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A generalized fractal model of flow and transport in randomly heterogeneous porous media

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A generalized fractal model of flow and transport in randomly heterogeneous porous media was proposed in this study. The random field is described by the fractional Levy motion (fLm), which is a generalized version of the traditional fractional Brownian motion (fBm) and is superior to describe a highly heterogeneous field. Understanding flow and transport in such a field expands the applicability of the stochastic theory. Truncated power variogram of the fLm was first derived using the weighted superposition of mutually uncorrelated exponential variograms. Then, first-order perturbation analyses of flow and transport in the fLm field were performed. Dimensionless velocity covariance, displacement covariance and macrodispersion coefficient in the fLm field were compared to those of the stationary exponential and fractal fBm fields at a fixed Hurst coefficient. Both of the dimensionless longitudinal and transverse velocity covariances in fLm fields show the fastest decreasing rate at short separation distance and diminish to zero slowest at largest separation distance. The dimensionless longitudinal displacement covariance has a constant increasing rate at large separation distance for all three models while the logarithmic increasing rate of the dimensionless transverse displacement covariance at large separation distance is fastest for the fLm model and is slowest for the exponential model. The asymptotic transport in the fLm field is reached slower than in the fBm and in the stationary fields. Therefore, solute transport in the fLm field results in slower growth of the plume size but with higher concentration than in the fBm and the exponential fields. Since the proposed generalized fractal model has wider applications than the stationary and fBm models, it is versatile to simulate flow and transport in different scenarios toward more accurate

modeling results.