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Numerical simulation of seasonal heat storage in a contaminated shallow aquifer – Temperature influence on flow, transport and reaction processes

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The energy market in Germany currently faces a rapid transition from nuclear power and fossil fuels towards an increased production of energy from renewable resources like wind or solar power. In this context, seasonal heat storage in the shallow subsurface is becoming more and more important, particularly in urban regions with high population densities and thus high energy and heat demand. Besides the effects of increased or decreased groundwater and sediment temperatures on local and large-scale groundwater flow, transport, geochemistry and microbiology, an influence on subsurface contaminations, which may be present in the urban surbsurface, can be expected. Currently, concerns about negative impacts of temperature changes on groundwater quality are the main barrier for the approval of heat storage at or close to contaminated sites. The possible impacts of heat storage on subsurface contamination, however, have not been investigated in detail yet. Therefore, this work investigates the effects of a shallow seasonal heat storage on subsurface groundwater flow, transport and reaction processes in the presence of an organic contamination using numerical scenario simulations.

A shallow groundwater aquifer is assumed, which consists of Pleistoscene sandy sediments typical for Northern Germany. The seasonal heat storage in these scenarios is performed through arrays of borehole heat exchangers (BHE), where different setups with 6 and 72 BHE, and temperatures during storage between 2°C and 70°C are analyzed. The developing heat plume in the aquifer interacts with a residual phase of a trichloroethene (TCE) contamination. The plume of dissolved TCE emitted from this source zone is degraded by reductive dechlorination through microbes present in the aquifer, which degrade TCE under anaerobic redox conditions to the degradation products dichloroethene, vinyl chloride and ethene. The temperature dependence of the microbial degradation activity of each degradation step is taken into account for the numerical simulations. Hence, the simulations are performed with the code OpenGeoSys, which is especially suited for simulating coupled thermal, hydraulic and geochemical processes. The scenario simulations show an increase in the source zone emission of TCE at higher temperatures, which is primarily due to the focusing of the groundwater flow in the area of higher temperatures within the source zone and to a lesser part to an increase in TCE solubility. On the other hand, a widening of the contaminant plume and enlargement of the area for TCE biodegradation is induced, which leads to an increase in biodegradation of the chlorinated hydrocarbons. In combination almost no change in the overall ratio of degraded to emitted TCE is found, which shows that the seasonal heat storage is not negatively influencing the present TCE contamination under these assumptions. The results of this work serve to support the risk assessment for the interaction between heat storage and contaminations in the shallow subsurface and show positive interactions as well as possible conflicts.