Task Group 4:
Assessment of Mt. Simon Sandstone Brine Chemistry for DDU Technology at the University of Illinois at Urbana-Champaign campus

Subtask 4.2: Geothermal Fluid Handling

The objective of this Subtask was to review available brine chemistry data for the Mt. Simon Sandstone in the Illinois Basin and make calculations to predict the potential for mineral scaling and precipitation that could occur based on expected changes in temperature, pressure, and/or exposure to air or other materials as brine is extracted and injected.

A representative composition of brine chemistry was selected for evaluation from data compiled for the BEST project (Okwen et al., 2017). An initial calculation of solubility at 77°F (25°C) indicated that several compounds are nearing their solubility limits, including calcium carbonate, calcium sulfate, barium sulfate, and ferrous carbonate. The likelihood of precipitation depends on variation in the pH, temperature, and quantity of dissolved CO2 in the brine.

Additional calculations were made using a different method to estimate the relative saturation of several minerals over a range of temperatures (90–110°F). Calcium carbonate and barium sulfate show scaling potential; insoluble iron and manganese oxides may precipitate and cause scaling if exposed to oxygen. Calcium sulfate dihydrate (gypsum), calcium sulfate (as anhydrite), ferrous carbonate, and silica show precipitation potential.

Treatment Concepts

The objective of this part of the assessment was to identify, develop, and estimate the costs for brine treatment procedures for managing and mitigating scaling and precipitation. Given the relatively high flow rate through the piping system and elevated level of dissolved solids in the brine, treatments were considered that would minimize the amount of bulk chemicals used and waste sludge produced.

Using a phosphonate-based scale inhibitor, such as a derivative of diethylenetriamine penta-(methylenephosphonic acid), could eliminate scale formation. A typical application would require ~10 ppmw of inhibitor in water. At a flow rate of 6,000 barrels per day (bbl/day), ~2.5 gallons/day of inhibitor would be required. This would add ~$75/day to overall operating costs. Based on the heating rate of 2 MMBtu/hr, the addition of inhibitor accounts for ~$1.60/MMBtu; an insignificant increase compared to the total operating cost.

In addition to scale inhibitors, filtration may be needed to remove suspended solids before injection. Based on results from a previous study of the Mt. Simon Sandstone (Kaplan et al., 2017), a significant amount of suspended solids (~ 2,800 mg/L) could accumulate during injection. Circulating 6,000 bbl/day would create ~3 metric tons/day (dry weight).

Brine from the Mt. Simon Sandstone is relatively corrosive to metal due to high levels of dissolved solids. Therefore, the brine should be transported in high density composite pipes manufactured using various materials, including PVC, CPVC, or fiberglass. Brine contact with heat exchangers and pumps manufactured from carbon steel must be avoided. Furthermore, stainless steel alloys may be unsuitable due to the high chloride concentration. A higher-grade alloy, such as Hastelloy® or titanium, would be required. Typically, a titanium pipe is up to 5 times the cost of stainless steel.

Impact of Water Flow on Sizing of Heat Exchanger

Compared to fresh water, brine from the Mt. Simon Sandstone has a lower thermal diffusivity and will consequently require larger heat exchangers. The impacts on heat exchangers regarding the expected differences in brine viscosity, density, heat capacity, and thermal properties were evaluated. For turbulent flow, variations in the heat transfer coefficient (and the required size of the heat exchanger) can be calculated while also evaluating changes to the physical properties of brine using the Colburn equation heat transfer correlation:

$$Nu = 0.023 Re^{0.8} Pr^{1/3}$$

Where Nu is the Nusselt number (the ratio of convective to conductive heat transfer), Re is the Reynolds number for fluid flow, and Pr is the Prandtl number (ratio of momentum diffusivity to thermal diffusivity).

Changes in flow rate or pipe diameter lead to variations in the heat transfer coefficient that are in the following proportions with these parameters:

- Thermal conductivity changes by $\lambda^{2/3}$
- Viscosity changes by $\eta\text{-}^{0.467}$
- Density changes by $\rho^{0.8}$
- Heat capacity changes by $c^{0.33}$

The estimated relative properties of the brine and fresh water are shown in Table 1. In this example, the brine contains 20 wt. % sodium chloride solution and has a temperature between 80–100°F.

Table 1: Estimated physical and thermal properties of fluids (from ASHRAE, 2017)

Property	Fresh Water	Brine
Thermal conductivity	1	0.78
Viscosity	1	1.60
Density	1	1.15
Heat Capacity	1	0.82

Based on these values, the heat transfer coefficient of brine from the Mt. Simon Sandstone could be ~30% lower than for fresh water under identical flow conditions. For heat exchange between the brine and fresh water loop, about half of the resistance in heat transfer might be on the brine side. This translates to a 20% decrease in the heat transfer coefficient.

References

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) (2017). “ASHRAE Handbook”. American Society of Heating, Refrigerating and Air Conditioning Engineers Atlanta, GA, 1088 p.

Kaplan R, Mamrosh D, Salih HH, Dastgheib SA. (2017). “Assessment of desalination technologies for treatment of a highly saline brine from a potential CO2 storage site”. Desalination, 404, 87-101. http://dx.doi.org/10.1016/j.desal.2016.11.018

Okwen R, Frailey S, Dastgheib S. (2017). “Brine Extraction and Treatment Strategies to Enhance Pressure Management and Control of CO2 Plumes in Deep Geologic Formations”. U.S. Department of Energy, Office of Scientific and Technical Information (OSTI), 349 p. http://dx.doi.org/10.2172/1363792