Geophysical Research Abstracts
Vol. 17, EGU2015-9573, 2015
EGU General Assembly 2015

The single well "push-pull" tracer method: A systematic approach for setup optimization

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In deeper aquifers, only a limited number of boreholes or groundwater monitoring wells is available for aquifer tests. The limited access and the low groundwater flow velocity makes it difficult to conduct classical tracer tests for the hydrogeological characterization of deep aquifers. The single-well "push-pull" tracer test ("PP Test") may be a suitable method to investigate the hydrogeological properties and the flow behavior in single-well settings or deeper aquifers.

During a PP Test, a test solution that contains a known amount of solutes and a conservative tracer is injected into the aquifer ("push") and extracted afterwards ("pull"). Optionally, the test solution is flushed out of the well and the casing with untreated test solution, a so called "chaser" before being extracted. Between the injection and the extraction phase a drifting or reaction time may be included. The breakthrough of the tracer and the solute compounds during the extraction phase is measured and used for analyses and interpretation of aquifer characteristics.

Several PP Tests were performed in a sedimentary coastal basin in northern Hokkaido (Japan). The objective was to study the influence of the test design on the results and to enhance the setup of the single well "push-pull" tracer method by a systematic approach.

During the campaign, six different PP Tests were performed, while only single aspects of the setup were varied from test to test. The tests differed in injection and extraction rate (5 L/min and 10 L/min), in the salinity of the injected test solution (brackish water and deionized water) and in the optional use of a chaser solution. The general shapes of the breakthrough curves are similar and a good applicability of this method is assumed for the test side. However, the Uranine mass balances of the different tests show a wide range of recoveries between 65 % and 126 %. The maximal normalized concentrations are in a range between c/c0 = 0.58 and c/c0 = 1.22. Even though the pumping rate determines indirectly the reaction time between groundwater and test solution, there was no big influence notable with the different pumping rates applied in our tests. On the other hand, ion analyses showed that the chemical composition of the injected test solution is a highly sensitive parameter in the test design of a PP Test.