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Estimating travel times of recharge water through the unsaturated zone using a transfer function model

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The effective large scale travel time of water and chemicals through the vadoze zone can be assessed by means of mathematical models of different complexity. For deep vadoze zone formations, the use of detailed numerical flow models is often prohibited as the spatial distribution of unsaturated hydraulic parameters within the formation is often badly known. Alternatively lumped transfer function models can be used to assess effective flow and mass transfer.

The objective of this study is to evaluate the travel time of percolating water through a deep unsaturated zone using time series of precipitation, actual evapotranspiration and groundwater piezometry, and using a lumped transfer function model. The methodology was applied to assess the travel time on 18 locations within the vadoze zone of the Brusselian aquifer (Belgium). The analysis results in a high variability of the local scale transfer times (from 0.9 to 4.3 years) and velocities (from 6.6 to 28.0 m/year). For a piezometer for which detailed hydrogeological data were available, results of the transfer function model were further compared with the travel times estimated using a detailed numerical model (Hydrus-1D). The flow velocity calculated with the transfer function model was two to four times higher than the one simulated with Hydrus. This could be explained by the fact that the deterministic model requires various hydrogeological inputs which are affected by considerable uncertainty and that it doesn't take the local soil characteristics and heterogeneities into account, which may affect fast flow through the unsaturated zone. The transfer function only needs easily measurable time series, and is more effective than the numerical model.