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Tracer tests in vertical groundwater circulation flow fields

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Robust vertical groundwater circulation flow fields could be established by groundwater circulation wells (GCW). Two separated filter screen sections are located above each other within one borehole. At one section groundwater is extracted and at the other infiltrated. This technology provides an efficient flooding of the aquifer for remediation purposes. Additionally, controlled injection of substances is possible, for instance co-solvents for pollution source removal or nutrients for enhanced biodegradation.

This technology can be used for groundwater exploration as well by conducting tracer tests. Injection of a conservative tracer in the infiltrated groundwater enables the determination of the hydraulic aquifer properties, such as anisotropy. By partial injection into the infiltration using a segmented inlet section spatial variability of those properties could be explored. Reactive tracers could be applied, e.g. as partitioning tracers for the investigation of the spatial extension of a contamination source.

Such tracer tests with partial injection were conducted in two- and three-dimensional lab experiments at different scales. Breakthrough curves of a conservative tracer were obtained at several sampling points within the circulation flow field and the outlet as well. The outlet was segmented like the inlet to obtain a spatial resolution of the tracer transport.

The analysis of such tracer tests in a heterogeneous aquifer is a challenge because simple one-dimensional analytical solutions are not applicable. The large non-uniformity of the flow field generates large dispersion effects at the outlet break through curves. Quantitative analyses could be done by inverse numerical modelling. This requires a

large effort due to the importance of local scale heterogeneities in the vicinity of the filter screen sections especially in the case of unknown aquifer structure.

The obtained experimental results were analysed by numerical modelling and analytical solutions applying the stream tube approaches. The stream tube approach was extended by the introduction of the apparent dispersivity concept to consider the strongly non-uniform flow. The comparison of the several analysis methods demonstrated the limits of the applicability.