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Biogeochemical impacts of aquifer thermal energy storage at 5, 12, 25 and 60°C investigated with anoxic column experiments

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Aquifer thermal energy storage (ATES) uses groundwater to store energy for heating or cooling purposes in the built environment. ATES systems are often located in the same aquifers used for public drinking water supply, leading to urgent questions on its environmental impacts. This contribution presents the results of research on the biogeochemical impacts of ATES in anoxic column experiments at 5, 12, 25, and 60˚C. In- and effluents are analyzed for major ions, trace elements, heavy metals, dissolved organic carbon (DOC) and UV extinction. Terminal restriction fragment length polymorphism (T-RFLP) of 16S rRNA genes and analysis of adenosine triphosphate (ATP) were used to detect changes in the microbiological population and activity.

Results from the column experiments at 5, 25, and 60˚C compared to the reference column at 12˚C showed a number of changes in biogeochemical conditions: At 5˚C, only changes were observed in alkalinity and calcium concentrations, resulting from calcite dissolution. The 25˚C and 60˚C column effluents from a sediment containing Fe-(hydr)oxides showed an increase in arsenic concentrations, well above the drinking water limit. This is due to either (reductive) dissolution of, or desorption from, iron(hydro)xides containing arsenic. In addition, at these two temperatures sulfate reduction occurred while this was undetectable at 5 and 12˚C within the given timeframe (25 days) and analytical accuracy. The carbon source for sulfate reduction is inferred to be sedimentary organic carbon. Increasing DOC with residence time in the 60˚C effluent suggests that at 60˚C the terminal sulfate reduction step is rate limiting, while at 25˚C the enzymatic hydrolization step in sulfate reducing bacteria is overall rate limiting. Specific ultraviolet absorption (SUVA, the ratio of UV extinction and DOC) however shows a clear decrease in reactivity of the humic acid fraction in DOC. This means that the DOC accumulation at 60˚C could also be interpreted as a shift from pure microbial mediated organic carbon hydrolysis to chemical organic carbon respiration, yielding less reactive humic acids. The results from the T-RFLP and ATP analyses showed that the microbial population at 60˚C was clearly different and less active than at lower temperatures.

Overall, it is concluded that water quality can change when higher temperatures (>25 ˚C) are invoked on anoxic sediments. Impacts from cold storage are limited. This implies that care should be taken when positioning ATES systems at higher temperatures in aquifers that are used for public drinking water supply.