Surface Mixing as Method for Minimizing Leakage Risk in CO2 Sequestration

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ABSTRACT

The economic feasibility and stakeholder acceptance of geologic CO2 sequestration must account for the risk of leakage from the target formation. The standard approach to geologic sequestration assumes that CO2 will be injected as a bulk phase. In this approach, the primary driver for leakage is the buoyancy of CO2 under typical deep conditions (depths > 800 m). An alternative approach is to dissolve the CO2 into brine at the surface, then inject the saturated brine into deep subsurface formations. The CO2-laden brine is slightly denser than brine containing no CO2, so ensuring the complete dissolution of all CO2 into brine at the surface prior to injection will eliminate the risk of buoyancy-driven leakage.

We estimate that the power consumption for injecting CO2 saturated brine is comparable to that for injecting bulk phase CO2 (Fig. 2). Injecting saturated brine requires greater initial capital investment than required for injecting bulk CO2 (Fig. 14) and a large volume of available brine (Fig. 3).

INTRODUCTION

A typical case of interest is the CO2 emission from a 1000MW coal-fired power plant which amount to 8Mt CO2/year (Benson, 2006) with realistic capture of 80% of the CO2 (Fisher, Better, Hunter, Sweney, Rochelle, & Jasmin, 2005). The mass, mole, and volumetric flow rates of the captured streams are shown in Table 1.

TABLE 1: Carbon dioxide disposal rates for 1000MW coal-fired power plant.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Mass Flow Rate (tonne/year)</th>
<th>Mole Flow Rate (mmole/year)</th>
<th>Volumetric Flow Rate (m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal-fired Plant</td>
<td>35,333</td>
<td>353,330</td>
<td>1,050,000</td>
</tr>
<tr>
<td>CO2 captured from 1000MW Coal-fired Plant</td>
<td>2,540,000</td>
<td>2,540,000</td>
<td>34,900</td>
</tr>
</tbody>
</table>

RESULTS and DISCUSSION

We compare CO2 saturated brine injection strategy (Fig. 2) and CO2 bulk phase injection strategy (Fig. 3) by measuring power consumption (Fig. 7-9) and capital costs (Fig. 10-12). The direct comparison can only be made from injection into same aquifer by means of the reservoir and wellbore model (Fig. 4-6). The information in Figure 5 can be combined with Figure 8 and 11 to produce Figure 13 and 14. Figures 13 compares the power consumption of the two strategies, and Figure 14 compares the capital costs.

Soil Mixability: We modeled the solubility of CO2 in brine with the Duan-EOS equation of state fitted by Hangx (2005). The solubility is pressure, temperature, and salinity (sodium chloride, NaCl) dependent. We fixed the temperature at 68°F, but we varied the pressure and salinity to observe the soil mixability. With the solubility expressed as mole fraction and the rate of CO2 from the power plant (shown in Table 1), we determine volumetric flow rate of brine (see Fig. 1).

Reservoir and Wellbore Model: The pressure in the wellbore can be related to the reservoir property NaCl permeability height product) by use of the steady-state reservoir performance equation (Eq. 1) given by Economides (1993). The AH for the reservoir varies from 2.5 x 10^9 to 2.5 x 10^9. After modeling the reservoir, we developed a simple wellbore model that can be applied to either strategy based on the mechanical properties of the reservoir to include the contribution of gravity and friction to the pressure profile along the length of the well (Eq. 2). We use the wellbore model to determine the pressure at the wellhead (Fig. 4, 5, 6). The wells are assumed to be represent a reservoir pressure of 100-3000psi (Fig. 3), determined by the wellbore model to determine the pressure at the wellhead (Fig. 4, 5, 6). The wells are assumed to be.

CONCLUSIONS

- The operating and capital costs for the saturated brine injection strategy proposed here are comparable with bulk phase CO2 injection.
- The operating costs (related directly to power consumption) will be competitive (Fig. 13) between the two strategies—assuming the source brine is cheap and low salinity.
- The capital costs for injecting saturated brine will exceed those for injecting bulk phase CO2 by ~20 million, although we assume a ~$500 million project and 6% of the annual operating budget of the capture process.
- Most importantly, risk of migration to the surface has been minimized, hence, monitoring of the subsurface CO2 will not be necessary.

FUTURE WORK

- Are there reservoirs available with storage capacity for the injected brine?
- Are there fluids sources (brine or seawater) available in sufficient quantity?
- With such a large injection volume, will become the displaced fluid?
- If the brine must be lifted from the same reservoir, what are the added operational costs and capital costs?

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