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Enhancement of stability of various nZVI suspensions used in groundwater remediation with environmentally friendly organic stabilizers

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The use of nanoscale zero-valent iron (nZVI) particles for in situ remediation of polluted soil and groundwater has been shown as one of the most promising techniques [1]. The success of this technology depends on the mobility, reactivity, and longevity of nZVI particles. The mobility of nZVI particles depends on the properties of the single particles, stability of the particle suspension, and the aquifer material [1,2]. In order to enhance the mobility of nZVI, the mobility-decisive properties of the nZVI particles in suspension such as concentration, size distribution, surface charge, and sedimentation rate have to be investigated and optimized. Previous studies showed that pristine nZVI particles aggregate rapidly in water, reducing the particles radius of influence after injection [3]. In order to prevent aggregation and sedimentation of the nZVI particles, and consequently improve the stability of nZVI suspension and therefore the mobility of the nZVI particles, surface stabilizers can be used to provide electrostatic repulsion and steric or electrosteric stabilization [3,4].
The objective of this lab-scale study is to investigate the potential for enhancing the stability of different nZVI suspensions by means of environmentally friendly organic stabilizers, including carboxymethyl cellulose, pectin, alginate, xanthan, and guar gum. The different nZVI particles used included pristine and polyacrylic acid-coated nZVI particles provided in suspension (Nanofer 25 and Nanofer 25S, respectively, NANOIRON s.r.o., Czech Republic), air-stable nZVI particles (Nanofer Star, (NANOIRON s.r.o., Czech Republic), and milled iron flakes (UVR-FIA, Germany). In order to study the enhancement of nZVI stability (1 g L-1 total iron) different concentrations of organic stabilizers (1–20 wt.%) were applied in these nZVI suspensions.
Each nZVI suspension was freshly prepared and treated for 10 minutes with Ultra-Turrax (15 000 rpm) and 10 minutes ultrasonic bath prior to characterization. Suspensions were characterized in terms of particle size distribution (Eyetech, Ambivalue; Malvern Mastersizer 2000), surface charge (Malvern ZetaSizer Nano), pH, EC, zero-valent iron content (H2 production after acid digestion), total iron content (ICP-OES), and sedimentation rate (TurbiScan LAB EXPERT).
The results of the first set of experiments carried out with a pristine suspension of milled iron flakes (1 g L-1 total iron) show that the sedimentation rate of the suspension decreased by a factor two when stabilized by a 20 wt.% solution of carboxymethyl cellulose. This indicates that carboxymethyl cellulose was able to increase the stability of the suspension of milled iron flakes. Moreover, the surface charge of milled iron particles became more negatively charged once carboxymethyl cellulose was applied as a stabilizer, confirming an increased potential for milled iron flakes repulsion in the presence of carboxymethyl cellulose. Nevertheless, the size of these particles in the presence of carboxymethyl cellulose did not change for more than 5% compared to the particle size of pristine suspension of milled iron flakes.
On the basis of the preliminary results from the sedimentation tests column reactors will be designed in order to compare the transport distances of milled iron flakes and other selected nZVI particles.

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[1] O'Carroll et al. (2013): Advances in Water Resources 51(0): 104-122. [2] Laumann et al. (2013): Environmental Pollutant 179: 53-60. [3] Phenrat et al. (2007): ES&T 41(1): 284-290. [4] Phenrat et al. (2008): Journal of Nanoparticle Research 10(5): 795-814.