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Numerical simulations of saltwater displacement via fault systems due to exploitation of the subsurface

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Injection of fluids into deep saline aquifers induces an increase in pore pressure in the storage formation, and thus displacement of resident brines. Upward brine migration into shallower aquifers via hydraulically conductive faults may therefore lead to unwanted salinization of potable groundwater resources. In the present study, we investigated different scenarios for a prospective storage site close to the city of Beeskow in the Northeast German Basin by using a representative 3D regional-scale model (100 km x 100 km x 1.34 km) that includes four regional fault zones. The focus was on assessing the impact of fault length and permeability as well as model boundary conditions on the potential salinization of shallow groundwater resources. Moreover, the effects of an overlying secondary brine-bearing reservoir as well as varying initial salt-freshwater boundaries were investigated. We employed numerical simulations of brine injection as a representative fluid based on an example case study discussed by Tillner et al. (2013).

Our simulation results demonstrate that pressure build-up within the reservoir determines the fluid rates and duration through the faults, and hence salinization of shallower aquifers. Application of different boundary conditions proved that these have a crucial impact on reservoir fluid displacement. If reservoir boundaries are closed, the fluid displaced via the faults into the shallow aquifer corresponds to the overall injected fluid mass. In that case, fault length and permeability as well as the presence of an overlying secondary reservoir have only temporal effects on brine migration. A fault zone with a hydraulically conductive segment of only two kilometres length causes brine flow into the shallow aquifer of 330 years, which is thus five times longer compared to the case with four faults open over their entire length of 193 km. The presence of an overlying secondary reservoir leads to an additional retardation of brine inflow into the uppermost aquifer up to a factor of three. If the reservoir boundaries are open, salinization is considerably reduced. In the presence of a secondary reservoir, 33 % of equivalent brine mass migrates into the shallow aquifer, if all four faults are completely hydraulically open, whereas the displaced equivalent brine mass is only 13 % if accounting for a single fault of two kilometres length. Without the secondary reservoir, 66 % of the brine mass is displaced in the four fault and about 30 % in the 2 km single fault cases. Taking into account the considered geological boundary conditions, the brine mainly originates from the upper 16 m to 300 m of the investigated faults, and hence the initial salt-freshwater boundary present in the fault is of high relevance for the resulting shallow aquifer salinization.

The present study successfully demonstrates that a quantification of brine displacement using numerical simulations is feasible at regional scale.

Tillner, E., Kempka, T., Nakaten, B., Kühn, M. Geological CO_2 Storage Supports Geothermal Energy Exploitation: 3D Numerical Models Emphasize Feasibility of Synergetic Use (2013) Energy Procedia 37:6604-6616. doi:10.1016/j.egypro.2013.06.593.