Impact of Heterogeneity on Oxygen Transfer in a Fluctuating Capillary Fringe

We performed quasi-two-dimensional flow through laboratory experiments to study the effect of a coarse-material inclusion, located in the proximity of the water table, on flow and oxygen transfer in the capillary fringe. The experiments investigate different phases of mass transfer from the unsaturated zone to anoxic groundwater under both steady-state and transient flow conditions, the latter obtained by fluctuating the water table. Monitoring of flow and transport in the different experimental phases was performed by visual inspection of the complex flow field using a dye tracer solution, measurement of oxygen profiles across the capillary fringe, and determination of oxygen fluxes in the effluent of the flow-through chamber. Our results show significant effects of the coarse-material inclusion on oxygen transfer during the different phases of the experiments. At steady state, the oxygen flux across the unsaturated/saturated interface was considerably enhanced due to flow focusing in the fully water-saturated coarse-material inclusion. During drainage, a zone of higher water saturation formed in the fine material overlying the coarse lens. The entrapped oxygen-rich aqueous phase contributed to the total amount of oxygen supplied to the system when the water table was raised back to its initial level. In case of imbibition, pronounced air entrapment occurred in the coarse lens, causing oxygen to partition between the aqueous and gaseous phases. The oxygen mass supplied to the anoxic groundwater following the imbibition event was found to be remarkably higher (approximately seven times) in the heterogeneous system compared with a similar experiment performed in a homogeneous porous medium.

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