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Hydrogeochemical characterization and evaluation of a Middle Triassic carbonate aquifer, as a potential High Temperature Aquifer Thermal Energy Storage in Berlin, Germany

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Aquifer thermal energy storages can be a possibility to master the challenges of the acyclic heat demand and supply by storing the surplus heat in an aquifer and discharging it during periods of heat deficit. The injection of hot water may have negative impacts on the aquifer caused by geochemical reactions due to shifting the natural equilibrium. Clogging of aquifer pores thus reducing the porosity and permeability may be a possible consequence. Deeper understanding of potential formation-specific rock-water interactions is aiming to prevent undesired effects on ATES systems.

As a former injection horizon of the Berlin natural gas storage facility, our target formation is exposed by several wells at about 525 m below the surface with an average thickness of 30 m and provides an optimal test field. A nitrogen lifting test including physical and chemical groundwater monitoring was carried out in summer 2020. Additionally, a downhole sample of formation fluid was collected from 510 m below the surface at in-situ pressure and temperature conditions. For the first time detailed chemical and microbiological analyses of formation water of this limestone formation (*Lower Muschelkalk*) were conducted.

Fluid analysis shows a 130 g L^{-1} Na-Cl dominated high salinity water with neutral pH of 7.1 at 32 °C aquifer temperature. The proportion of dissolved gases were less than 3 %, whereby CO_2 represents 50 vol.-% of the total gas phase. The reservoir forms a dual porosity aquifer consisting of fractured layers of highly varying porosity. XRD-analysis of core samples shows a mineral composition of > 96 wt.-% calcite with minor proportions of quartz, siderite and ankerite. Hydrogeochemical modeling with PHREEQC shows the general potential of carbonate precipitation during heat storage due to increasing temperature and CO_2 degassing. However, existing databases do not suite the encountered physical-chemical conditions. Results from batch experiments at well-defined conditions of temperatures up to 120 °C and elevated salinity are used to feed the thermodynamic databases, which are required for accurate modeling. This allows predicting the temperature optimum for efficient and sustainable heat storage in carbonate aquifers.