typical of a full-scale aquifer remediation, nanoparticle mobility and distribution are optimized and clogging is minimized by using high flow rates, low concentrations, and frequent injection steps without intermediate flushing [5].

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