CO₂ Storage Monitoring, Verification and Accounting

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The University of Texas at Austin

- 20 years experience
- Develop and implement monitoring programs for geological CO$_2$ storage sites
- Monitored >9 demonstration CO$_2$ storage projects
- Actively monitored over 10 million tonnes of CO$_2$ in the ground
- Mostly from CO$_2$-EOR sites
Evolution of Monitoring

Pilots ➞ Demonstrations ➞ Industrial

500 T

Frio Brine Storage Pilot 2004

SECARB Early Test - Cranfield Mississippi

Injector CFU 31F1

Obs CFU 31 F2

Obs CFU 31 F3

Hastings Project

The Green Pipeline

NRG Petranova Project

1.6 MMT/year
Monitoring For New Tax Incentives and Credits

Need to demonstrate secure storage
Post-injection Site Care -100 years!

Carbon Dioxide Sequestration Credit

Carbon Capture and Sequestration Protocol
under the Low Carbon Fuel Standard
August 13, 2018
Monitoring to Show Secure Storage

- MRV Plans Approved under EPA - Subpart RR
  - One saline (ADM)
  - Four \( \text{CO}_2 \)-EOR
- Data collection from existing oil field practices

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Type</th>
<th>Date of Final Decision</th>
<th>Final Decision Documents</th>
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<tbody>
<tr>
<td>Core Energy Northern Niagara Pinnacle Reef Trend</td>
<td>MRV plan</td>
<td>October 12, 2018</td>
<td>Decision</td>
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<td>Shute Creek Facility</td>
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<td>June 20, 2018</td>
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<td>Archer Daniels Midland Company Illinois Industrial Carbon Capture and Sequestration Project</td>
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<td>January 19, 2017</td>
<td>Decision</td>
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<td>Hobbs Field</td>
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<tr>
<td>Denver Unit</td>
<td>MRV plan</td>
<td>December 22, 2015</td>
<td>Decision</td>
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Overall Plans for Subpart RR

• Mass balance approach
• Delineation of monitoring area (plume modelling)
• Leakage pathways assessment
• Leakage detection monitoring:
Main Questions from Stakeholders

• Is it safe?
• Will it leak?
• What happens if it leaks?
CCS- Safe by Design

1. Site Characterization – Permitting requires high level of assurance
2. Risk Assessment- Modeling identifies potential unwanted outcomes
3. Project Design - to minimize potential risk
4. Monitoring Plan
   Deep Subsurface – Verification
   Behavior conforms to predictions
   Shallow Subsurface - Assurance
   No unwanted outcomes to environment
Overview of Monitoring Zones

Strong variability, dynamic, many challenges, release to atmosphere, biosphere impacts

Moderate baseline variability, assurance of no damage to drinking water, easy access

Minimal variability, early detection, small signals

Static, quiet environment, variability is from CO$_2$ injection, CO$_2$/brine migration

“Near-Surface” Monitoring

Vadose zone

Shallow groundwater

Above Zone Intervals

“Deep” Monitoring

Reservoir

Figure courtesy of Sue Hovorka
The Lengths We Go To - Finding a Leak

- Soil gas Grids
- Remote Sensing
- Drones/AUVs
- Sonar
- Open path lasers
- Eddy covariance
- Hyperspectral for Vegetation health

Weyburn soil-gas grid: 14 km², 200 m spacing (Riding and Rochelle, 2009).

(Jones et al. 2009)
Walking traverses over gas vents at Latera with the ground surface measurement system (infrared analyzer) measuring CO₂ concentrations (Jones et al. 2009)

Weyburn soil-gas grid: 14 km², 200 m spacing. Jones et al., 2006, Soil Gas Monitoring at the Weyburn Unit in 2005
CO$_2$ Variability

- CO$_2$ is naturally everywhere
- Dominant source is biological respiration
- Dynamic over space and time (temperature, rainfall, pressure...)
- CO$_2$ is reactive
- Very difficult to discern leakage from natural variability.
- Difficult to determine what is anomalous

Source: DOE, 1999: Carbon Sequestration Research and Development
Determining Anomalies Using Baselines

• Measure “baseline” CO₂ for 1 year before project starts to document seasonal variability.

• Monitor CO₂ during project and compare to baseline.

• Significant increase from baseline during a project signals an anomalous CO₂ anomaly.

• Did the storage project cause the anomaly?

• “Attribution” is a missing step
# Global Regulations

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<td>Protection of the marine environment</td>
<td>Protection of the marine environment</td>
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<td>Protection of the environment (underground sources of drinking water)</td>
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<td>Only in terms of retention</td>
<td>✔</td>
<td>Only in terms of pressure and plume extent</td>
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<td>✔</td>
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“Baselines” in Soils are Shifting Upwards
Increasing shallow groundwater CO2 and limestone weathering, Konza Prairie, USA

G.L. Macpherson a,*, J.A. Roberts a, J.M. Blair b, M.A. Townsend c, D.A. Fowle a, K.R. Beisner d

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b Kansas State University, Manhattan, KS, USA
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Increased dissolution of CO2 in groundwater and associated mineral dissolution
“Baselines” in Seawater are Shifting Upwards

Time series of surface seawater CO$_2$ level near Japan. Source data by Japan Meteorological Agency, Courtesy of Jun Kita, RITE
Example – Soil Gas at Cranfield Project (Mississippi, USA)
Revelation #1

- Naturally produced CO₂ in the biosphere is increasing due to climate change
- Use of “concentration-based” or “baseline” methods will result in false positives for leakage
- The risk of false positives is greater than the risk of actual leakage
- False positives put projects at unnecessary risk
Tomakomai Project

- Tomakomai Offshore demonstration project Hokkaido Japan
- Derived leakage thresholds from 1 year of baseline data
- Injection began April 2016 with routine environmental monitoring plan
- May, 2016, operations were halted after 7,163 ton CO$_2$ was injected
- High CO$_2$ levels observed in the routine monitoring
- February 2017 operations resumed

Shifting baselines cause false positives and project shutdowns
Revelation #2

• If we actively look for “leakage” (e.g. via routine monitoring) we will find an abundance of natural anomalies.
• We will need to attribute the source of these anomalies.
• Baseline methods are not effective or accurate.
• So how do we adequately assure environmental safety?
2011 Kerr Leakage Allegation

• IEAGHG Weyburn CO$_2$ Monitoring and Storage project, Saskatchewan Canada
• Perceived environmental change was blamed on the CO$_2$ storage project
• Protocols for responding to stakeholder concerns were not in place
• Unexperienced consultant wrongly attributed leakage
Carbon capture leak forces Saskatchewan couple to save farm

Carbon injected underground is leaking: Sask. farmers

CO2 leaks worry Sask. farms

Land fizzing like soda pop: farmer says CO2 injected underground is leaking

Pfft Goes Promise Of Pumping CO2 Underground
Revelation #3

- Environmental change resulting from climate change will cause stakeholders to question the storage project.
- When CCS is fully deployed, responding to stakeholders’ concerns may be our main activity.
- Develop fast accurate stakeholder-friendly methods with clear thresholds.
- Methods that are easily communicated to stakeholders are needed.
Process-Based Soil Gas Ratios

- Uses simple gas relationships to identify processes.
  - Biologic respiration
  - Methane oxidation
  - Dissolution
  - Leakage
- No need for years of background
- One time characterization
- Method can be applied in any environment regardless of variability

Process-Based Example

• Uses geochemical relationships to identify key processes rather than concentration comparisons
“User-Friendly” for Public Engagement

- Respiration line as a universal trigger point
- No need for years of baseline—only need a one-time characterization.
- Easy to explain and engage stakeholders
- Instant data reduction and graphical analysis

Katherine Romanak BEG
Process-based Attribution

B) CO2 flux (g/m2/d) - October 2005

Natural Signal

Leakage Signal

\[ y = 0.1879x + 18.417 \]

\[ R^2 = 0.9992 \]
Learning from our Experience

Sometimes the reason you have to learn lessons the hard way is because you didn't learn your lesson the first time (the easy way).
Summary

• Monitoring plans are evolving with experience and new incentives
• CO₂ storage is safe by design
• Baselines should not be used for attribution! They are shifting due to climate change, will result in false positives for leakage, and will cause project shutdowns.
• Protocols and regulations need updating.
• The Kerr claim shows a great need for accurate methods and protocols for attribution for responding to stakeholders concerns.
• The risk of a false leakage claim is higher than the risk of actual leakage.
• A process-based type of approach will give more accurate, immediate, and stakeholder-friendly monitoring results and may be useful for quantification and remediation monitoring.
Thank You

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