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Transport in porous media of iron-based bioslurries for groundwater remediation

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Colloidal suspensions of engineered nanoparticles have been studied in recent years for waste water and in-situ groundwater remediation. Zero-valent iron particles represent a promising technology for groundwater remediation via abiotic reduction. However, due to strong magnetic particle-particle attraction (in the case of nano-sized particles) and to gravitational settling (in the case of nano-sized particles), iron colloids dispersed in pure water are not stable. Therefore, solutions of green biopolymers (e.g. starch, guar gum, xanthan gum), characterized by viscous - shear thinning - properties, have been recently studied as dispersants and stabilizers for iron slurries, thus enhancing stability against sedimentation and increasing particles mobility in saturated porous media (Tiraferri et al. 2008, Tiraferri and Sethi 2009). Therefore, contaminant degradation is first achieved via rapid chemical reduction (provided by the iron particles), and then by long-term biological processes, enhanced by the degradation of the biopolymers used to stabilize the slurry. In this work, co-funded by European Union project AQUAREHAB (FP7 - Grant Agreement Nr. 226565), a modelling approach is described to simulate the transport in porous media of nanoscale iron bioslurries.
Colloid transport in saturated porous media is controlled by particle-particle and particle-collector interactions. In case of highly concentrated suspensions of iron particles, the hydrodynamic parameters (porosity, hydraulic conductivity) and fluid properties (e.g. viscosity) cannot be considered independent on the concentration of deposed and suspended colloids (Mays and Hunt 2005, Tiraferri and Sethi 2009). None of the colloid transport models previously reported in the literature could simulate the non-Newtonian nature of the carrier fluid, nor the influence of the concentration of suspended colloids on the fluid properties. Consequently, a numerical model (E-MNM1D, Enhanced Micro-and Nanoparticle transport Model in porous media in 1D geometry) was developed to simulate the transport of the iron bioslurries. The complex, non-Newtonian rheological properties of the suspensions are accounted for through a variable apparent viscosity, function of polymer and suspended iron particle concentrations. The transport of iron particles is modelled using a dual-site approach accounting for straining and physico-chemical deposition/release phenomena (Tosco and Sethi 2010). The progressive clogging of the porous medium, due to deposition and filtration of a relevant mass of particles and aggregates, is modelled including changes in pore velocity, viscosity, density and porosity due to the progressive deposition of iron particles, and to highly viscosity of the carrier fluid. A general formulation for reversible deposition is also proposed, that includes all commonly applied dynamics (linear attachment, blocking, ripening). Clogging of the porous medium due to deposition of iron particles is modelled by tying porosity and permeability to deposited iron particles.
E-MNM1D, implemented in a Matlab environment with an Excel input/output interface, can be downloaded at www.polito.it\groundwater\software .
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