



Modeling particle-facilitated solute transport using the C-Ride module of HYDRUS

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Strongly sorbing chemicals (e.g., heavy metals, radionuclides, pharmaceuticals, and/or explosives) in soils are associated predominantly with the solid phase, which is commonly assumed to be stationary. However, recent field- and laboratory-scale observations have shown that, in the presence of mobile colloidal particles (e.g., microbes, humic substances, clays and metal oxides), the colloids could act as pollutant carriers and thus provide a rapid transport pathway for strongly sorbing contaminants. Such transport can be further accelerated since these colloidal particles may travel through interconnected larger pores where the water velocity is relatively high. Additionally, colloidal particles have a considerable adsorption capacity for other species present in water because of their large specific surface areas and their high concentrations in soil-water and groundwater. As a result, the transport of contaminants can be significantly, sometimes dramatically, enhanced when they are adsorbed to mobile colloids.

To address this problem, we have developed the C-Ride module for HYDRUS-1D. This one-dimensional numerical module is based on the HYDRUS-1D software package and incorporates mechanisms associated with colloid and colloid-facilitated solute transport in variably saturated porous media. This numerical model accounts for both colloid and solute movement due to convection, diffusion, and dispersion in variably-saturated soils, as well as for solute movement facilitated by colloid transport. The colloids transport module additionally considers processes of attachment/detachment to/from the solid phase, straining, and/or size exclusion. Various blocking and depth dependent functions can be used to modify the attachment and straining coefficients. The module additionally considers the effects of changes in the water content on colloid/bacteria transport and attachment/detachment to/from solid-water and air-water interfaces. For example, when the air-water interface disappears during imbibition, particles residing on this interface are released into the liquid phase. Similarly, during drainage, particles residing at the solid-water interface may be detached from this interface by capillary forces and released into the liquid phase or become attached to the air-water interface. The solute transport module uses the concept of two-site sorption to describe nonequilibrium adsorption-desorption reactions to the solid phase. The module further assumes that the contaminant can be sorbed onto surfaces of both deposited and mobile colloids, fully accounting for the dynamics of colloids movement between different phases. We will demonstrate the use of the module using selected datasets and numerical examples.