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Assessment of the Underground Hydrogen Storage (UHS) Prospect in the Depleted Gas Fields of Japan

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Underground hydrogen (H_2) storage (hereinafter UHS) in depleted gas reservoirs provides a solution for power peak shaving. The availability of the depleted gas reservoirs offers a larger storage capacity in comparison to other options, e.g., salt caverns or aquifers. However, the proper selection of a gas field for the UHS and how to conduct it is a challenge. Therefore, this work aims at screening and ranking Japanese gas fields for the UHS and its characterization in the selected field.
At first, we used the Analytical Hierarchy Process (AHP) to screen and rank tentative H_2 storage sites in Japan. We then used CMG reservoir simulator to study the H_2 injection, storage, and withdrawal capacities at the selected site in the Niigata Prefecture based on a volumetric reservoir. Our calculations with the AHP method showed the best possible sites for UHS as follows: Sekihara, Kumoide, Katakai, Nakajo, Kubiki, Shiunji, Iwafune-oki (gas), and Minami-Nagaoka. The high position of these fields results from the high flow capacity, depth, current reservoir pressure, and dip angle.
Next, the results of simulations with the CMG software in the selected gas field demonstrated that hysteresis trapping, number of injections and withdrawal cycles, and type of cushion gas are the most influential parameters that can affect the UHS in the studied field. It was observed that hysteresis trapping decreased the recovery factor of H_2 by 7% in one cycle of production compared to the case without it. Implementation of consecutive injection and production cycles improved recovery the factor of H_2 from 53% in the first cycle to 74% in the sixth cycle. Injection of one period of nitrogen (N_2) as cushion gas, before start of the H_2 injection, helped to keep the reservoir pressurized and increased the recovery factor in each cycle by 0.5-2.5% compared to the case when there is no cushion gas. On the other hand, Carbon dioxide (CO_2) injection as a cushion gas significantly decreased (58 to 16% in different cycles compared to N_2) the recovery factor as a result of the methanation reaction.
For the first time in Japan, this work offers a framework for evaluating and ranking potential depleted gas reservoirs as a UHS option. It also includes a reservoir simulation study to comprehend the impact of various mechanisms on the efficiency of H_2 storage and withdrawal on a volumetric gas reservoir.