Investigation of Brine Exchange between Kansas Oil Reservoirs as an Alternative Means of Produced Water Management

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Introduction

Brine exchange (Figure 1) has potential to facilitate the beneficial reuse of produced water (saline wastewater generated during oil extraction). However, geochemical incompatibility between brines may lead to precipitation reactions[1], which in turn would result in damaged equipment and inhibition of oil recovery due to rock pore blockage[2]. To address these concerns and to assess the financial feasibility of brine exchange, we conducted:

- Mixing experiment (Figure 3) followed by ICP-OES analysis of Ca and Mg concentrations
- Geochemical modeling using various thermodynamic databases (Figure 6)
- Construction of an economic model (Figure 2) incorporating construction cost, energy requirements, and increased oil recovery benefits

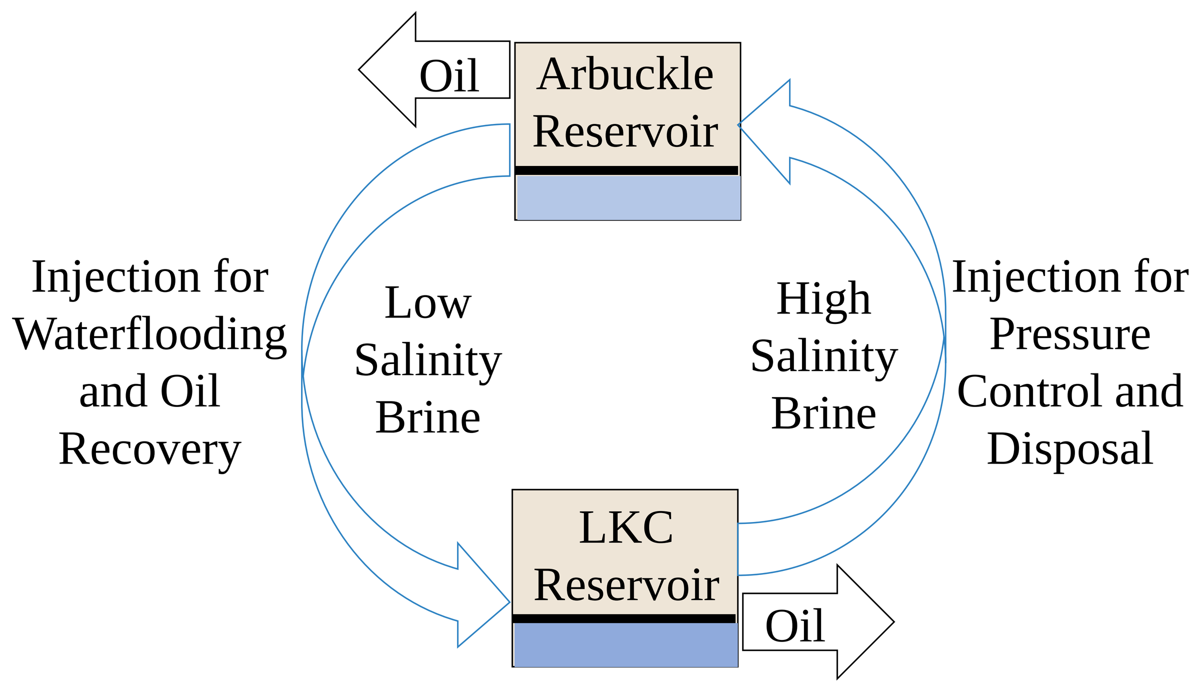

Figure 1 Proposed brine exchange sequence between Arbuckle and LKC reservoirs

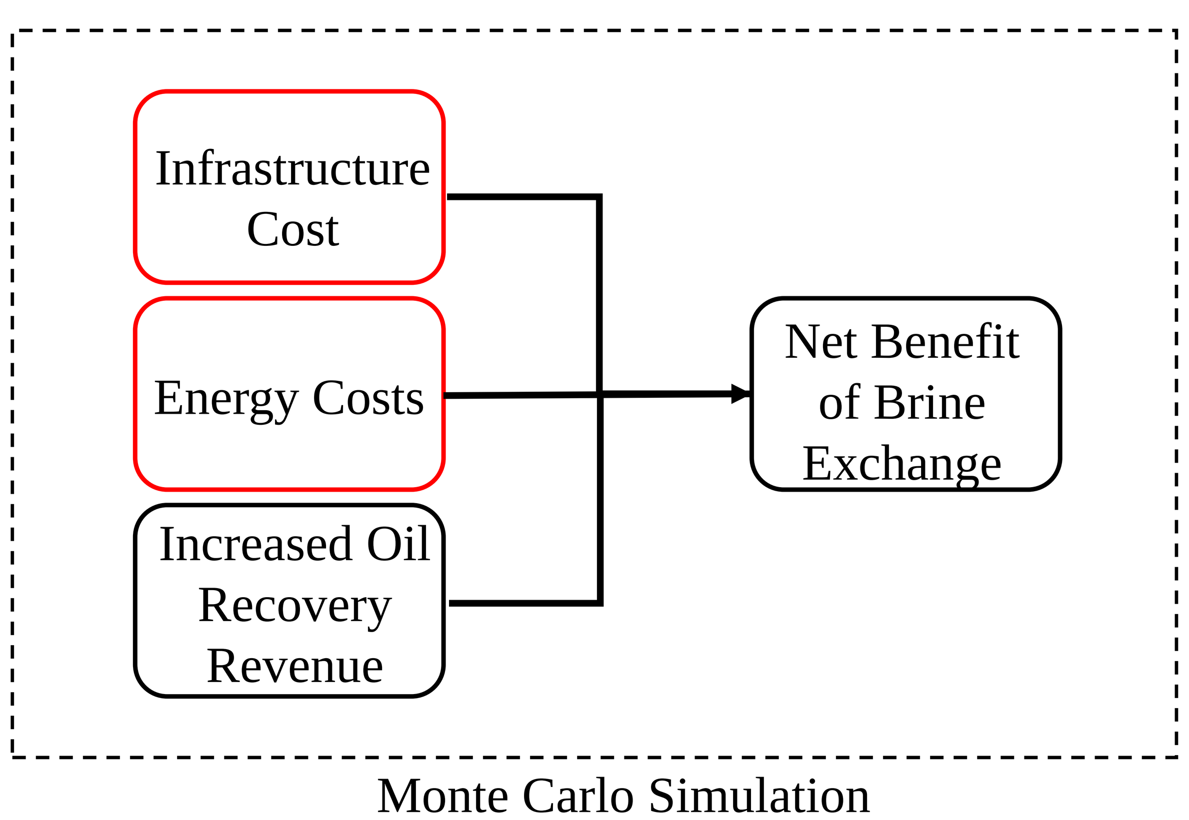

Figure 2 Inputs of economic analysis model. Monte Carlo simulation conducted by running multiple iterations

Methodology

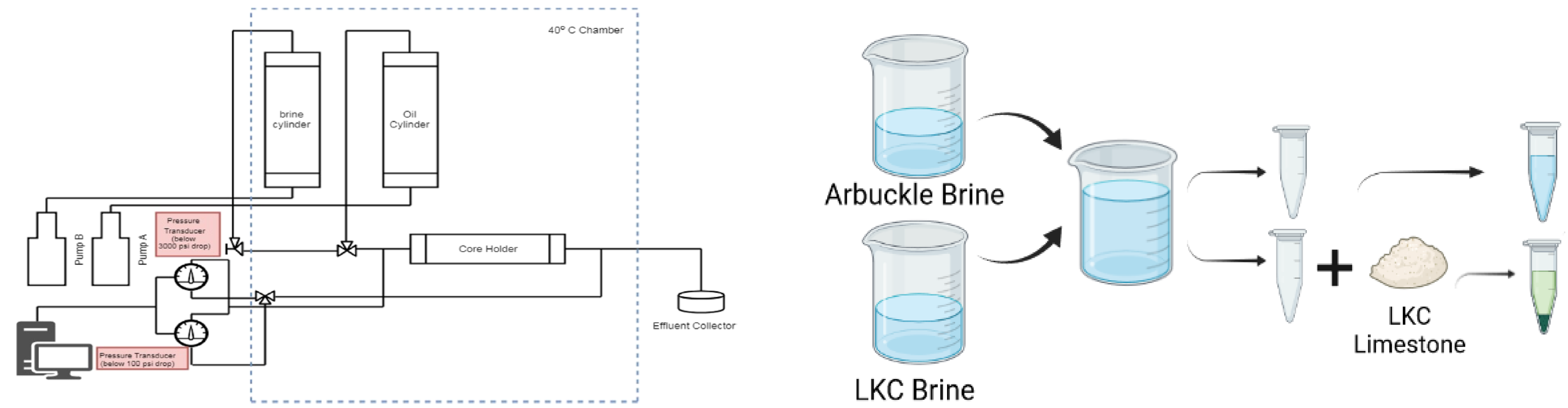

Figure 3 Coreflooding experiments[3] (Left) were conducted to evaluate compatibility under real world conditions by incorporating fluid flow through rock media while bulk mixing experiments (Right) were conducted to evaluate brine compatibility in Liquid-Liquid and Liquid-Liquid-Solid conditions. Samples were analyzed via ICP-OES to measure Ca and Mg concentrations

Results

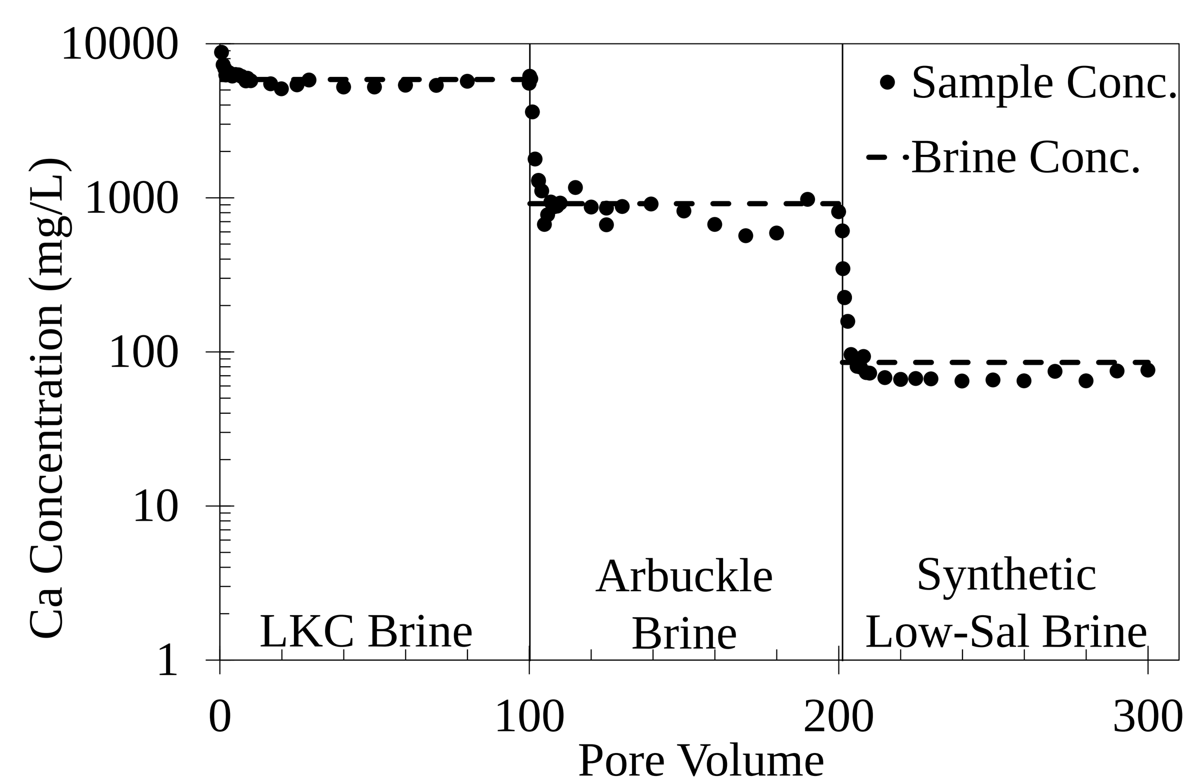

Figure 4 Ca concentration of coreflooding effluent. Core sample was flooded with three brine samples to evaluate effects of injection of brines with progressively lower ionic concentration. Similar trends were observed for Mg

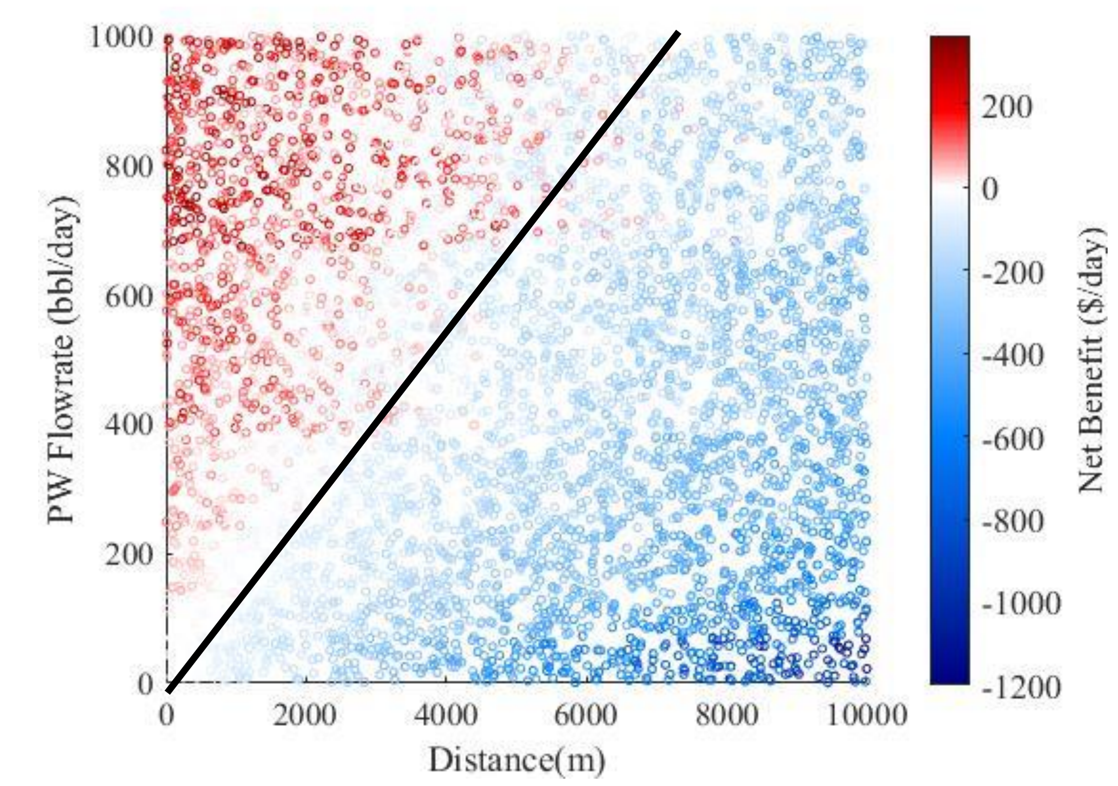

Figure 5 Monte Carlo simulation of economic analysis with approximate breakeven line plotted. Analysis incorporated construction cost, energy requirements, and enhanced oil recovery benefits

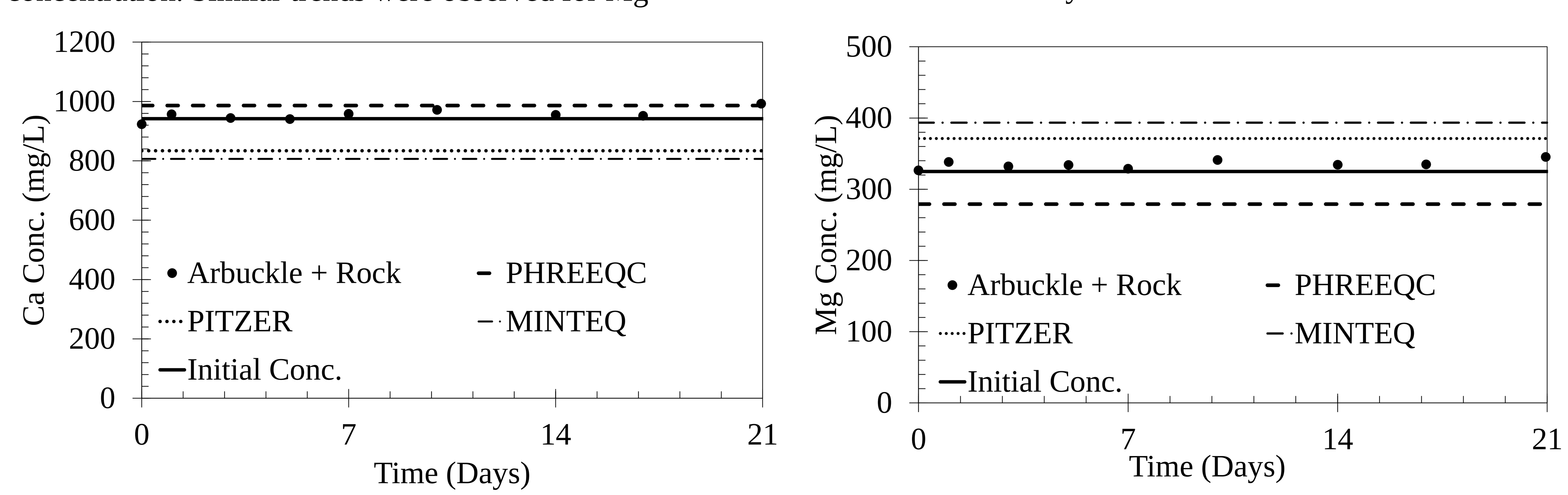

Figure 6 Ca (Left) and Mg (Right) concentrations of Arbuckle brine mixed with limestone from the LKC formation. Predicted concentration utilizing various thermodynamic databases plotted alongside experimental values

Conclusions

The following are key takeaways from the results of the mixing experiments, geochemical modeling, and economic analysis:

- Minimal mixing occurs between injected brine and in-situ brine as the injected brine displaces the in-situ brine within 10 PV
- Due to brine displacement, the most significant geochemical process occurring is the Liquid-Solid interaction between the Arbuckle brine and LKC reservoir rock
- Incompatibility between the Arbuckle brine and LKC rock is not expected as there was no significant decrease in Ca or Mg concentrations of the mixture
- Variations in the geochemical predictions are due to differences in how each database corrects for salinity as well as number of potential solid species formed through precipitation
- Economic analysis revealed the viability of conducting brine exchange is highly dependent upon the distance between wells and the flowrate of brine

Future Direction

- Refine geochemical modeling by evaluating additional produced water samples and fit of thermodynamic databases
- Conduct large scale pilot brine exchange operation to investigate effects on oil recovery
- Validate economic modeling by comparing predictions to real world construction data

References

1. Mokhtari (2019). 10.1016/j.petrol.2019.106194
2. Wang (2020) 10.1016/j.fuel.2020.117156
3. Tetteh (2020). 10.1016/j.cis.2020.102253