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Use of environmental Tracer Data for Groundwater Modeling

O. Onnis (1), A. Althaus (2), K. Klump (3), H Hendricks-Franssen (1), K. Kipfer (3), P. Purtschert (2), S. Stauffer (1), K. Kinzelbach (1)

(1) Institute of Environmental Engineering, ETH Zürich, Switzerland (onnis@ifu.baug.ethz.ch), (2) Climate and Environmental Physics, University of Bern, Switzerland (ralt@climate.unibe.ch), (3) Department of Water Resources and Drinking Water, EAWAG Dübendorf (stephan.klump@eawag.ch).

Environmental tracers are isotopic and chemical compounds which have been increasingly used in hydrological sciences to investigate the water cycle. Early studies in the '80s demonstrated the potential of environmental tracers' also in groundwater investigations. Dissolved in the water or being part of the water molecule, these tracers are present in the groundwater body, allowing the hydro-geologist to gain information about water movement in the subsurface (groundwater age, travel times, streamline information, ratio of fluxes and recharge rates). Compared to artificial tracer tests over short time scales, transient environmental tracers were released into the atmosphere since the early '50s, providing a tool to investigate the groundwater flow and transport over time scales from 0 to 50 years.

Following a study from Cook and Solomon (1995), the presence of a thick unsaturated zone ($>$10m) above an aquifer is crucial to the fate of the tracers in the subsurface. The time-delay and the hydrodynamic dispersion occurring in the vadose zone significantly modify the tracer concentrations in time and in depth. For any meaningful modelling of tracer transport in the subsurface, these effects have to be properly accounted for deep groundwater tables. While the tracer movement is almost the same for all tracers when transported in the saturated zone, different tracers show different timescales due to their different transport mechanisms (advection or diffusion/dispersion) in the unsaturated zone.

We present a case study for the environmental tracers ^{3}H, ^{3}He and ^{85}Kr in a small

catchment in Northern Switzerland, near Baltenswil. The site is chosen as test site for our environmental tracer modelling and sampling since it is hydro-geologically well known with well defined boundary conditions. The measured ^{3}H, ^{3}He and ^{85}Kr concentrations during the years 2003-2005 in this aquifer system show significant variations on a seasonal timescale without an apparent trend. We investigate the transport of the tracers ^{3}H, ^{3}He (decay product of ^{3}H), ^{85}Kr in the unsaturated zone by means of a numerical solution to the vertical advection-dispersion equation. We use this solution to calculate a correct tracer input at the groundwater table.

The groundwater flow model is determined by means of Stochastic Inverse modelling in a transient regime. A number of equally likely transmissivity fields that honour both transmissivity and time-varying heads measurements are generated. The number of acceptable solutions is reduced by the conditioning of the model parameters to more and different types of data. For transient inverse calibration, a detailed evaluation of the recharge parameter is of utmost importance. This estimation has been carried out in an independent hydrological budget model. To investigate the behaviour of environmental tracers in the subsurface, selected calibrated transmissivity fields are then used as input into a deterministic transport model. Effects of tracers transport in the saturated zone to the observation locations are simulated via PMWIN.

The chosen approach allows the modeller to gain insight into the subsurface transport mechanisms of environmental tracers, with a special attention to the impact of the unsaturated zone, and to combine hydraulic analysis with information coming from tracer data for an improved groundwater flow modelling. A combination of several tracers makes their application to groundwater investigations more reliable. The use of a variety of transmissivity realizations allows the quantification of the uncertainties in the modelled head fields and solute particle trajectories.