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Mobility of multispecies solute transport through porous media with varying dispersivities

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The significant presence of contaminants in the sub-surface not only degrades drinking water quality but also exerts adverse effects on the surrounding environment, particularly near chemical and nuclear repositories. Understanding the drivers and controls of these solutes becomes essential for futuristic mitigation. Thus, to reliably predict the fate of reactive solute transport in deeper subsurface, accurate modeling is required. This study deals with the two-dimensional numerical model to address multispecies transport in saturated porous media, considering advection, longitudinal and transverse dispersion with the first-order decay and the same is validated with the analytical solution having an excellent agreement. Focusing on four-species radionuclide (RN) decay chain and five-species chlorinated solvents (CS), this study explores three dispersion scenarios considering constant (ADC), linear (ADL) and exponential distance-dependent dispersivities (ADED) and a comparative analysis reveals the mobility of plumes, emphasizing the crucial role of dispersivity in shaping solute transport dynamics. Moreover, the analysis incorporates effective dispersivity rather than local dispersivity, enabling a conventional interpretation of the tracer breakthrough curves and enhancing the efficiency and precision of the numerical process, thereby generating results that resemble the actual field scenario. The results show that all the RN and CS concentrations exhibit their peak values within the source area and demonstrate a discernible decrease as the distance from the source increases. The substantial disparity in retardation factors in RN and CS species underscores the applicability of the model across diverse environments having non-identical physical and chemical characteristics. Also, an intriguing finding is that the daughter species with the largest plume may not necessarily dominate migration in the sub-surface, thereby challenging conventional assumptions. Further, the spatial moments are used to encapsulate the sensitivity analysis, extending the applicability to simulate other reactive transport scenarios. This study enhances the ability to predict and understand the enduring effects of environmental perturbations, aiding in formulating methodologies for modeling and forecasting the long-term effects of reactive contaminants that are crucial to providing effective remediation strategies and safeguarding environmental health.