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Experimental quantification of solute transport through the vadose zone under dynamic boundary conditions with dye tracers and optical methods.

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Knowledge of subsurface solute transport processes is vital to investigate e.g. groundwater contamination, nutrient uptake by plant roots and to implement remediation strategies. Beside field measurements and numerical simulations, physical laboratory experiments represent a way to establish process understanding and furthermore validate numerical schemes.

Atmospheric forcings, such as erratically varying infiltration and evaporation cycles, subject the shallow subsurface to local and temporal variations in water content and associated hydraulic conductivity of the prevailing porous media. Those variations in material properties can cause flow paths to differ between upward and downward flow periods. Thereby, the unsaturated subsurface presents a highly complicated, dynamic system.

Following an extensive systematical numerical investigation of flow and transport through bimodal, unsaturated porous media under dynamic boundary conditions (Cremer et al., 2016), we conduct physical laboratory experiments in a 22 cm x 8 cm x 1 cm flow cell where we introduce structural heterogeneity in the form sharp material interfaces between different porous media. In all experiments, a constant pressure head is implemented at the lower boundary, while cyclic infiltration-evaporation phases are applied at the soil surface. As a reference case a stationary infiltration with a rate corresponding to the cycle-averaged infiltration rate is applied.

By initial application of dye tracers, solute transport within the domain is visualized such that transport paths and redistribution processes can be observed in a qualitative manner. Solute leaching is quantified at the bottom outlet, where breakthrough curves are obtained via spectroscopy. Liquid and vapor flow in and out of the domain is obtained from multiple balances.

Thereby, the interplay of material structural heterogeneity and alternating flow (transport) directions and flow (transport) paths is investigated. Results show lateral transport through the material interface which differs between the stationary (unilateral) and dynamic cases (bilateral). This qualitative observation is confirmed by breakthrough curves for dynamic experiments which generally show the trend of faster initial breakthrough and increased tailing when compared to stationary infiltration results.

Literature

Cremer, C.J.M., I. Neuweiler, M. Bechtold, J. Vanderborght (2016): Solute Transport in Heterogeneous Soil with Time-Dependent Boundary Conditions, Vadose Zone Journal 15 (6) DOI: 10.2136/vzj2015.11.0144