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Simulation of the injection of colloidal suspensions for the remediation of contaminated aquifer systems

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Concentrated suspensions of microscale and nanoscale zerovalent iron particles (MZVI and NZVI) have been studied in recent years for the remediation of contaminated aquifers. The suspensions are injected into the subsurface to generate a reactive zone, and consequently the prediction of the particles distribution during the injection is a key aspect in the design of a field-scale injection.

Colloidal dispersions of MZVI and NZVI are not stable in pure water, and shear thinning, environmentally friendly fluids (guar gum and xanthan gum solutions) were found to be effective in improving colloidal stability, thus greatly improving handling and injectability $(1-3)$. Shear thinning fluids exhibit high viscosity in static conditions, improving the colloidal stability, and lower viscosity at high flow rates enabling the injection at limited pressures.

Shear thinning fluids exhibit high viscosity in static conditions, improving the colloidal stability, and lower viscosity at high flow rates enabling the injection at limited pressures. In this work, co-funded by European Union project AQUAREHAB (FP7 - Grant Agreement Nr. 226565), laboratory and pilot field tests for MZVI injection in saturated porous media are reported. MZVI was dispersed in guar gum solutions, and the transport behaviour under several polymer concentrations and injection rates was assessed in column tests (4). Based on the experimental results, a modelling approach is proposed to simulate the transport in porous media of nanoscale iron slurries, implemented in E-MNM1D (www.polito.it/groundwater/software). Colloid transport mechanisms are controlled by particle-collector and particle-particle interactions, usually modelled by a non equilibrium kinetic model accounting for deposition and release processes. The key aspects included in the E-MNM1D are clogging phenomena (i.e. reduction of porosity and permeability due to particles deposition), and the rheological properties of the carrier fluid (in this project, guar gum solution). The influence of colloid transport on porosity, permeability, and fluid viscosity is explicitly lumped into the model and the shear-thinning nature of the iron slurries is described by a modified Darcy law generalized for non Newtonian fluids.

Since during the injection in wells the velocity field is not constant over the distance, E-MNM1D was modified in order to account for variable colloidal transport coefficients on flow rate thus allowing the estimation of the radius of influence during a full scale intervention. The flow and transport of MZVI slurries is solved in a radial domain for the simulation of field-scale injection, incorporating the abovementioned relevant mechanisms. The governing equations and model implementation are presented and discussed, along with examples of injection simulations.

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