Old Wells, Potable Water, and Carbon Dioxide-Enhanced Oil Recovery and Sequestration Projects in the Appalachian and Illinois Basins of Kentucky*

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Search and Discovery Article #80140 (2011)
Posted March 11, 2011

*Adapted from oral presentation at AAPG Eastern Section Meeting, Kalamazoo, Michigan, September 25-29, 2010

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Abstract

Seventy Paleozoic reservoirs in 51 oil fields were evaluated with data from the Tertiary Oil Recovery Information System for carbon dioxide-enhanced oil recovery (CO₂-EOR) and sequestration potential. The fields and their respective reservoirs were ranked into quartiles using the reservoir parameters oil gravity, CO₂ storage density, porosity X oil saturation, and permeability X net pay thickness. Our analysis also showed that if maximum allowable EPA injection pressures (0.8 X lithostatic gradient) were attained during CO₂ injection, then near-miscible or miscible conditions could occur in approximately 60 percent of the fields. In doing so, however, reservoir pressures would exceed initial pressure in 92 percent of the fields.

For environmental and project efficacy reasons, repressurization is a concern in older, preregulatory fields (pre-1960) having large numbers of wells, where locations may be poorly documented and plugging integrity suspect. For example, the number of wells in the top-quartile fields ranged from 88 to 802 and discovery dates ranged from 1929 to 1965. An additional concern is possible contamination of potable groundwater as CO₂ migrates upward along improperly plugged wells or breached seal rocks. The former seems to be more likely inasmuch as the average thickness of strata between the top of the oil reservoir and base of the potable water zone equals 1,957 ft.

References


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Previous EOR Evaluation

- 70 Paleozoic reservoirs in 51 oil fields were evaluated for carbon dioxide-enhanced oil recovery (CO$_2$-EOR) and sequestration potential using Tertiary Oil Recovery Information System (TORIS) data.
- BUT—what we did not know is the condition of the infrastructure, and we still don't
Introduction

- Possible Injected CO$_2$ Leakage paths:
  - Injected CO$_2$ encounters faults, fractures, groundwater recharge areas
    - Possibility of seal fracture
  - Injected CO$_2$ flows beyond spillover point of stratigraphic or structural trap
  - Leakage out of injection wellbore or other wellbores in field
Introduction

- In KY, pre-regulatory (pre-1960) fields with a large number of wells, are a big concern for potential well leakage during CO$_2$-EOR projects
  - Poorly documented and unknown well locations
  - Suspect plugging methods/wellbore cement integrity
Previous Reservoir Assessment

- **TORIS Fields**
- **Non-TORIS Fields**

**Basins and Arch:**
- Illinois Basin
- Appalachian Basin
- Cincinnati Arch
Reservoir Screening Criteria

- The reservoirs were ranked in Excel using the parameters:
  1. porosity ($\phi$) * oil saturation ($S_o$),
  2. permeability ($k$) * pay thickness ($h$),
  3. API oil gravity,

Reservoir Screening Criteria

4. effective CO\(_2\) storage capacity:
   
   \[ \text{ESC (kilotons)} = 43,560 \times \phi \times \rho \times S_o \times 0.001 \]
   
   \(\phi\) = porosity, \(\rho\) = density CO\(_2\), \(S_o\) = oil saturation

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21 reservoirs in 19 oil fields fell into the top quartile
Summary of Reservoir Analysis

• Top quartile fields/reservoirs-83% are Miss. Ss. reservoirs in W. KY; 67% of these fields are 1,500 ft or deeper, & 83% initially exceed MMP.

• Statistical analysis shows top quartile ranking results from composite influence of all ranking parameters.

• Gross estimated CO₂ storage capacity in all 71 fields/reservoirs= 79,134,000 tons, 44% occurs in the upper quartile fields.

Assessing Potential for CO$_2$ Leakage

- Try to find data on wellbore condition
  - Well age, producing status, casing, direction, cemented intervals, timeline of field drilling activity, regulations, drilling and plugging practices before and after regulations enacted (Bachu and Celia, 2009)
  - Any wells in a field that penetrate seal rock
  - Well cement integrity

Injection Pressure and Possible Miscibility

- EPA suggested max. injection pressure = 0.8 * lithostatic gradient (1 psi per foot)
- Near-miscible or miscible conditions could occur in ~60% of the reservoirs in this study
- However, initial reservoir pressures would be exceeded in 92% of the reservoirs in this study
- Corollary: Many oil reservoirs were initially under pressure
Leakage Potential and Potable Water

- Well status issues - online well data
  - Pre-1960 fields are suspect
  - Number of wells listed as Plugged & Abandoned
    - Were these wells really plugged or plugged properly?
  - Number of active producing and injection wells

- Thickness interval between wells that penetrate a reservoir and the potable groundwater table
  - CO₂, oil, brines could contaminate potable water
Discovery Date - Top Quartile

Number of Fields/Reservoirs vs. Year

- Discovery Date
- Top Quartile
- Cumulative %

Year:
- 1905
- 1910
- 1915
- 1920
- 1925
- 1930
- 1935
- 1940
- 1945
- 1950
- 1955
- 1960
- 1965
- 1970
- 1975
- 1980

Cumulative %: 0% to 110%

Number of Fields/Reservoirs: 0 to 8

Diagram showing the discovery date and top quartile for different years.
Status and Types of Wells in Upper Quartile

- #SRI/WS/WI/SWD
- #D&A
- #PA
- #Gas
- #Oil
Target EOR-Sequestration Reservoir and Base of Potable Water Aquifer

- Thickness interval between wells that penetrate a reservoir and the potable groundwater table can be a concern
  - CO\textsubscript{2}, oil, brines could contaminate potable water if CO\textsubscript{2} is able to migrate upward via wellbores
Approximate Vertical Thickness Between Top of Reservoir to Base of Groundwater Table (All Reservoirs)

Number of Reservoirs/Fields

Vertical Thickness

- Cumulative %
Summary

- Attaining miscible/near miscible conditions requires pressures > original pressures for 96% of fields.
- Concern for leakage out of wellbores in field.
- CO₂, oil, brines could contaminate potable water if CO₂ is able to migrate upward via wellbores.
- 47% fields studied-vertical thickness between potable water & oil reservoir < 1000 ft.
Future Research

• Thorough documentation of water chemistry for reservoirs above EOR reservoir in order to corroborate possible leakage from oil reservoirs

• Assessing leakage from a large number of wellbores is an operational challenge

• Before implementing a project, use stochastic modeling to get a feel of the probability of leakage