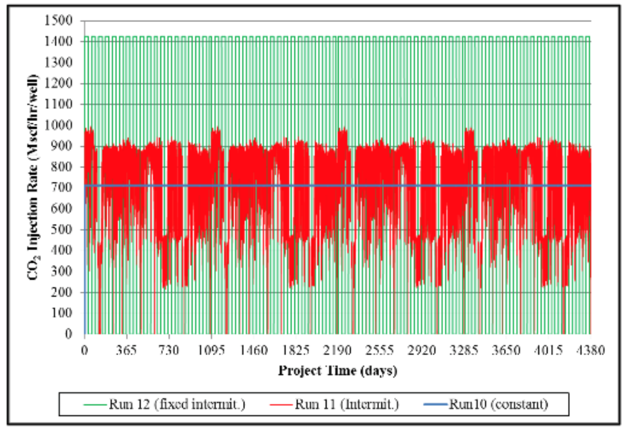
Unconventional EOR: Impact of CO_2 Source Intermittency

Project Description

Sources of large-volume anthropogenic (LVA) CO_2, such as gas processing plants and coal-fired power plants, could serve as a major CO_2 supply in enhanced oil recovery (EOR) fields. As expected, CO_2 emitted from utilities would fluctuate on a daily and seasonal basis, and this concern necessitated a study to investigate the impact of intermittent emissions of LVA CO_2 on EOR operations. The GCCC sponsored a thesis on reservoir performance and impact from using large-volume, intermittent, anthropogenic CO_2 for EOR.



Three injection scenarios assumed for study on source intermittency

Methods

The study involved direct use of CO_2 in EOR from three years of hourly CO_2 emissions data from a Texas coal plant. The 3 years of data was repeated four times to develop 12 years of CO_2 emissions data to be piped to the EOR field. Each fourth-hour data point was used. All CO_2 produced was recycled and had to be reinjected before purchased CO_2 from the pipeline could be injected. CO_2 is transported as a supercritical fluid, which must maintain a temperature of above 87.8°F (31°C) and high pressure of above 1,071 psi (7.38 MPa).

Sweep efficiency is critical to minimizing the impact of CO_2 recycling on reservoir storage potential. This study assumed pure CO_2 injection to maximize the reservoir volume available for storage. As reservoir pressures are elevated and CO_2 recycle rates increase, the volume of anthropogenic CO_2 that can safely be injected is reduced over time.

An existing Cranfield reservoir model was modified to inject CO_2 emissions. The reservoir model assumed five injection wells and two production wells. The fault was always a closed boundary, and other boundaries were analyzed as both open and closed.

An injection pressure limit was set at 7,000 psi, which is 90% of the reservoir fracture pressure, to incorporate a factor of safety. The emission piped to the field was evenly divided among the five injectors.

To test the impact of CO_2 intermittency on EOR, three injection scenarios were used. Each scenario had an equal amount of cumulative CO_2 injection after 12 years.

- **Constant injection:** Same injection rates over 12 years.
- **Intermittent injection:** Injection rate is based on CO_2 emission from utility company (equals emission data).
- **Fixed intermittent:** Monthly alternating injection rates from maximum rate to zero injection.

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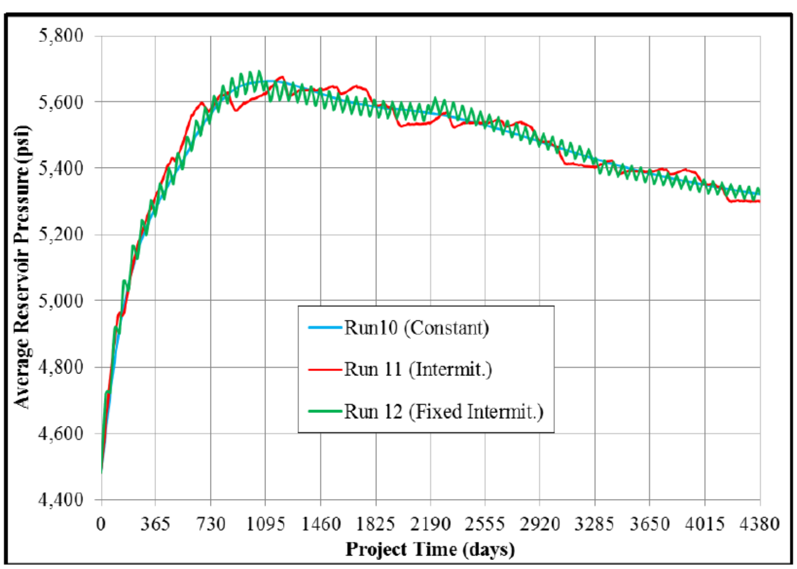
Key Findings

- Injection optimization may extend CO_2 breakthrough, improve storage efficiency, and improve oil production.
- With a given volume of CO_2 injected, intermittency does not impact cumulative oil production.
- As reservoir pressures are elevated and CO_2 recycle rates increase, the volume of "purchased" CO_2 that can safely be injected is reduced over time.
- With an adequate price on CO_2 emissions, additional storage formation(s) must be utilized to effectively inject and store all CO_2 captured from a coal-fired power plant at one field.
- Given the volume of CO_2 being injected, heterogeneity restrictions can be overcome with time, extending the production life as CO_2 has time and pressure to invade lower permeability regions.
- Although the production rate may vary at different times, equal oil production was achieved if an equal volume of CO_2 was injected in each scenario.
- Provided a specified volume of anthropogenic CO_2 is supplied for a given period, the rate and frequency at which that volume of CO_2 is delivered to the EOR field should not impact overall oil production.
- Intermittency in the initial three-year simulations increased production.
- Oil recovery from LVA CO_2 EOR is a function of total pore volumes injected and not CO_2 injection rate.
- Sustaining higher injection rates is subject to permeability because increased permeability prevents reaching the injection pressure limit even at higher injection rates.
- Lower injection rates per well helped maintain a better storage efficiency.
- With more open boundaries, the injection fluctuations are more pronounced at the production wells and throughout the reservoir.
- Because of CO_2 buoyancy, a greater volume of oil is contacted and displaced in the upper portions of the reservoir.
- To improve performance of LVA CO_2 EOR, well spacing should be reviewed, and the volume of CO_2 injected per well should be optimized.



Average reservoir pressure over time for each intermittency scenario.

Additional Findings

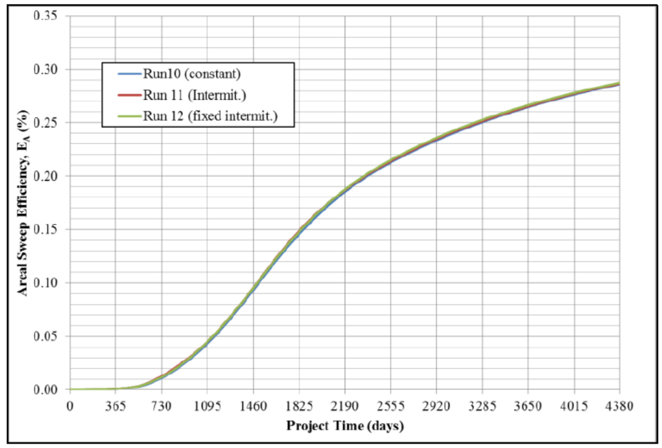
Carbonate and clastic reservoirs are viable candidates for LVA CO_2 EOR. In addition to the volume of CO_2 injected, other factors affecting oil recovery such as oil properties, mobility ratio, reservoir characteristics, and heterogeneity were examined.

The mobility ratio is a critical aspect in determining CO_2 breakthrough and oil displacement efficiency. The longer CO_2 breakthrough can be delayed, the less CO_2 is recycled, thereby improving storage efficiency.

For effective CO_2 EOR, oil gravity must be greater than 22° API for miscible displacement of oil. Miscibility is controlled by critical pressure and temperature of CO_2 and is defined by reservoir depth and oil composition. Oil viscosity of less than 10 cp is preferred, as well as a high-percentage composition of C5 to C12 and a minimum oil saturation of 20%.

Impurities like methane (CH_4) reduce miscibility, whereas hydrogen sulfide (H_2S) improves it. The minimum miscibility pressure (MMP) of injected CO_2 must be exceeded for multiple-contact miscibility (MCM) in an EOR field. A minimum accepted depth of 2,500 ft is required for maintaining miscible displacement. Greater depth is required for heavier oils because pressure and temperature increase with depth to create CO_2 miscibility with denser oils.

Deep, large, and permeable oil reservoirs are more capable of accepting LVA CO_2, with less risk of fracturing the reservoir or the overlying confining unit. Deeper reservoirs can have a higher injection pressure limit, most likely improving the overall injection efficiency of the field.



Areal sweep efficiency in the three intermittency scenarios.

Shallow reservoirs must have more ideal characteristics to compensate for the lower injection pressure threshold. CO_2 initially invades and displaces oil in the higher permeability regions, but reservoir heterogeneity is overcome as CO_2 eventually invades lower permeability regions.

Just as different injection wells have different injection efficiencies, their capacity to inject more or less CO_2 is also different. The injection rates for each well could be optimized to increase the overall injection efficiency. High vertical permeability in horizontal reservoirs can create preferential flow paths, or thief zones, for the CO_2. Thief zones cause CO_2 to bypass a significant volume of recoverable oil and allow early breakthrough of CO_2 in the production wells.

Citation

Coleman, S. H., 2012, The reservoir performance and impact from using large-volume, intermittent, anthropogenic CO_2 for enhanced oil recovery: The University of Texas at Austin, Master's thesis, http://repositories.lib.utexas.edu/handle/2152/ETD-UT-2012-05-5351.

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