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Experimental studies of nonlinear flow and solute transport dynamics at different scales in a fractured formation

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The knowledge of flow and transport dynamics in fractured rock aquifers is essential for groundwater resources assessment and management and also to protect groundwater against contamination. Existing theory of fluid flow and solute transport through porous media is of limited usefulness when applied to fractured rocks.
Critical emerging issues for fractured aquifers are the validity of the Darcian-type “local cubic law” which assumes a linear relationship between flow rate and pressure gradient to accurately describe flow patterns and of the classical advection-dispersion equation to describe the propagation of solute.
Many field and laboratory tracer tests have been carried out to understand how solute disperses in fractured rocks, and their breakthrough curves have shown faster-than-Fickian growth rates, skewness and a long tailing of the concentration at late times.
Nevertheless, most studies of transport through discrete fractures are still based on simpler flow models which has limited the interpretation of solute breakthrough curves.
Experimental data obtained under controlled conditions such as in a laboratory allow to increase the understanding of the fundamental physics of fluid flow and solute transport in fractures.
In this study the presence of non linear flow and non-Fickian transport has been analyzed at different scales in a limestone formation, from bench scale laboratory tests to field tracer tests.
Hydraulic and tracer tests on artificially created fractured rock samples have shown evidence of non linearity in flow and tailing in breakthrough curves. These results are coherent with experimental data coming from field tracer tests that show presence of nonlinear laminar/non-laminar flow regime and concentration profiles that cannot be described by typical advection-dispersion breakthrough curves.
The presence of roughness, obstructions or sharp changes in fracture profile might lead to differential advective processes as well as immobile domains and multi-rate exchange processes that might be responsible for a non-Fickian behavior in breakthrough curves.
Therefore in the presence of a fractured aquifer flow analysis predictions based upon a linear relationship such as Darcy’s law can lead to inaccuracies up to significant errors in problems such as contaminant transport.