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AI assisted prediction of Sweep Efficiency of Hydrogen –Water Displacements in Porous Media

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In the present era of escalating global energy consumption, there has been a marked shift in the dynamics of energy supply and demand, resulting in significant disparities between these two variables throughout the year. To address this imbalance, energy storage technologies have emerged as a potential remedy to facilitate the integration of renewable energy sources. Among these technologies, underground hydrogen storage has received considerable attention as a viable option for large-scale energy storage. Hydrogen can be stored in various subsurface structures, including aquifers, depleted oil and gas reservoirs, and salt caverns. Aquifers, defined as layers of permeable and porous rock containing fresh or saline water at considerable depths, are widespread in sedimentary basins worldwide. Therefore, exploring the potential of utilizing aquifers for hydrogen storage may help overcome the geographical constraints associated with alternative storage options.
The retrieval of stored hydrogen is a critical consideration that can significantly impact feasibility assessments and performance projections of the storage process. Factors such as hydrogen dilution with cushion gas, chemical reactions, and entrapment within the aquifer can lead to reduced hydrogen recovery. These phenomena are influenced by pore structure, interfacial properties between hydrogen and water, and flow dynamics.
Accurate modeling of the injection-production cycles to estimate the residual hydrogen saturation, and consequently the recoverable amount of hydrogen, necessitates time allocation and multi-phase flow parameters, often unavailable. As a result, machine learning methods have been explored for sensitivity assessment and displacement efficiency estimation. In this study, a machine learning approach was employed to predict the sweep efficiency of hydrogen –water displacement in synthetically designed porous media.
To achieve this objective, artificial porous environments with varying particle size distributions and random spatial arrangements were generated and incorporated into the simulation software. A numerical model was developed to simulate displacement processes within these environments. The simulation results, including the image of the porous medium, and the parameters defining the displacement scenario such as injection rate, fluid properties, and interfacial characteristics, were utilized as input data to the algorithm. During the training phase using machine learning, two approaches based on image processing of the porous medium—Multi-Layer Perceptron (MLP) and Convolutional Neural Network (CNN)—were employed. The primary goal of both algorithms was to predict displacement performance and saturation profiles within the porous space. The results show the aptness of these algorithms for prediction of recoverable hydrogen in terms of the porous medium's description and two-phase flow parameters.

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