Comparative study of three H_2 geological storages in deep aquifers simulated in high pressure reactors

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Abstract

In the context of climate change and resource depletion, an adaptation in the energy mix towards decarbonation and renewable energy is crucial. Dihydrogen (H_2) is a promising alternative to traditional carbonated energy sources. Besides being storable, it also has the potential to be produced using renewable and low carbon processes. In order to use H_2 on a large scale, it will be necessary to store massive quantities by means of, for example, Underground Gas Storage (UGS) in deep aquifers.

H_2's behavior in deep aquifer is related to its geochemical reactivity and to the microbial activity. Also, it is an electron donor as well as an energy source for numerous indigenous microorganisms. In this study, H_2 injection in three different UGS, with different formation waters, rocks and microbial communities, were simulated in a high-pressure reactor following a previously defined protocol [1].

To better understand the intricate phenomena at work, extent of reaction equations based on microbial diversities were solved to identify the main reactions taking place in the reactor. The broadly used geochemical modeling software PHREEQC was used to calculate gases solubilities, resulting pH and redox potential inside the reactor.

While methanogens were only observed in some of the experiments, the appearance of formate seems to be a constant and should therefore be considered in the evolution of storage conditions. The effect of H_2 on microbial communities and thus their activities seem to extend well beyond the metabolisms usually targeted for hydrogenotrophy.

In the first experiment with low sulfate concentration, sulfate was totally depleted during the experiment and H_2 consumption stopped when CO_2 had disappeared. In the two other experiments with higher sulfate concentration, H_2 consumption was observed throughout the experiment while CO_2 and sulfate remained at the end of experiment. Acetogenesis was also observed on a lower scale. It appeared that H_2 injection led to alkalinization, mainly through the consumption of CO_2 by sulfate-reducers and methanogens micro-organisms. Depending on the UGS conditions, especially sulfate concentration, the microbial reactions and their scale varied, highlighting the importance of a site-specific study.

[1] Haddad et al. 2022, Energy Environ. Sci. 15, 3400.