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Simulation study of hydrogen storage in a depleted gas reservoir: Microbiological influences in porous media

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Storing hydrogen in depleted gas reservoirs is a viable method for balancing seasonal energy demand fluctuations. However, these reservoirs harbor a diverse population of microorganisms. H_2 are considered one of the most important electron donors for subsurface microbial respiration. Under high salinity, high temperature, and high pressure conditions, microbial reactions such as methane generation, sulfate reduction, and acetate production are most common [1]. These reactions result in hydrogen loss, gas acidification, pore plugging by metabolic biofilms, and alteration of the hydrogen-brine-rock three-phase interface properties due to the generation of organic acids [2]. Currently, there is very little research on the impact of microorganisms in depleted gas reservoirs.

This study was conducted on a specific depleted gas reservoir, utilizing the CMG-STARS to simulate the impact of microorganisms on hydrogen storage. Firstly, the diffusive distribution of solid-phase microorganisms (biofilms) on porous media was designed, and Fick's law was employed to characterize the concentration-driven microbial transport process. Subsequently, based on reaction conditions, four reactions were designed to generate CH_4 (PH>7), H_2S, acetic acid (PH<7), and microbial growth. The microbial population within the community was considered to control the rates of hydrogen uptake and microbial growth. The shedding of biofilms was influenced by the number of microorganisms and shear rate. Multiple sets of relative permeability curves were designed to match changes in wetting angle caused by acetic acid generation. Finally, the injection pressure was limited by reservoir fracture pressure and capillary forces causing leakage to the overlying formation. Seasonal hydrogen storage was conducted over four cycles, with a cycle consisting of 6 months of injection and 6 months of production.

The simulation results revealed the presence of high microbial saturation zones in near-wellbore region and higher parts of structure. The generated CH_4 and H_2S account for a maximum of 1.4% and 0.1% of the injected hydrogen volume, respectively, and accumulated below the H_2 layer. The loss of hydrogen gas was highest at 5% in first cycle and decreased to a minimum of 0.6% in third cycle. As cycling period increased, the purity of hydrogen in produced gas became higher. Throughout the entire process, the effective porosity of the gas reservoir decreased by a value ranging from 0.1% to 0.5%, while the pH remained relatively unchanged.

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