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Numerical simulations of the impact of seasonal heat storage on source zone emission in a TCE contaminated aquifer

Steffi Popp, Christof Beyer, Andreas Dahmke, and Sebastian Bauer
Geohydromodelling, Institute of Geosciences, Kiel University, Ludewig-Meyn-Str. 10, D-24118 Kiel

In urban regions, with high population densities and heat demand, seasonal high temperature heat storage in the shallow subsurface represents an attractive and efficient option for a sustainable heat supply. In fact, the major fraction of energy consumed in German households is used for room heating and hot water production. Especially in urbanized areas, however, the installation of high temperature heat storage systems is currently restricted due to concerns on negative influences on groundwater quality caused e.g. by possible interactions between heat storages and subsurface contaminants, which are a common problem in the urban subsurface. Detailed studies on the overall impact of the operation of high temperature heat storages on groundwater quality are scarce. Therefore, this work investigates possible interactions between groundwater temperature changes induced by heat storage via borehole heat exchangers and subsurface contaminations by numerical scenario analysis.
For the simulation of non-isothermal groundwater flow, and reactive transport processes the OpenGeoSys code is used. A 2D horizontal cross section of a shallow groundwater aquifer is assumed in the simulated scenario, consisting of a sandy sediment typical for Northern Germany. Within the aquifer a residual trichloroethene (TCE) contaminant source zone is present. Temperature changes are induced by a seasonal heat storage placed within the aquifer with scenarios of maximum temperatures of 20°C, 40°C and 60°C, respectively, during heat injection and minimum temperatures of 2°C during heat extraction. In the scenario analysis also the location of the heat storage relative to the TCE source zone and plume was modified.
Simulations were performed in a homogeneous aquifer as well as in a set of heterogeneous aquifers with hydraulic conductivity as spatially correlated random fields. In both cases, results show that the temperature increase in the heat plume and the consequential reduction of water viscosity lead to locally increased groundwater flow. Depending on the positioning of the heat storage relative to the TCE contamination, groundwater fluxes hence may be induced to increase within or partially bypass the TCE source zone. At the same time, TCE solubility decreases between 10 and 40 °C, which reduces TCE emission and almost compensates for the effects of a temperature induced increase of groundwater flow through the source zone. In total, the numerical simulations thus show only minor influences of the heat plume on the TCE emission compared to a thermally undisturbed aquifer.

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