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Is macrodispersivity a meaningful parameter? – Applicability of simple ADE-equation for modeling of a tracer test

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In the last decades, numerical modeling has been developed as the common method to investigate solute transport in groundwater. Thereby in science, various numerical procedures have been applied for understanding complex processes of transport in highly heterogeneous aquifers. Beside this, numerical modeling of transport is also standard practice in engineering and consulting. The numerical approaches differ due to factors such as scope of modeling, knowledge about site characterization and time and manpower constraints. In general, there is a lack of knowledge about the hydraulic properties of a site like information of lithology and deterministic subunits. Therefore, assumption have to be made and standard Advection-Dispersion-Equation (ADE) is used involving macrodispersion coefficients.
In this study we analyze a tracer test in the Lauswiesen aquifer, Baden-Wuerttemberg, Germany, described in the literature by Ptak et al. (2004) and Riva et al. (2008) and use a straightforward numerical model to reproduce the integral and depth-dependent transport behavior. Depth-dependent tracer test data show a clear depth dependency including two different breakthrough behaviors. Previous model approaches for evaluation of the mentioned tracer test by Riva et al. (2008) included a large set of Monte-Carlo simulations by describing the aquifer heterogeneity by a double stochastic process. Information about the geostatistical parameters could be gained mainly by a large number of sieve analyses. Finally, stochastic modeling of Riva et al. (2008) created a large amount of breakthrough curves due to high uncertainty of the distribution of hydraulic conductivity. However, stochastic modeling and a precise reproduction of the variability of hydraulic properties in space help to better understand the transport processes driven by heterogeneity and to provide assessment of uncertainty at a site.
In our straightforward modeling we include only two deterministic subunits, more precisely, two layers of different hydraulic conductivity, and macrodispersivity. These layered structure was identified by Direct-Push Injection Logging (DPIL). DPIL is a rapid and robust technique to analyze vertical variability of hydraulic properties and, combined with Direct-Push slug tests, allows quantifying hydraulic conductivity of layered structures. Based on this information the deterministic model fits to the measured tracer test data better than most of the stochastically generated breakthrough curves. This is especially apparent for the depth-averaged transport but also for the obviously layer-based breakthrough behavior. The comparison of both the straightforward and the stochastic model shows that macrodispersion coefficients can be a meaningful parameter in describing transport in heterogeneous aquifers. However, representation of aquifer heterogeneity clearly depends on the scope of work and the data available. Beside this, DPIL showed to be a valuable and cost-efficient method in gaining the important deterministic structures at the site.

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Ptak, T., M. Piepenbrink, E. Martac. 2004. Tracer tests for the investigation of heterogeneous porous media and stochastic modelling of flow and transport – a review of some recent developments. J. Hydrol. 294, no. 1-3: 122-163.