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Applied Cross-Hole Nano-Iron Tracer Tests to Delineate the Preferential Flow Path

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Recent advances in borehole geophysical techniques have improved characterization of cross-hole fracture flow. The direct detection of preferential flow paths in fractured rock, however, remains to be resolved. A novel approach using nanoscale zero-valent iron (nZVI) particles as tracers was developed for detecting fracture flow paths directly. As nZVI particles are magnetic, they can be attracted to magnets; hence, a magnet array was designed for locating the position of incoming tracers. When nZVI particles are released in an injection well, they can migrate through the connecting permeable fracture and be attracted to a magnet array when arriving in an observation well. Such an attraction of incoming iron nanoparticles by the magnet can provide quantitative information for locating the position of the tracer inlet.

Two nZVI tracer tests were implemented in fractured rock at a hydrogeological research station in central Taiwan. The first tracer test was conducted in two open boreholes; the second test was carried out between an open hole and a screened well. Before both nZVI tracer tests, a series of field experiments were conducted in these experiment wells. A heat-pulse flowmeter can be used to detect changes in flow velocity for delineating permeable fracture zones in the borehole and providing the design basis for the tracer test. Two nZVI tracer tests with the same injection method were then conducted in these wells to compare test results. 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.