Industrial Waste-Fluid Disposal and Availability of Pore-space: Technical and Regulatory Challenges

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Kansas oil field where CO2-EOR has been modeled
Outline

• Underground Injection Control (UIC) Class I, II, and VI in KS
• Induced seismicity in KS and OK and implications for CCUS:
  – Aquifer fill-up?
  – Competition for resources?
• Resource characterization
  – Capacity estimations for CO₂ geological storage/disposal
  – Alternatives, solutions, path forward?
Who is Injecting in Arbuckle?

• UIC Class I – Kansas Department of Health and Environment (KDHE)
  – Wells used to inject hazardous wastes or dispose of industrial and municipal fluids beneath the lowermost formation containing, within one quarter (1/4) mile of the well bore, a source of fresh or usable water
  – “On vacuum” – no WHP

• UIC Class II – Kansas Corporate Commission (KCC)
  – Class II wells are used only to inject fluids associated with oil and natural gas production. Class II fluids are primarily brines (salt water) that are brought to the surface while producing oil and gas
  – Some WHP is allowed (~500 psi)

• UIC Class VI - ???
Class I & Class II Disposal Volumes (2015)

2015 Class I Injection Volume 2015 Class II Disposal
Millions of Barrels Millions of Barrels

- >.25  - >.25
- .25 - .5  - .25 - .5
- .5 - 1  - .5 - 1
- 1 - 5  - 1 - 5
- 5+  - 5+

Sources: Kansas Department of Health and Environment, ESRI, USGS, Kansas Corporation Commission, Kansas Geological Survey
Earthquakes over time
Kansas Arbuckle disposal wells

- 49 Class I and 2381 Class II Arbuckle wells across Kansas
- Volumes increase in 2005, peak in 2013-2014 to >750 million barrels, and drop to 500 million barrel in 2015

Bidgoli et al., 2019
Increases in pressure and static fluid level

- Class I wells show increase in pressure and SFL
- Class II would show similar tendencies if data is available
- Pressure increase more pronounced near Harper and Sumner counties
- Reno County well (orange) shut-in for two decades
Why Arbuckle?

Although some shallower formations are used for disposal or could be used as disposal targets, Arbuckle Group tops all other formations in the MidCon region:
- Continues extent through the region
- Thickness
- Under-pressed, or pressure potential
- Reservoir properties
- Alternatives?
Geologic Setting
Basement geology from sample rock types in the area of the induced seismicity

→ thick arkosic sediment fill indicative of the Midcontinent Rift System (MRS)
Depth (in feet) Below Ground Surface to Top of Arbuckle
Salinity of Cambrian-Ordovician Arbuckle Group in Kansas
Maximum Allowable Increase in Pore Pressure from Ambient Conditions
Based on UIC Class VI rule limitation of pore pressure to not exceed 90% of fracture gradient
We monitor seismicity: no events are registered at the site.
• Reverse faults identified in the Patterson area offset the reservoir intervals, but not interrupt the Morrow Formation primary seal.

Time structure map on top of the Arbuckle Group of the Patterson-Hartland area.
Storage Units

Stratigraphy illustrated by wireline log from a key well in the Patterson Site (Longwood Gas Unit #2 well).

Sealing intervals

Barrier intervals

Storage intervals

3-D volume of permeability from the top of the basement to Meramec; map above the is the top of the Morrow; map at the base of the cross section is the top of the basement.

Modified from ICKan Project Final Report (DEFE0029474)
Additional SWDW Resources

- Cedar Hills – 820 SWDW
- Lansing-KC – 326 SWDW
- Mississippian – 264 SWDW
- Glorietta – 101 SWDW
- Stalnaker – 86 SWDW
- Topeka – 54 SWDW
- Hunton – 51 SWDW

Maybe it is time to update inventory?
**CO₂ EOR in Kansas**

### Kansas Oil Production is Falling

![Graph showing Kansas oil production trend from 1950 to 2020.](image)

**Numerous Potential Sites for EOR**

![Map showing potential EOR sites in Kansas.](image)

<table>
<thead>
<tr>
<th>Basin</th>
<th>EOR Potential (mill bbl)</th>
<th>Net CO₂ Demand (MMT)</th>
<th>Direct Jobs Created</th>
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<tbody>
<tr>
<td>Illinois-Indiana</td>
<td>500</td>
<td>160-250</td>
<td>1550-3100</td>
</tr>
<tr>
<td>Ohio</td>
<td>500</td>
<td>190-300</td>
<td>1550-3100</td>
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<tr>
<td>Michigan</td>
<td>250</td>
<td>80-130</td>
<td>800-1800</td>
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<tr>
<td>Kansas</td>
<td>750</td>
<td>240-370</td>
<td>2300-4600</td>
</tr>
<tr>
<td>2000</td>
<td>670-1050</td>
<td>3200-12400</td>
<td></td>
</tr>
</tbody>
</table>

### Injection Rate, CO₂ Storage, Primary and Secondary CO₂ EOR (MMBO)

<table>
<thead>
<tr>
<th>Site</th>
<th>Injection Rate (Mt/yr)</th>
<th>CO₂ Storage (Mt)</th>
<th>Primary and Secondary (MMBO)</th>
<th>CO₂ EOR (MMBO)</th>
<th>Basis for Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuck</td>
<td>0.4</td>
<td>1.5</td>
<td>7.9</td>
<td>3.6</td>
<td>DE-FE000256</td>
</tr>
<tr>
<td>Cutter</td>
<td>0.5</td>
<td>1.3</td>
<td>5.4</td>
<td>2.8</td>
<td>DE-FE000256</td>
</tr>
<tr>
<td>N Eubank</td>
<td>0.6</td>
<td>1.5</td>
<td>7.4</td>
<td>4.6</td>
<td>DE-FE000256</td>
</tr>
<tr>
<td>Pleasant Prairie</td>
<td>0.3</td>
<td>0.5</td>
<td>4.7</td>
<td>2.2</td>
<td>DE-FE000256</td>
</tr>
<tr>
<td>Hall-Gurney</td>
<td>1</td>
<td>11.3</td>
<td>62.5</td>
<td>26.8</td>
<td>DE-AC26-00BC15124 and Pilot C12 Energy</td>
</tr>
<tr>
<td>Trapp</td>
<td>0.5</td>
<td>4.3</td>
<td>31.3</td>
<td>10.3</td>
<td>KGS reports</td>
</tr>
<tr>
<td>Wellington</td>
<td>0.6</td>
<td>2.2</td>
<td>16.2</td>
<td>5.3</td>
<td>DE-FE0002056 and Pilot</td>
</tr>
</tbody>
</table>

**Co2 EOR Injection Sites**

Sources: EERE, USGS, Kansas Corporation Commission, Kansas Geological Survey, D45C
Alternatives and Underutilized Resources

Hugoton Gas Field for SWD?

- Pressure depletion
- Gas production is falling
- What is the capacity?
- What are the risks?

![Graph showing average reservoir pressure and gas production over time. The graph indicates a decline in gas production and a decrease in reservoir pressure.]
Resource Management

• What do we know about injection of fluids with different properties?

• What is optimal design of injection site?
  – How many wells?
  – Well density?
  – Completions?
Many Potential Pipeline Routes Cross Kansas

Crabtree (2018) Midwest Region Meeting

October 2018

Regional Carbon Capture Deployment Initiative

Multiple Entry Points into TX
Permian and East Texas Gulf

Texas EOR demand:
156 million tons CO2 / year
at $20/ton
Summary

• Competition for resources means that careful site selection is essential
• Alternative resources for disposal/storage are likely available but reevaluation and research is needed
• CO$_2$-EOR option is important for CCUS success in the Mid-Continent
• Better design of disposal well sites and management strategies are needed
• Nation-wide infrastructure could help to solve the logistics
Acknowledgements

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