Shear thinning fluids to optimize the injection of engineered microparticles for groundwater remediation

Shear thinning fluids to optimize the injection of engineered microparticles for groundwater remediation

Poster Session

Description

Authors: Rajandrea Sethi; Tosco Tiziana; Gastone Francesca

Nanoscale and microscale zerovalent iron particles (NZVI and MZVI) are promising materials for the remediation of contaminated aquifers [1]. These particles are dispersed in water-based slurries and injected in the subsoil to generate a reactive zone. However, the successful injection of MZVI and NZVI may be significantly hindered by the reduced colloidal stability, and therefore mobility in the porous medium, due to the fast sedimentation (MZVI) and aggregation (NZVI) of the particles when dispersed in water [2-4]. To overcome this issue the use of stabilizing agents wax proposed: shear thinning solutions of green biopolymers have been recently studied as kinetic stabilizers and viscous carrier fluids for the delivery of MZVI and NZVI [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 [5]. In this work the use of guar gum is presented.

Polymeric solutions (1.5 to 7 g/l) were prepared following different procedures, and their efficacy in stabilizing highly concentrated dispersions of MZVI (20 g/l, average size 1.2 um) was evaluated. Ideally, the optimal guar gum suspension should (i) keep the MZVI suspended for a time sufficient for its injection; (ii) be easily degradable, to avoid possible negative effects on MZVI reactivity; (iii) do not clog the porous medium due to residual undissolved guar gum. With these targets in mind, a detailed rheological characterization of the guar gum, both in the bulk and when injected in a porous medium, was carried out. A modified Cross model, linking guar gum concentration and bulk shear viscosity, was derived based on bulk rheological measurements. Column filtration tests were then performed, and a modified Darcy law was derived to predict pressure gradients arising during guar gum injection. The kinetics of guar gum degradation was studied to investigate the correct enzymes dosage required to achieve a complete breakdown of the suspensions, and a modified Stokes law for the prediction of the sedimentation rate of the MZVI was proposed and validated.

All derived empirical relationships (namely, rheological model, modified Stokes law and Darcy law) were finally included in MNMs (www.polito.it/groundwater/software/MNMs.php), a software for particle transport simulation in 1D (column) and radial domain. MNMs can be used as a tool for a preliminary design of the field injection of MZVI/NZVI - guar gum mixtures, providing an estimate of particle transport and pressure build up associated to the injection at the pilot scale.

Funded by: EU FP7 Aquarehab Grant Agreement No. 226565

References:

1. Tosco, T., M. Petrangeli Papini, C. Cruz Viggi and R. Sethi (2014), Journal of Cleaner Production, 77, 10-21.

2. Tiraferri, A., K.L. Chen, R. Sethi and M. Elimelech (2008), Journal of Colloid and Interface Science, 324(1-2), 71-79.

3. Gastone, F., T. Tosco and R. Sethi (2014), Journal of Colloid and Interface Science, 421, 33-43.

4. Xue, D. and R. Sethi (2012), Journal of Nanoparticle Research, 14(11), Art. No.: 1239.

5. Gastone, F., T. Tosco and R. Sethi (2014), Journal of Contaminant Hydrology, 166, 23-33.