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Impact of water table fluctuations on water flow and solute transport in 1D column systems

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Although hydrological processes and mass fluxes in the unsaturated and saturated zone have been well studied separately, little is known about transition processes between these zones. Since the transition zone is dynamic and varies spatially and temporally with fluctuations of the water table, water flow and solute transport are believed to vary dynamically, too. This may influence the transport and fate of dissolved contaminants and consequently the quality of groundwater. In order to protect and maintain drinking water resources, improved understanding about hydrological processes at the dynamic interface between the unsaturated and saturated zone is needed. The objective of this study was to investigate the impact of water table fluctuations on one-dimensional vertical flow and solute transport in laboratory column systems. Therefore, two flow-through columns were constantly irrigated with groundwater at an infiltration rate of 4.7 cm/d. In one column the water table was kept statically fixed in the middle, in the other column the water table was continually fluctuated by regularly raising and lowering the outflow tube. Several multi-tracer experiments were conducted and compared injecting the tracers bromide, deuterium and 18-oxygen at different water levels. Data modelling was performed with a lumped parameter model to simulate the hydrological fluxes. Our results showed that at static water table and similar water fluxes in both columns, structural heterogeneities due to packing lead to differences in solute transport, e.g. different dispersivity. Tracer breakthrough curves were well simulated with the lumped parameter model indicating that the systems were at steady state. When the water table was fluctuated small differences in solute transport were observed. Even with a fluctuating water table the lumped parameter model yielded high modelling accuracy and indicated that under certain hydrological conditions water table fluctuations lead to slightly increased dispersivity. It is suggested that the increased dispersivities are caused by a falling water table, which was faster declining compared to the water flux resulting in a more extensive solute distribution over depth. For a more precise identification of hydrological processes and mechanisms occurring near fluctuating water tables a model is needed that accounts for physical non-equilibrium of the system. In conclusion, water table fluctuations contribute to spreading of solutes and have to be considered in predicting the behaviour of dissolved contaminants in soils.