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Nano iron particles transport in fractured rocks: laboratory and field scale

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Our study deals with the transport potential of nano iron particles (NIPs) in fractured media. Two different systemswere used to investigate transport on two scales: (1)a laboratory flow system of a naturally discrete fractured chalk core, 0.43 and 0.18 m in length and diamater, respectively; and (2) a field system of hydraulically connected boreholes located 47 m apart which penetrate a fractured chalk aquifer.
We started by testing the transport potential of various NIPs under different conditions. Particle stability experiments were conducted using various NIPs and different stabilizersat two ionic strengths. Overall, four different NIPs and three stabilizers were tested. Particles and solution properties (stability, aggregate/particle size, viscosity and density) were tested in batch experiments, and transport experiments (breakthrough curves (BTCs) and recovery) were conduted in the fractured chalk core. We have learned that the key parameters controlling particle transport are the particle/aggregate size and stability, which govern NIP settling rates and ultimately their migration distance. The governing mechanism controlling NIP transport was found to be sedimentation, and to a much lesser extent, processes such as diffusion, straining or interception. On the basis of these experiments, Carbo-Iron® particles (∼800 nm activated carbon particles doped with nano zero valent iron particles) and Carboxymethyl cellulose (CMC) stabilizer were selected for the field test injection.
In the field, Carbo-Iron particles were initially injected into the fractured aquifer using an excess of stabilizer in order to ensure maximum recovery. This resulted in high particle recovery and fast arrival time, similar to the ideal tracer (iodide). The high recovery of the stable particle solution emphasized the importance of particle stability for transport in fractures. To test mobility manipulation potential of the particles and simulate more realistic scenarios, a second field experiment was conducted where the CMC – Carbo Iron ratio was reduced from 0.8:1 to 0.05:1. As expected, the lower stabilizer ratio resulted in lower recovery of the particles, demonstrating that particle mobility can be manipulated by changing stabilizer concentration. Additionally, a sudden increase in the hydraulic gradient between the injection and pumping well resulted in the release and remobilization of Carbo-iron particles which had settled within the fractures, indicating thatparticle settling is reversible within the aquifer.