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Flow and transport modeling and isotope monitoring of a dug well SAT prototype in Shafdan, Israel

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The Shafdan case (Israel) offers the unique opportunity to investigate the long-term behaviour of a large scale Soil Aquifer Treatment system over a timescale of several decades. Specific problems occurred only after 20 years of successful operation, like the reduction of infiltration capacity, partly due to physical and chemical clogging, and the sudden appearance of significant concentrations of dissolved manganese in several wells. In the framework of the European FP6 ReclaimWater project, a new injection system through dug wells was developed and tested, destined to complete the existing infiltration basins, and the design and testing of the dug-well prototype was accompanied by different modelling activities. A preliminary 3D flow and conservative transport model was set up a the onset of the project to plan and design the dug well prototype and the monitoring wells. The radial pattern of solute transport obtained by the 3D model showed that a 2D radial model could satisfyingly describe the system so that a 2D flow and transport model was developed to model tracer tests and transfer scenarios of accidental peaks of organic contaminants.

Boron and Li isotopes have been tested as environmental tracers of treated sewage injected into the sandy aquifer during a 38 days injection test in the newly dug injection well, a conservative artificial tracer (Br-) was monitored together with δ^{11}B and δ^{7}Li in the injectate, in the unsaturated soil zone (porous cup) and an observation well in the aquifer. Boron isotope ratios show a breakthrough curve delayed with respect to Br- breakthrough due to some reversible sorption on the aquifer material. No isotope fractionation was observed in the unsaturated or the saturated zone so that B-isotopes can be considered as conservative in the investigated part of the aquifer system. Lithium isotopes are strongly fractionated, probably due to sorption processes whereas Boron isotopes reveals a valuable tracer of artificial recharge of freshwaters derived from treated sewage, both for short term tracer tests and for long term monitoring of artificial recharge, even if in aquifers with higher clay contents, sorption-linked isotope fractionation cannot be excluded.

Redox conditions were addressed through a 1D vertical unsaturated and 1D horizontal saturated reactive transport model. This model combines kinetics of microbiological degradation of organic matter (Monod kinetics), kinetic control of electron acceptors, with water-mineral interactions (dissolution-precipitation reactions). It was possible to reproduce the observed redox sequence in the Shafdan system even if this example demonstrates the limits of current bio-geochemical concepts, in particular for an element like Mn for which no stable oxidised (MnIV) aqueous species exists. Clearly, the consideration of bacterially catalysed, non-equilibrium reactions, and, simultaneously, of water-mineral equilibria through coherent bio-geochemical models is currently one of the major challenges in modelling such complex systems as are MAR systems using reclaimed water. Such models are a prerequisite for risk assessment in the field of MAR, to go beyond the use of bulk parameters like sorption isotherms and biodegradation half lifes when looking on the behaviour of organic contaminants. A thorough understanding of biogeochemical reactions occurring both in the unsaturated and the saturated zone is needed to develop predictive tools that are able to address and foresee potential drawbacks of MAR systems like pollutant breakthrough, release of trace contaminants from the aquifer material and mineral precipitations leading to a degradation of the hydraulic properties of the receiving reservoir.