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Experimental Assessment of hydrogen consumption by microbial communities from underground reservoirs: a European case study

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Underground hydrogen (H_2) storage is a promising solution for storing large amounts of energy and addressing the intermittency of renewable energy sources. However, H_2 can be metabolized by part of the indigenous microbial communities inhabiting deep subsurface environments. Microbial H_2 consumption poses several risks, including loss of stored H_2, deterioration of gas quality due to the production of secondary gases (e.g., H_2S, CH_4), and alterations of the physicochemical properties of the reservoirs. Through the HyLife CETP project, four potential hydrogen storage reservoirs (3 depleted reservoirs and 1 aquifer), exhibiting contrasting characteristics (temperatures ranging from 13°C to 70°C, salinity from 0.02% to 2%, etc.), were thoroughly investigated to characterize their hydrogenotrophic microbial communities and assess their capacity for H_2 consumption. Experiments were achieved by the four microbiology laboratories involved in the project (NORCE, BRGM, TUL, and Isodetect). A series of triplicate batch experiments were conducted in serum flasks to monitor H_2 consumption over time under varying conditions: temperature shifts (+10°C and −10°C compared to on-site temperature), pH variations (+1 and −1 unit), presence of mixed rocks, and a second H_2 injection. Gas composition, aqueous geochemistry, and microbial DNA were analyzed to track changes in geochemical parameters and microbial diversity. Methanogenesis, sulfate reduction, and acetogenesis were the main microbial metabolic pathways involved. For all the samples from the depleted hydrocarbon reservoir, H_2 was completely consumed within 20 days, with a maximum consumption rate of approximately 1.6 mmol/L/day. In contrast, H_2 consumption in the aquifer was significantly lower, with only 20% of the injected H_2 metabolized after 100 days. H_2 consumption was strongly influenced by experimental conditions. For depleted reservoirs, temperature variations reduce hydrogenotrophic methanogenesis and promote acetogenic pathways and the accumulation of organic acids. The presence of rocks also significantly influenced microbial diversity and metabolic activity by promoting the reduction of sulfate and fermentation. A re-feed of H_2 into the bottles revealed variable H_2 consumption rates depending on the timing of the reinjection and the availability of CO_2. These findings highlight the importance of considering transient states and temporal dynamics when evaluating H_2 behavior in deep environments.