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Temporal behavior of a solute cloud in a fractal heterogeneous porous medium at different scales

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ABSTRACT

Water pollution is still a very real problem and the need for efficient models for flow and solute transport in heterogeneous porous or fractured media is evident. In our study we focus on solute transport in heterogeneous fractured media.

In heterogeneous fractured media the shape of the pores and fractures in the subsurface might be modeled as a fractal network or a heterogeneous structure with infinite correlation length. To derive explicit results for larger scale or effective transport parameters in such structures is the aim of this work.

To describe flow and transport we investigate the temporal behavior of transport coefficients of solute movement through a spatially heterogeneous medium. It is necessary to distinguish between two fundamentally different quantities characterizing the solute dispersion: The *effective* dispersion coefficient $D^{eff}(t)$ represents the physical (observable) dispersion in one given realization of the medium. It is conceptually different from the mathematically simpler *ensemble* dispersion coefficient $D^{ens}(t)$ which characterizes the (abstract) dispersion with respect to the set of all possible realizations of the medium. In the framework of a stochastic approach DENTZ ET AL. (2000 I[2] & II[3]) derive explicit expressions for the temporal behavior of the center-of-mass velocity and the dispersion of the concentration distribution, using a second order perturbation expansion. In their model the authors assume a finite correlation length of the heterogeneities and use a GAUSSIAN correlation function.

In a first step, we model the fractured medium as a heterogeneous porous medium with infinite correlation length and neglect single fractures. ZHAN & WHEATCRAFT (1996[4]) analyze the macrodispersivity tensor in fractal porous media using a non-integer exponent which consists of the HURST coefficient and the fractal dimension D. To avoid this non-integer exponent for numerical reasons we extend the study of DENTZ ET AL. (2000 I[2] & II[3]) and derive explicit expressions for the center-of-mass velocity and the longitudinal dispersion coefficient for isotropic and anisotropic media as well as for point-like (where the extent of the source distribution is small compared to the correlation lengths of the heterogeneities) and spatially extended injections. Our results clearly show that the difference between D^{eff} and D^{ens} persists for all times. In other words, ensemble mixing and effective mixing coefficients do not approach the same asymptotic limit. The center-of-mass fluctuations between different flow paths for a plume traveling through the medium never become irrelevant and ergodicity breaks down in such media.

Our ongoing work concerns the investigation of the transversal dispersion coefficient and the extension of the upscaling method *coarse graining*[1] to heterogeneous fractal porous media with embedded single fractures.

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