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Transport of Reactive Carbo-Iron Composite Particles for in situ Groundwater Remediation Investigated at Laboratory and Field Scale

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Abstract : The in-situ dechlorination of contamination by chlorinated solvents in groundwater via zero-valent iron (nZVI) is potentially an efficient and prompt remediation method. A key requirement is that nZVI has to be introduced in the subsurface in a way that substantial quantities of the contaminants are actually brought into direct contact with the nZVI in the aquifer. Thus it could be a more flexible and precise alternative to permeable reactive barrier techniques using granular iron. However, nZVI are often limited by fast agglomeration and sedimentation in colloidal suspensions, even more so in the aquifer sediments, which is a handicap for the application to treat source zones or contaminant plumes. Colloid-supported nZVI show promising characteristics to overcome these limitations and Carbo-Iron Colloids is a newly developed composite material aiming for that. The nZVI is built onto finely ground activated carbon of about a micrometer diameter acting as a carrier for it. The Carbo-Iron Colloids are often suspended with a polyanionic stabilizer, and carboxymethyl cellulose is one with good properties for that. We have investigated the transport behavior of Carbo-Iron Colloids (CIC) on different scales and for different conditions to assess its mobility in aquifer sediments as a key property for making its application feasible. The transport properties were tested in one-dimensional laboratory columns, a two-dimensional model aquifer and also an injection experiment in the field. Those experiments were accompanied by non-invasive tomographic investigations of the transport and filtration processes of CIC suspensions. The laboratory experiments showed that a larger part of the CIC can travel at least scales of meters for favorable but realistic conditions. Partly this is even similar to a dissolved tracer. For less favorable conditions this can be much smaller and in all cases a particular fraction of the CIC injected is retained mainly shortly after entering the porous medium. As field experiment a horizontal flow field was established, between two wells with a distance of 5 meters, in a confined, shallow aquifer at a contaminated site in North German lowlands. First a tracer test was performed and a basic model was set up to define the design of the CIC injection experiment. Then CIC suspension was introduced into the aquifer at the injection well while the second well was pumped and samples taken there to observe the breakthrough of CIC. This was based on direct visual inspection and total particle and iron concentrations of water samples analyzed in the laboratory later. It could be concluded that at least 12% of the CIC amount injected reached the extraction well in due course, some of it traveling distances larger than 10 meters in the non-uniform dipole flow field. This demonstrated that these CIC particles have a substantial mobility for reaching larger volumes of a contaminated aquifer and for interacting there by their reactivity with dissolved contaminants in the pore space. Therefore they seem suited well for groundwater remediation by in-situ formation of reactive barriers for chlorinated solvent plumes or even source removal.

Keywords : carbo-iron colloids, chlorinated solvents, in-situ remediation, particle transport, plume treatment
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