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Aged streams: Time lags of nitrate, chloride and tritium assessed by Dynamic Groundwater Flow Tracking

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Groundwater connects the agricultural fields in a catchment with the drainage network and it therefore plays an important role in the pollution of surface waters. To study this transport mechanism, we derived dynamic groundwater travel time distributions from a distributed, transient 3D groundwater flow model using forward particle tracking. We then calculated in-stream concentrations by coupling the travel time distributions with input time-series of tritium and the agricultural tracers chloride and nitrate, representing the water quality of the groundwater recharge throughout the catchment. We tested this approach for a lowland stream in the Netherlands and found that the variable contribution of different groundwater flow paths to stream water quality reasonably explained most of the long-term and seasonal variation in the measured stream nitrate concentrations. To study the observed lag in the breakthrough of agricultural solutes we performed a sensitivity analysis and found that the main contributors to such a time lag are the unsaturated zone, increased mean travel times and longer distances between agricultural fields and the drainage network. We found that the time between the application and effect of measures aimed to reduce in-stream concentrations depends on the combination of the input reduction rate and the mean travel time of the catchment. Furthermore, the location of agricultural fields in relation to the catchments' drainage network was found to be an important factor that largely governs the travel times of the agricultural pollutants.