Environmental Quality Over CO₂ Injection Sites

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The Gulf Coast Carbon Center has been conducting research on all aspects geologic CO₂ storage for over 15 years.
Talk Outline

• Scientific approach to understanding environmental impacts.
• Groundwater: SACROC Oilfield
• Soil Gas: Cranfield Oilfield
• Public Claims of leakage: Weyburn Oilfield
• Summary Points
Science Addressing Environmental Concerns

• Controlled Releases/Injections
  - Demonstration Project Deep Injection
  - Shallow Controlled Releases
• Laboratory Simulations
• Numerical Modeling
• Natural CO$_2$-rich Analogs
• Industrial Analogs
Potential Impacts of Concern

**CO\textsubscript{2}**
- pH decrease
- Mobilization of heavy metals
  - Mineral dissolution
  - Detachment of metals from grain surfaces

**Brine**
- Organics, injection impurities, total dissolved solids
Brine Migration Pathways

- Brine leakage through faults/wells to the shallow subsurface
- Along-dip water displacement

Nicot et. al, 200, 9GCCC Digital Publication Series #08-03g
Brine Migration

- Abandoned wells should be properly plugged.
- Best practices should be followed for new well construction.
- Injection pressure management can reduce risk.

Carrizo-Wilcox system
Nicot et. al, 2008
Evaluating Metal Mobilization

Laboratory:
• Rapid trace metal mobilization followed by decline. (Lu et. al, 2009)

Shallow Controlled Release (ZERT)
• Metals mobilized but were below drinking water standards and transient (Kharaka, 2010).

Natural Analogs (Mammoth Mt., Vesuvius, Chimayo)
• Metals not present in some high CO₂ environments. Metals are absorbed by mineral precipitation. (Stephens and Hering, 2004; Aiuppa et al., 1995, Keating et al., 2010)
Industrial Analogue
SACROC Oilfield

- CO₂ injected for CO₂-EOR since 1972
- 175 Mmt CO₂ injected
- 78 Mmt recovered
- 2008 study - has CO₂ impacted environmental quality?

Smyth et al., 2009, Assessing risk to fresh water resources from long term CO₂ injection—laboratory and field studies

Romanak et al., 2012, Sensitivity of groundwater systems to CO₂
Groundwater Quality Study

- Data from inside SACROC were compared with data from outside SACROC.
- Has CO$_2$ injection impacted potable water?
SACROC Area Wells & Drinking Water Standards

36 wells; 17 wells inside and 19 wells outside of SACROC; filtered cations, unfiltered anions; highest concentration measured in each well.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Drinking Water Standard (DWS) (mg/L)</th>
<th># Wells</th>
<th>Exceeding DWS Wells Inside SACROC</th>
<th>%</th>
<th># Wells</th>
<th>Exceeding DWS Wells Outside SACROC</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EPA Primary - Maximum Contaminant Level</strong></td>
<td></td>
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<tr>
<td>Arsenic (As)</td>
<td>0.01</td>
<td>1</td>
<td>2.8%</td>
<td></td>
<td>5</td>
<td>13.9%</td>
<td></td>
</tr>
<tr>
<td>Fluoride (F⁻)</td>
<td>4.0</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>2</td>
<td>5.6%</td>
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</tr>
<tr>
<td>Nitrate (NO₃-N)</td>
<td>10</td>
<td>3</td>
<td>8.3%</td>
<td></td>
<td>2</td>
<td>5.6%</td>
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</tr>
<tr>
<td>Selenium (Se)</td>
<td>0.05</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>2</td>
<td>5.6%</td>
<td></td>
</tr>
<tr>
<td>Ag, Ba, Be, Cd, Cr, Cu, Pb, Sb, Th, U</td>
<td>variable</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>0</td>
<td>0.0%</td>
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<tr>
<td><strong>EPA Secondary Drinking Water Standard</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aluminum (Al)</td>
<td>0.05</td>
<td>5</td>
<td>13.9%</td>
<td></td>
<td>6</td>
<td>16.7%</td>
<td></td>
</tr>
<tr>
<td>Chloride (Cl⁻)</td>
<td>250</td>
<td>6</td>
<td>16.7%</td>
<td></td>
<td>4</td>
<td>11.1%</td>
<td></td>
</tr>
<tr>
<td>Fluoride (F⁻)</td>
<td>2.0</td>
<td>6</td>
<td>16.7%</td>
<td></td>
<td>10</td>
<td>27.8%</td>
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</tr>
<tr>
<td>Manganese (Mn)</td>
<td>0.05</td>
<td>3</td>
<td>8.3%</td>
<td></td>
<td>3</td>
<td>8.3%</td>
<td></td>
</tr>
<tr>
<td>Sulfate (SO₄²⁻)</td>
<td>250</td>
<td>1</td>
<td>2.8%</td>
<td></td>
<td>5</td>
<td>13.9%</td>
<td></td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>1000</td>
<td>7</td>
<td>19.4%</td>
<td></td>
<td>8</td>
<td>22.2%</td>
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<tr>
<td>Fe, Hg, Zn</td>
<td>variable</td>
<td>0</td>
<td>0.0%</td>
<td></td>
<td>0</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td><strong>WHO Drinking Water Standard</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Boron (B)</td>
<td>0.5</td>
<td>3</td>
<td>8.3%</td>
<td></td>
<td>5</td>
<td>13.9%</td>
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</tr>
</tbody>
</table>
Soil Gas Study
Large Volume Injection at Cranfield

Mississippi River
Natchez
Mississippi

- 3,000 m depth reservoir
- Gas cap, oil ring,
- Production 1947-1965
- Re-entered 2008 for CO₂-EOR

Illustration by Tip Meckel
Cranfield

- ~ 100 P&A wells
- Initial injection (2008) ~500,000 tons/yr ramping up to 1 MMT/year
- Soil gas survey of P&A wells showed no surface gas flux except at one site.
Soil Gas Anomaly

- Historic well
- Localized soil gas anomaly
  - $\text{CH}_4 < 50$ vol. %
  - $\text{CO}_2 < 45$ vol. %
- Monitored for 6 years
- 13 multi-depth soil gas sampling stations - 5 m depth
- Well re-entered in 2010 for production
Tricky Source Attribution

Example: Mudgas Analysis

- Initially believed to indicate well failure.
- Potential origin from reservoir or intermediate units.
- Based on $^{14}\text{C}$ was found not to be from the reservoir.
Environmental Aspects

- Anomaly spatially compact
- Relatively low surface flux
- No visible impacts
IEAGHG Weyburn-Midale CO₂ Monitoring and Storage Project

- Largest geologic CO₂ monitoring and storage project
- Since 2000 > 24 M tonnes of CO₂ injected
- CO₂-EOR operated by Cenovus Energy
- Studied by an international team of CO₂ storage experts
- Managed by Petroleum Technology Research Centre (PTRC)

2011 Kerr Farm Alleged Land Disturbances
Industry and Government Response to Kerr Complaints

- **1998**: (Operator) Weyburn Pump and Water Conditioning, groundwater test report
- **2002 – 2005**: (Operator) Farm well Inventory Project, regional groundwater analysis
- **2004**: (Operator) KBL Land Use Consulting Ltd., gravel pit water and soil samples
- **2005**: (Operator) Enviro-Test Analytical soil sample
- **2005**: (Government) Saskatchewan Health Provincial Laboratory, gravel pit and domestic well water
- **2006**: (Operator) Aqua Terre Solutions Inc., well and gravel pit water test
- **2006**: (Landowner) MR2 McDonald & Associates, water quality investigation
- **2007**: (Landowner) Consultation with Dr. Malcolm Wilson, Office of Energy & Environment, University of Regina
- **2008**: (Government) Ministry of Environment – Review of studies
- **2008**: (Government) SRC Analytical Laboratories, soil, water and air quality monitoring
- **2008**: (Government) Droycon Bioconcepts Inc., Bacteriological content of water
- **2010-2011**: (Landowner) Petro-Find Geochem Ltd., Soil gas surveys.
“The...source of the high concentrations of CO$_2$ in soils of the Kerr property is clearly the anthropogenic CO$_2$ injected into the Weyburn reservoir.”

News of a “Leak” at Weyburn
January 11, 2011

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

By: Bob Weber and Jennifer Graham, The Canadian Press
Postmd: 01/11/2011 10:22 AM | Comments: 9

Carbon capture leak forces Saskatchewan couple to leave farm

Carbon injected underground is leaking: Sask. farmers

CO2 Levels at Leaking Canadian Carbon Storage Project Could Asphyxiate You in One Place

Study Region

Pffft Goes Promise Of Pumping Co2 Underground
Expert Investigations in Response to Leakage Claim

CONCLUSION: NO LEAKAGE
How To Avoid This?

• High risk of false positives from inaccurate attribution.

• Need protocols and techniques for responding to leakage claims in place before a project begins.

• Quick response tools and protocols are being developed
  – Process-based approach
  – $^{14}$C versus $^{13}$C

Dixon and Romanak, 2015, Improving monitoring protocols for CO$_2$ geological storage with technical advances in CO$_2$ attribution monitoring, IJGGC vol 41

Romanak et al., 2014, Process-based soil gas leakage assessment at the Kerr Farm: Comparison of results to leakage proxies at ZERT and Mt. Etna, IJGGC vol 30
Summary Points

- No impact to groundwater at SACROC
- No environmental impact from soil gas anomaly at Cranfield
- Risk of leakage is less than risk that leakage will be perceived when it is absent
- Techniques and protocols for attribution are critical

Dixon and Romanak, 2015, Improving monitoring protocols for CO₂ geological storage with technical advances in CO₂ attribution monitoring, IJGGC Volume 41, Pages 29–40
Thank You

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