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Exploring the feasibility of underground hydrogen storage in carbonate reservoirs: insights into biogeochemical reactivity from an aquifer in Loenhout, Belgium

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Underground hydrogen storage (UHS) in deep geological reservoirs is a promising technology for large-scale renewable energy storage. Hydrogen injection into the subsurface alters the chemical potential, resulting in a reducing environment that may trigger geochemical and microbial reactivity. This can lead to hydrogen conversion and loss, introduction of impurities, and pore clogging, impacting storage efficiency. Carbonate reservoirs, which make up a quarter of the potential UHS sites in Europe, are theoretically more susceptible to these types of reactivity. This is also true for pyrite-containing reservoirs [*1–3]*, as the latter can react with hydrogen in redox reactions. While several studies have addressed reactivity during UHS, the extent and interactions of these reactions in carbonate aquifers, under reservoir-relevant conditions, remain unclear.

Here, we present results of a hydrogen storage pilot test in a karstified carbonate aquifer in Loenhout, Belgium, to study geochemical, microbial and combined reactivity and its effects on UHS. The reservoir rock is a limestone containing pyrite and anhydrite. To aid the interpretation of the results, the pilot test was combined with a series of laboratory-scale low- and high-pressure batch experiments under reservoir temperatures (65°C) and salinities (120g NaCl/L), with groundwater and mineral samples from the Loenhout reservoir.

Preliminary results show low microbial cell counts (~10^3 cells/ml) in the groundwater, with microbial communities mainly consisting of previously undiscovered species of sulfate reducing bacteria, and low microbial activity after 12 months of incubation. Chemical tests show no detectable reactivity of pyrite-containing limestone under H_2 atmospheres after 12 months. While further experiments are ongoing, these outcomes suggest limited reactivity during UHS under the tested conditions. This suggests that carbonate reservoirs may potentially be candidates for efficient and economically viable hydrogen storage, subject to detailed site characterization.

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