Residence Time Distribution Derived from Independent Gamma Distributions of Tracer Travel Distance and Linear Velocity

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Abstract

The advection dispersion equation (ADE) is widely used as a predictor of residence time distributions (RTDs) for tracer breakthrough curves for karst systems. Solutions of the ADE for tracer breakthrough studies with near plug flow behavior are characteristically Gaussian in appearance. However, very few, if any, quantitative tracer studies result in tracer concentrations that are normally distributed about the mean residence time. While the symmetry of Gaussian breakthrough curves often correctly predicts finite tracer concentrations at zero time, it generally does not accurately predict actual tracer breakthrough curves, which invariably are characterized by relatively long tails. This suggests that a different conceptual approach may be appropriate for describing these systems in easily visualized terms. The objective of this project was to develop a more descriptive approach of tracer break-through data based on the gamma probability density function. The tracer travel distance and tracer linear velocity were assumed to be randomly distributed variables with gamma distributions. The RTD for tracer breakthrough curves was derived from the individual distributions of tracer travel distance and linear velocity. This approach was compared and contrasted with the traditional approach based on the ADE for modeling tracer break-through data at a karst site, as well as, modeling the rate of biodegradation of toluene in laboratory karst aquifers.