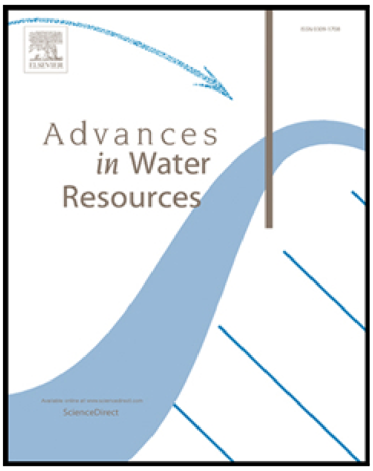

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Determination of the diffusivity, dispersion, skewness and kurtosis in heterogeneous porous flow. Part I: Analytical solutions with the Extended Method of Moments.

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Abstract

The extended method of moments (EMM) is elaborated in recursive algorithmic form for the prediction of the effective diffusivity, the Taylor dispersion dyadic and the associated longitudinal high-order coefficients in mean-concentration profiles and residence-time distributions. The method applies in any streamwise-periodic stationary d-dimensional velocity field resolved in the piecewise continuous heterogeneous porosity field. It is demonstrated that EMM reduces to the method of moments and the volume-averaging formulation in microscopic velocity field and homogeneous soil, respectively. The EMM simultaneously constructs two systems of moments, the spatial and the temporal, without resorting to solving of the high-order upscaled PDE. At the same time, the EMM is supported with the reconstruction of distribution from its moments, allowing to visualize the deviation from the classical ADE solution. The EMM can be handled by any linear advection-diffusion solver with explicit mass-source and diffusive-flux jump condition on the solid boundary and permeable interface. The prediction of the first four moments is decisive in the optimization of the dispersion, asymmetry, peakedness and heavy-tails of the solute distributions, through an adequate design of the composite materials, wetlands, chemical devices or oil recovery. The symbolic solutions for dispersion, skewness and kurtosis are constructed in basic configurations: diffusion process and Darcy flow through two porous blocks in "series", straight and radial Poiseuille flow, porous flow governed by the Stokes-Brinkman-Darcy channel equation and a fracture surrounded by penetrable diffusive matrix or embedded in porous flow. We examine the moments dependency upon porosity contrast, aspect ratio, Péclet and Darcy numbers, but also for their response on the effective Brinkman viscosity

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