A two-dimensional semi-analytical model for multispecies transport influenced by rate-limited sorption with decay in the solid phase

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Abstract

Aside from advection and dispersion, which are recognized as fundamental processes in contaminant transport models, sorption and degradation/decay are also important. Most of the current analytical models assume that the sorption process is equilibrium-controlled sorption; however, in some cases, the sorption should be considered as rate-limited sorption. Additionally, degradation is typically presumed to occur only in the aqueous phase. This may be relevant for organic compounds, but for other types of multispecies contaminants that decay in the solid phase should be considered, such as radioactive waste. This study develops a two-dimensional model for multi-species contaminants under the influence of rate-limited sorption with decay in the solid phase. The multispecies contaminant transport in the aqueous and solid phases is represented by the advection-dispersion equation (ADE) and by using different time-dependent input conditions. The multispecies contaminant simulated in this study is radioactive waste, consisting of four species: ^{238}Pu, ^{234}U, ^{230}Th, and ^{226}Ra. The results show that the concentration of the first contaminant in the decay chain (^{238}Pu) tends to decrease when considering the decay process in the solid phase. Meanwhile, the contaminants formed through the decay process (^{234}U, ^{230}Th, and ^{226}Ra) significantly increase in concentration when the decay occurs in both phases. This demonstrates that not considering the decay process in the solid phase can lead to an erroneous assessment of contaminant concentrations in groundwater, especially for hazardous contaminants such as radioactive waste.

Keywords: Semi-analytical model, decay/degradation in solid phase, radionuclide decay chain, time-dependent input conditions