The Impacts of Carbon Dioxide Storage in the Saline Arbuckle Aquifer on Water Quality in Freshwater Aquifers in Kansas

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Midwest Groundwater Association Conference
Lawrence, KS

October 1st, 2014
Global CO₂ Cycle

CO₂ Cycle (billion tons per year, BT)

- Emissions: 800 BT
- Natural Sequestration: 788 BT
- Balance: 12 BT

- Atmospheric CO₂ levels rising since start of industrial era.
- Present concentrations of 400 ppm CO₂ close to 2050 target of 450 ppm.
Geologic Sequestration of CO$_2$ a Viable Bridge Technology for Post Fossil-Fuel Economy
Optimal CO$_2$ Phase for Geologic Sequestration

- CO$_2$ most dense in supercritical phase

- Supercritical conditions encountered at 1 km (3,200 ft) below ground
Arbuckle Aquifer Targeted for Sequestration in Kansas

- Cambrian-Ordovician Arbuckle aquifer (Dolomitic)

- Top of Arbuckle >3,000 feet below ground in SW Kansas
Thickness of Arbuckle Aquifer

- Arbuckle ~ 1,000 ft thick in SW Kansas
- Porosity ~ 5%
Arbuckle Salinity

- Total Dissolved Solids > 100,000 ppm in SW Kansas
DOE Estimated Arbuckle CO2 Storage Capacity

Total Arbuckle CO2 capacity  ~ 60 BT
Total Annual US Emission  ~ 5.4 BT
Total Annual KS Emission  < .1 BT

Arbuckle can sequester over a century of Kansas emissions and several decades of US emissions.
Wide Spread Increase in Pore Pressures Expected Due to CO2 Injection

Multistate Scale Simulated Pressure Impacts Due to Injecting 100 MT/year for 50 years (1MPa = 145 psi)

- Will induced pressures due to commercial scale CO$_2$ injection in Kansas cause brines to migrate into freshwater aquifers through abandoned wells and faults?
Freshwater Aquifers in Kansas

- Dakota
- Glacial Drift
- High Plains/Ogallala
- Alluvial
- Ozark
Large Degree of Hydraulic Confinement and Separation Between Arbuckle and Freshwater Aquifers
Large Degree of Hydraulic Confinement and Separation Between Arbuckle and Freshwater Aquifers

CO₂ Injection Test Site in Sumner County, KS
Vertical Separation (ft) between the Top of Arbuckle and Base of Freshwater Aquifers

Dakota

High Plains
Potentiometric Surface of Arbuckle

- Merging of two regional flow fields (Rocky Mountain & Anadarko Basin)
- Groundwater flow across state takes approximately ¼ to ½ million years
Distance (ft) from Base of Freshwater Aquifers to In-situ Water Levels in the Arbuckle

- Hydraulic buffer exists to accommodate increased pressures due to CO₂ injection without causing brines to migrate into freshwater aquifers via improperly abandoned wells and open faults.
Required Increase in Pore Pressure (psi) for Migration of Brines from Arbuckle into Freshwater Aquifers

- Need to ensure these pressures are not exceeded if improperly abandoned wells or communicative faults are present within zone of influence.
Maximum Allowable Fracture-Based Increase in Pore Pressure

- Induced pore pressures should not exceed 90% of the “Fracture Gradient” in Kansas of ~ 0.75 psi/ft [EPA Class VI injection well requirement]
• Injection of 12 million tons/year of CO2 over a 50 year period at 10 targeted sites in Kansas
Simulated Sequestered Volumes of CO$_2$

- Large number of injection wells required to utilize all available pore space in Arbuckle due to injection pressure restrictions for preventing fracturing.

- Total sequestered volume over 50 year period $\sim 0.65$ BT (almost a decade of CO$_2$ emissions in Kansas).
Ongoing Field-Scale Injection Study at Wellington, KS

Goals:

• Demonstrate that CO2 plume and pressures can be simulated, monitored, and verified.

• Carbon Capture and Storage is a viable climate-change mitigation technology.
Extensive Monitoring and Visualization of CO₂ Plume and Pressures at Wellington CO₂ Test Site
Pressure and Seismic Monitoring
(Seismometer Network)
Pressure Monitoring (InSAR)
CO$_2$ Plume Monitoring
(Soil Flux and Gas)
CO$_2$ Plume Monitoring
(Borehole U-Tube)
CO₂ Plume Monitoring (Fiber Optic)
CO$_2$ Plume Monitoring  
(Cross-Hole Seismic)
CO$_2$ Plume Monitoring
(Continuous Active Source Seismic, CASSM)

Traveltime Response to CO2 Injection

Real time detection using continuous source cross-well seismic

- Sensor Depth (m)
  - 1630
  - 1650
  - 1658
  - 1666
  - 1680

Delay Time (ms)
Conclusions

• The saline Arbuckle aquifer has large capacity to store anthropogenic CO₂ emission from Kansas and surrounding states for many decades.

• Pressures due to injection will need to be managed to ensure that dissolved brine-CO₂ mixture as well as gaseous phase CO₂ does not migrate into freshwater aquifers or cause fractures to develop.

• Pressure constraint maps have been prepared to guide in developing an optimal state wide plan for commercial scale storage of anthropogenic CO₂ using computer simulation models.

• Pilot scale study at Wellington is ongoing to demonstrate the feasibility of injection and the viability of real-time CO₂ monitoring.
Acknowledgements & Disclaimer

Acknowledgements

The work supported by the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) under Grant DE-FE0002056 and DE-FE0006821, W.L. Watney and Jason Rush, Joint PIs. Project is managed and administered by the Kansas Geological Survey/KUCR at the University of Kansas and funded by DOE/NETL and cost-sharing partners.

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Required Increase in Pore Pressure for Migration of Brines from Arbuckle into Alluvial Aquifers

Delta-Pressure (psi)
• In-situ water levels lower by about 600 ft in SW Kansas due to heavier brines in the Arbuckle.