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Underground Hydrogen Storage for Cleaner and Sustainable Future

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Extended Abstract

Global carbon emissions continue to increase despite the efforts to decarbonise.CO_2 emissions increased by 1.5% in 2022 relative to 2021, reaching 36.1 $GtCO_2$ globally [1]. So, more efficient decarbonising efforts should be implemented. Using hydrogen as a clean energy carrier is one emerging path, although it has several challenges. Because of hydrogen's lowest density, storage is one of its main challenges. Gaseous hydrogen storage requires a higher volume, liquid phase storage requires higher energy, and solid-state methods are still in their infancy [2]. Gaseous storage is the most common and popular method because of the low energy requirement and the industry's novelty. Underground hydrogen storage (UHS) is a potential method that has emerged to overcome the challenge of high-volume requirements. It also benefits from higher storage pressures, longer operational lifetime, higher safety, lower investment costs and a smaller surface footprint [3, 4]. The stored hydrogen can be withdrawn and utilised conveniently based on the application type and duration. Potential UHS locations include depleted hydrocarbon reservoirs, aquifers, and rock and salt caverns. However, several challenges exist, including hydrogen loss due to solubility and bio- and geochemical reactions with underground residual phases like hydrocarbons, brine, and minerals. Because of the reactivity, petrophysical and petrographic properties can be changed, affecting storage capacity and diffusion rates. Very little research has been done in the literature to understand the mineralogical variations in an underground system, and some results are contradictory. It was found that hydrogen has little impact on silicate minerals and high reactivity with clay minerals and calcite [5, 6]. However, some have found no interaction between calcite and clay minerals [7, 8] but a possibility of reactions based on the presence of bacteria [9, 10].

Focusing on the above research gap and contradictions, this study is pioneering in its aim to understand the feasibility of UHS by addressing challenges on reactivity and petrographic and petrophysical variation of the reservoir and cap rock after the injection and storage of hydrogen. This investigates the impact of hydrogen on the reactivity of reservoir rock and caprock and how this influences long-term storage behaviour, emphasising the microstructural and mineralogical changes resulting from fluid-rock and fluid-fluid interactions induced by hydrogen injection. A high-pressure saturation chamber is developed to replicate a typical hydrogen storage system and to understand the reactivity of hydrogen with the reservoir and cap rock. Actual field core samples of sandstone and claystone were collected from the Western Australian core library. They will be used for the experiment series under 10 MPa and 80ºC conditions to mimic the actual field conditions. XRD, SEM, Micro-CT, and ICP-OES analysis will be done to analyse the powder samples, thin slices and liquid solutions before and after the hydrogen injection. To validate the experimental results and to predict the long-term reactivity, a PHREEQC model will be developed for the underground reservoir, quantifying the mineral reactivity and hydrogen loss.

The storage capacity and hydrogen loss due to the reactivity are crucial to measuring the efficiency of the storage system. So, this study will conduct a detailed chemical analysis on a nano-micro and meso scale with different underground conditions and parameters, focusing on experimental and modelling methods.

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