Modelling the transport of iron micro and nanoparticles in saturated porous media

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ABSTRACT

In the framework of groundwater remediation, the injection of nanoscale and microscale zerovalent iron particles (NZVI and MZVI, respectively) for the generation of reactive zones proved effective, and represents a promising remediation technology for the treatment of contamination sources and dissolved plumes [1]. To improve colloidal stability and mobility in the subsurface, the use of biopolymers is usually required [2]. Polymers are dosed in low concentrations to modify surface properties and increase particle-particle repulsion (mainly for NZVI) or in high concentration to form shear-thinning fluids preventing particle sedimentation and improve delivery (mainly for MZVI) [3].

Shear thinning fluids exhibit high viscosity at low flow rates (which improves colloidal stability in static conditions) and lower viscosity at high flow rates, corresponding to the injection in the subsurface, when low viscosity (and consequently low pressures) is required. In this work a modelling approach is described to simulate the transport in porous media of nanoscale iron slurries, implemented in MNMs (www.polito.it/groundwater/software). Colloid transport mechanisms are controlled by particle-particle and particle-collector interactions, typically modelled with kinetic terms of deposition onto the porous medium and corresponding release. Ionic strength, flow rate and fluid viscosity all play a major role in determine the interactions between particles and porous medium, and therefore deposition and release mechanisms and kinetics [4]. The key aspects included in MNMs are the influence of salt concentration on attachment and detachment kinetics (both under constant and transients in I.S), clogging phenomena (i.e. reduction of porosity and permeability due to particles deposition), and the rheological properties of the carrier fluid. Colloid transport is modelled with a dual-site (physico-chemical interactions plus straining) advection-dispersion-deposition equation. A general formulation for attachment/detachment dynamics is adopted. The influence of colloid transport on porosity, permeability, and fluid viscosity is explicitly embedded into the model through correlations from the literature, or derived on purpose. The software also implements a tool for the simulation of particle transport in radial geometry, for the estimate of the radius of influence of the slurry injection.

ACKNOWLEDGEMENTS

This work was co-funded by European Union project AQUAREHAB (FP7 - Grant Agreement Nr. 226565). The authors want to acknowledge Dr. Francesca Gastone for the laboratory tests and Carlo Bianco for the development of the user interface of MNMs.

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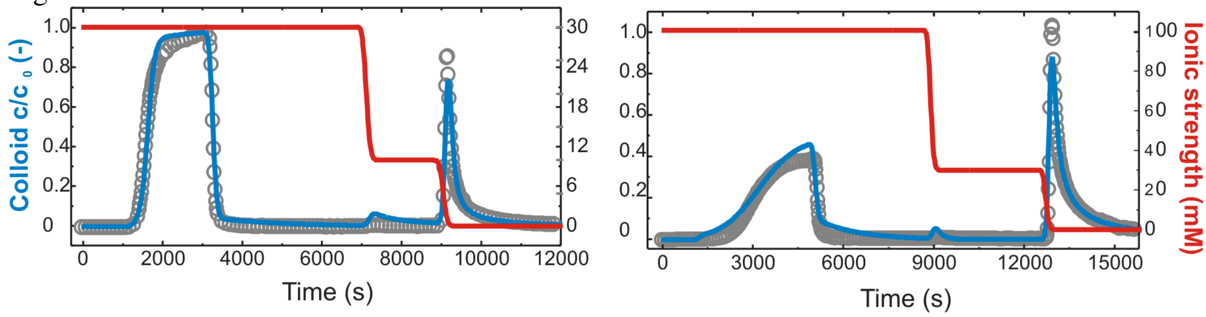
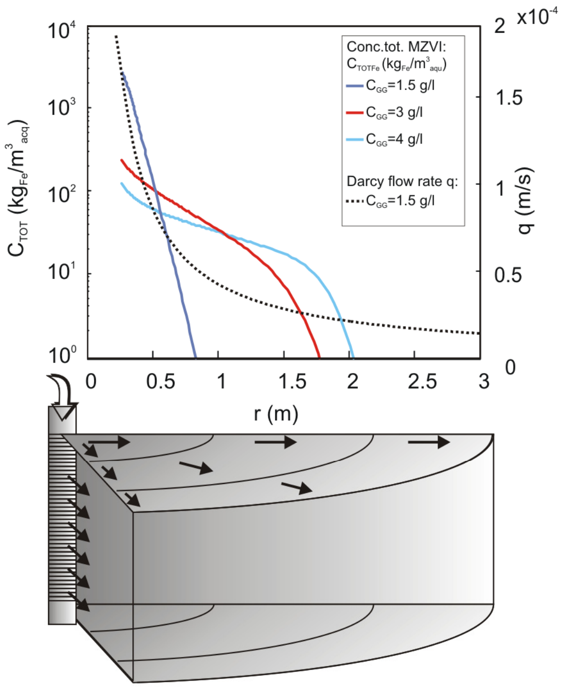
Figures:



Column transport tests of latex particles injected in 30 mM (left) and 100 mM NaCl (right) followed by flushing steps of transient ionic strength. The graphs report experimental data (grey circles) and modelled curves (blue for colloid, red for ionic strength).



Simulation of the injection of 5 m^3 of MZVI (20 g/l) dispersed in guar gum (1.5, 3, 4 g/l) at a discharge rate of 1 m^3/h: total iron concentration (dispersed + deposited) at the end of the simulation