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Multispecies transport analytical model with scale-dependent dispersion subjected to rate-limited sorption

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Multispecies transport models are effective tools for predicting the transport and fate of the decaying or degradable contaminants such as dissolved chlorinated solvents, pesticides, radionuclides, and nitrogen chains in the subsurface environment because they should have the ability to account for mass contribution to daughter species resulting from parent species. For simplification of the solution derivation, currently existing multispecies transport analytical models are derived assuming instantaneous equilibrium sorption and constant dispersion processes. However, experimental and theoretical research results have indicated that both the rate-limited sorption and scale-dependent dispersion have profound effects on the transport during the movement of contaminants in the subsurface. Although models for instantaneous sorption or scale-dependent dispersion have individually been derived, analytical models that integrate both processes into the governing equation system have not been reported in the literature yet. This study is thus designed to develop a multispecies transport analytical model that the first-order reversible kinetic sorption reaction equation system is incorporated into two sets of simultaneous advection-dispersion equations with scale-dependent dispersion coefficients coupled by sequential first-order decay reactions. The analytical solutions to the complicated governing equation system are obtained by using the Laplace transform and the generalized integral transform technique. The correctness of the derived analytical model and its corresponding computer code are proved by excellent agreements between the computational results obtained from the derived model and those obtained with a numerical model where the same governing equations are solved using the advanced Laplace transform finite difference method. The new model is compared to the previous model to demonstrate the synergy of rate-limited sorption and scale-dependent dispersion on multispecies transport.