Experimental risk assessment of carbonate scaling in the operation of high temperature – aquifer thermal energy storage (HT-ATES) systems

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High temperature - aquifer thermal energy storage (HT-ATES) is gaining momentum as sustainable option for the (seasonal) storage of heat, where geothermal heat may be one of the sources. To maximize the impact of geothermal systems, the heat produced in the summertime, which is not directly needed, can be temporarily stored in a groundwater aquifer for use in the winter. However, HT-ATES does not come without technical complications. One potential complication is carbonate scaling of the technical installation and/or the aquifer in the vicinity of the injection well. Precipitation of carbonates may occur when carbonate-saturated groundwater becomes heated, upon which the groundwater becomes increasingly supersaturated for carbonates. As part of the GEOTHERMICA project HEATSTORE, both a sampling method and an experimental set-up were developed. This experimental procedure enables the sampling and testing of groundwater from HT-ATES sites or else to determine the likelihood of calcium carbonate scaling in a HT-ATES system and, if so, identify the nature and extent.

For the HEATSTORE project, Groundwater was sampled at a HT-ATES test well drilled in Middenmeer, the Netherlands down to 370 meter depth. The sampling was done with a double walled vessel, which made it possible to maintain pressure on the water sample to prevent degassing of natural occurring dissolved gases like methane and carbon dioxide during sampling and storage, as well as preventing atmospheric contamination of the groundwater. The experiments were performed in two stainless steel autoclaves which were kept at 85 degrees Celsius for up to 5 days. Three types of experiments were performed to mimic the different components of the HT-ATES system: addition of a plate of stainless steel, addition of calcium carbonate crystals and addition of aquifer sediment. The first experiment did not show any carbonate precipitation, although geochemical modelling suggests oversaturation of calcite for the applied conditions. Calcite precipitation and recrystallization were observed only in the experiments with calcite crystal seeds added. The experiment with the aquifer sediment added to the reaction vessel, containing shell fractions and intact shells (e.g. Foraminifera), did not show calcite precipitation, neither showed the chemical analysis of the water at the end of the experiment a reduction in calcium concentration. Isotope analysis suggests that carbon dioxide was released by thermally enhanced degradation of sedimentary organic matter, which would have lowered the supersaturation of calcite.
These results suggest that aquifers, in which calcite is already present and limited (or no reactive) organic matter is available, could face a risk of scaling and subsequent injectivity/productivity issues when HT-ATES is applied in these aquifers. A proper water treatment, such as the addition of carbon dioxide or hydrochloric acid to the groundwater abstracted prior to heating, could be required to prevent groundwater from getting supersaturated with carbonate minerals.