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Simplified modeling of the dipole tracer test for heterogeneous porous media

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This work focuses on the derivation of a new analytical solution for the interpretation of the dipole tracer test. The purpose is the characterization of heterogeneous porous media in terms of hydraulic conductivity through the tracer breakthrough curve and the log-conductivity variance. The proposed method is tested against three illustrative example. The model considers a perfectly stratified formation, of variable hydraulic conductivity, in which the breakthrough curve is measured at the pumping well. The analysis is carried out considering the travel time of a generic solute particle that moves from the injection to the pumping well. We show solutions for resident and flux proportional injection modes and for instantaneous pulse and continuous solute injections. Detailed investigations on the impact of heterogeneity, the tracer input conditions and ergodicity conditions are performed. In particular, heterogeneity influences the spreading of the solute particles, leading to a further increase of the natural spreading induced by the test. A relatively large number of layers is needed to reach the ergodic condition if the heterogeneity is high. Consequently, the proposed method might underestimate the log-conductivity variance if the dipole test takes place in highly heterogeneous fields. Summarizing, the method takes into account the spatially variable hydraulic conductivity in a simple and effective manner, being a promising tool for inferring the log-conductivity variance of natural aquifers after a standard dipole tracer test.