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Effects of Aquifer Salinity on Underground Hydrogen Storage

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Underground hydrogen storage (UHS) is a promising technology for enabling large-scale clean energy resilience. Deep saline aquifers, known for their abundance and ample storage capacity, are promising sites for UHS. Despite considerable research on the technical feasibility of UHS in saline aquifers, a significant knowledge gap persists regarding the impact of aquifer salinity on UHS performance. To bridge this gap, we conducted high-fidelity reservoir simulations to quantitatively evaluate the effects of salinity on three critical UHS performance metrics: the maximum reservoir pressure buildup, the liquid-gas ratio of the produced fluids, and the hydrogen withdrawal efficiency. Our results indicate that aquifer salinity significantly impacts the UHS performance. Hydrogen injection into saline aquifers can desiccate the near-well formation, causing salt precipitation that reduces the formation porosity and permeability. Under the geological and operational conditions of our simulations, the precipitated halite is mostly dissolvable in aquifers with a salinity not exceeding 10%, causing only minor permeability reduction. Within this range, an increasing salinity can benefit UHS performance by decreasing the produced liquid-gas ratio and improving the hydrogen withdrawal efficiency, without significantly raising the maximum reservoir pressure buildup. However, when the aquifer salinity rises to 15% or higher, UHS operations suffer from massive halite accumulation during successive storage cycles. Such accumulation elevates halite saturation, severely clogging the near-well zone, drastically increasing the maximum reservoir pressure buildup, and reducing hydrogen withdrawal efficiency. To our knowledge, this is the first study to evaluate the effects of aquifer salinity on UHS performance at the field scale. Our proposed simulation workflow can be applied to any saline aquifer targeted for UHS, yielding useful insights for site selection, design, and operational management of future UHS projects.

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References

Primary author: MAO, Shaowen (Los Alamos National Laboratory)

Co-authors: MEHANA, Mohamed; YU, Siqin (Stanford University); Prof. MORIDIS, George (Texas A&M University); Dr KANG, Qinjun (Los Alamos National Laboratory); Dr GROSS, Michael (Los Alamos National Laboratory)

Presenter: Dr GROSS, Michael (Los Alamos National Laboratory)

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