DISSOLVED GAS, HEAT AND COLD WATER AS INNOVATIVE SMART TRACERS FOR TRANSPORT HETEROGENEITY CHARACTERISATION IN FRACTURED MEDIA

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In fractured rocks, a realistic assessment of the actual heterogeneity may be crucial for robust decisions dealing with solute and heat transport. Heterogeneity may actually induce fast preferential transfers and very long recovery periods of contaminants. Solute tracer test data results frequently in difficulties during the model calibration, especially for the late time tailing. Often, artificially high dispersive coefficients are then used for fitting the measured breakthrough curve with oversimplified conceptual assumptions of medium homogeneity, which can lead to biased decisions.

To assess the actual heterogeneity more realistically, smart tracers like dissolved gases and heat/cold water offer broader diffusion variations, without complex chemical reactions. In this study, smart tracers are used in radial convergent flow fields, between two wells located in a double porosity chalk aquifer in Southwest Belgium (1a, 1b) and in a weathered granite medium in South India (2). A sub-horizontal main fracture is isolated with an inflatable double packer system in the injection well. The pumping well is in the chalk in 7.55 m and in the granite in 5.50 m distance. Tests to be discussed are:

(1a) Dissolved gases (e.g. Helium) jointly injected with uranine during a 10-minutes pulse injection.

(1b) Continuous heat (ΔT = +38 °C) injection for 70 hours, complemented by two 10-minutes uranine pulse injections in the same well. Natural groundwater temperature is 12 °C.

(2) Successive 1 hour-injections of hot water (ΔT = +20 °C) and cold water (ΔT = -20 °C) in a granite fracture. Natural groundwater temperature is 30°C.

(1a) Injecting tracers with different diffusion behaviors leads to various tracer arrival times and a clearer image of the respective effects of advection, matrix diffusion and multiple flow-paths. Quantifying the tailing slope in a log-log normalized visualization shows, for example, that Helium, which is one order of magnitude more diffusive than uranine, is significantly more exchanged with the matrix. (1b) Heat diffusion results show also a first detectable temperature change after 12.5 hours compared to an uranine arrival after 10 minutes, at 7.55 m distance. Remarkable, when the heat injection is stopped, a temperature anomaly decreases from 0.40 to 0.33 °C is observed, followed by a slow temperature rebound till 0.44 °C, indicating a matrix effect. (2) Injecting in fractured granite, the temperature peak in the 5.50 m distant observation well is reached after around 45 minutes. Heat transfer seems slightly faster than cold transfer. In both cases, a temperature difference of 3 °C is observed at the peak arrival time.

The presented convergent tracer tests highlight the added value of using smart tracers, considering the detailed investigation of the geological medium heterogeneity. It improves significantly the prior information on the considered test areas and is a very useful requirement for more realistic transport modelling. If Monte Carlo approaches are considered in conjunction with direct predictive approaches (e.g. Bayesian Evidential Learning), more robust results can be deduced (i.e. based on statistical relationships in the data obtained by smart tracer, instead of a unique parameterization). Consequently, better decisions are expected for contaminated flow and transport issues and possible remediation optimization.