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Transport of zero-valent iron nanoparticles in carbonate-rich porous aquifers

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Use of nanoscale zero-valent iron (nZVI) for in situ dechlorination of chlorinated solvents in groundwater is a promising remediation technology, due to a high dechlorination efficiency of nZVI and possible applications in e.g., great depth or under above-ground infrastructure. The success of the in situ nZVI dechlorination strongly depends on the particle delivery to the contaminants. Previous studies reported a limited transport of nZVI through porous media (cm- to dm-range) and this has been recognized as one of the major obstacles in a widespread utilization of this technology (TRATNYEK & JOHNSON, 2006). Factors that limit the transport are particle aggregation and deposition onto the aquifer solids. Both depend on particle properties (e.g., size, shape, iron content, surface coating, surface charge), on concentrations of suspensions, and on site-specific parameters, such as the groundwater chemistry and the properties and inhomogeneity of the aquifer material.

Adsorbed anionic polyelectrolyte coatings provide electrostatic double layer repulsions between negatively charged nZVI particles (SALEH ET AL., 2007), hindering their aggregation and also deposition on the negatively charged quartz surfaces (usually prevailing in aquifers). However, it is shown that the presence of surface charge heterogeneities in the aquifer effects the particle transport (JOHNSON ET AL., 1996). Carbonates, iron oxides, and the edges of clay minerals, for instance, carry a positive surface charge at neutral pH (often encountered in groundwater). This leads to a favorable deposition of negatively charged nZVI particles onto carbonates, metal oxide impurities or clay edges, and finally to a decreased particle transport.

Considering the high proportion of carbonates commonly encountered in Alpine porous aquifers, in this study we aimed to evaluate the transport of commercially available polyelectrolyte coated nZVI (polyacrylic acid coated-nZVI, NANOIRON s.r.o., CZ) in both quartz and carbonate-rich porous media and to quantify alteration in travel distances with the increasing proportion of carbonate sands.

Transport studies using Nanofer 25S are carried out in 1 D columns filled with different proportions of quartz and carbonate sands at a pH typically encountered in groundwater.

Column experiments demonstrated that the travel distance of coated-nZVI systematically decreases with increasing portion of carbonate sand. The transportability of Nanofer 25S was reduced by ∼45% in pure carbonate sand, compared to that in pure quartz sand. These results demonstrated different attachment affinities of coated-nZVI for the investigated solids. Current experiments are carried out in order to provide a mechanistic understanding of the observed nanoparticle-solid matrix interactions. Furthermore, the effects of varying groundwater chemistry, size and shape of the packing material, as well as the presence of metal oxides and natural organic matter on the nZVI transport will be investigated.

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Literature

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