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Delineation of Groundwater Flow Pathway in Fractured Bedrock Using Nano-Iron Tracer Test in the Sealed Well

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Deterministic delineation of the preferential flow paths and their hydraulic properties are desirable for developing hydrogeological conceptual models in bedrock aquifers. In this study, we proposed using nanoscale zero-valent iron (nZVI) as a tracer to characterize the fractured connectivity and hydraulic properties. Since nZVI particles are magnetic, we designed a magnet array to attract the arriving nZVI particles in the observation well for identifying the location of incoming tracer. This novel approach was examined at two experiment wells with well hydraulic connectivity in a hydrogeological research station in the fractured aquifer. Heat-pulse flowmeter test was used to detect the vertical distribution of permeable zones in the borehole, providing the design basis of tracer test. Then, the less permeable zones in the injection well were sealed by casing to prevent the injected nZVI particles from being stagnated at the bottom hole. Afterwards, hydraulic test was implemented to examine the hydraulic connectivity between two wells. When nZVI slurry was released in the injection well, they could migrate through connected permeable fractures to the observation well. A breakthrough curve was obtained by the fluid conductivity sensor in the observation well, indicating the arrival of nZVI slurry. The iron nanoparticles that were attracted to the magnets in the observation well provide the quantitative information to locate the position of tracer inlet, which corroborates well with the depth of a permeable zone delineated by the flowmeter. Finally, the numerical method was utilized to simulate the process of tracer migration. This article demonstrates that nano-iron tracer test can be a promising approach for characterizing connectivity patterns and transmissivities of the flow paths in the fractured rock.