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Natural saltwater upconing by boils: field measurements and numerical modeling

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In this study, natural saltwater upconing by boils was investigated using field measurements and numerical simulations. As one-quarter of The Netherlands lies below mean sea level, the upward flow of saline groundwater leads to the salinization of surface waters for large areas, impacting on agriculture and aquatic ecosystems. The largest seepage fluxes are found in deep polders with surface water levels maintained as low as 6 to 8 m below sea level. Recent studies showed that preferential groundwater discharge through boils is the dominant salinization source in these deep polders. Boils occur as conduits in the upper aquitard that connect the underlying aquifer to the surface through which groundwater discharges at high velocities. Groundwater preferentially discharging through boils contains up to hundred times more salt than diffuse forms of groundwater discharge. The upconing of deep saline groundwater induced by the localized, high-velocity flow through boils is the mechanism that leads to the high boil water salinities.

The local boil system and associated natural salt water upconing were explored in the field in three different hydrogeological settings. Measurements of the aquifer salinity distribution, temperature, boil discharge, boil salinity and aquifer heads showed that the preferential flow through boils creates localized and narrow saltwater upconing spikes. The possibility to seal the boil at its source vent as a measure to abate surface water salinization was explored in the field.

Numerical modeling with the code SEAWAT was applied to investigate the upconing processes in more detail. The field measurements were largely reproduced by the numerical model. 56 different cases, which differ in aquifer properties, salinity distribution, boil discharge and lateral regional flow,were defined to determine the most important boil salinity controlling factors. For each upconing case the sources of boil water, i.e. the contribution to boil discharge from different aquifer depths, were derived from the model results. The contributing depth distributions showed a form opposite to the aquifer salinity distribution, with higher contributions from shallower and less saline groundwater. This illustrates the importance of the density distribution in the aquifer on the saltwater upconing mechanism. The numerical results showed that the most important factors controlling the contributing depths and boil salinity are boil discharge, the horizontal hydraulic conductivity of the aquifer, the depth of the interface and the salinity (and therefore density) contrast within the aquifer. Within a small area of clustered boils, boil salinity varies between individual boils and is determined by the combination of its discharge and its position within the boil area, whereas the total discharge of boil clusters is the principal factor that controls natural saltwater upconing and total salt loads. Regional lateral flow had a large impact on the upconing mechanism in terms of flow patterns but had a minor effect on both the contribution of saline and fresh groundwater to boil discharge and boil salinity.

Both measurements and model results will be presented at the EGU.