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Local-scale structure parameters in dual-permeability modelling of preferential flow in field soils

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Accounting for preferential flow in quantitative simulation models of variably-saturated water flow and solute transport remains a challenge especially when attempting to relate soil structural properties to model parameters and to use experimental methods for model calibration and verification. Macroscopic model approaches often assume a partitioning of the structured soil into two separate but interacting porous domains. A number of two- (and even multiple-) domain models have been proposed that consider flow and transport in two or more interacting pore continua, separately. The empirical parameters of two-domain models that characterize the properties of the pore domains and the mass transfer between the domains are inherently representing the local- or sub- macroscopic-scale effects of structural properties. Currently, structure-related parameters are estimated or obtained by fitting rather than by direct measurements. This contribution summarizes recent attempts to evaluate and parameterize sensitive soil structures and discusses how the local-scale parameters are affecting the larger scale results depending on the model and the dimensionality of the problem. Examples are from 1D and 2D simulations of a tracer experiment at a subsurface drained field site.

The key macroscopic parameters of the dual-permeability water and solute mass transfer terms are describing the geometry (shape and size) and the hydraulic conductivity and diffusivity of the soil matrix. While the shapes and sizes may directly be obtained from soil observations, the hydraulic and diffusive resistances (e.g., due to coatings) at 'internal' surfaces of flow paths are hard to define or to measure. The properties at such 'internal' interfaces between flow path and porous matrix can depend on the mineralogical and organic matter composition, thus soil dynamics and land management can strongly affect these structures that control the nonequilibrium-type of preferential flow via mass transfer.

When increasing the scale and dimensionality of the problem, the local structure-related parameters become less sensitive; and ambiguous interpretations of tile flow are possible. In contrast to 1D dual-permeability analyses, where mass transfer effects were sensitive, the 2D analyses suggest that boundary conditions at the soil surface or near the water table, and field-scale mixing processes are affecting leaching patterns in addition to physical nonequilibrium effects. Although the complex simulation scenarios can predict relatively similar curves of Br drainage effluent concentrations, the predicted residual distributions of Br concentration in the soil profile are unique and different. Separate boundary conditions may be required for each of the pore domains. Still, the spatial and temporal patterns of soil surface structures and the local distributions of rain or irrigation water at the soil surface have hardly been identified or described.