Environmental Impacts of Geologic CO$_2$ Storage

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Presentation Outline

• Overview of environmental impacts
• How science is addressing environmental concerns
• Examples of environmental impacts
  – Release from storage formation
  – Groundwater impacts
  – Ecosystem impacts
• Value of Information
• Communication
Definition of Environmental Impact

• Working Definition
  – Possible effect to the environment caused by the release of CO$_2$ and/or brine from a geologic CO$_2$ storage formation.

http://www.dailykos.com
Environmental Protection

- Begins in the project planning phase
  - Site characterization
  - Risk assessment
  - Permitting
  - Criteria for choice of sites
  - Project engineering and management with regard to potential migration pathways
    - CO₂
    - Brine

A Release Is Not Expected
Environmental Concerns

- CO$_2$ and/or brine migration
  - Drinking water impacts
    - CO$_2$ causing degradation of water quality
    - Brine contamination
  - Human and livestock health and safety
    - CO$_2$ displacing oxygen in low-lying areas
    - “catastrophic release”
  - Crops and overall ecosystem health
    - marine
    - terrestrial
Questions

• What circumstances will create an adverse impact?
• How likely is a release to occur?
• How likely is a release to reach the environments of concern?
• How can we predict the magnitude of an impact?
• How can we communicate impacts to the public?
Science Addressing Questions

- Controlled Releases/Injections
  - Deep Pilot Injection Projects
  - Shallow Controlled Releases
- Natural Analogs
- Industrial Analogs
- Laboratory Simulations
- Numerical Modeling
IEAGHG Environmental Research Network

Addressing knowledge gaps to predict impacts

1. Defining R&D Needs to Assess Environmental Impacts of Potential Leaks from CO$_2$ storage, Keyworth, Nottingham, UK, 2008

2. Natural Releases of CO$_2$ : Building Knowledge for CO$_2$ Storage Environmental Impact Assessments, Maria Laach, Germany. 2010


4. Combined Meeting with Monitoring Network, 2013, Canberra Australia
Outcrop Analogs

Hydrothermal Systems as Analogs for Breached Traps and Subsurface Healing: Outcrop and Subsurface Examples and Escape Mechanisms

*David Bowen*, David Lageson, Lee Spangler (Montana State University)
Bryan Devault, Herbert Mosca (Vecta Oil and Gas)
David Eby (Eby Petrography)

Natural Releases of CO$_2$ Workshop
Maria Laach, Germany
November 2-4, 2010
Outcrop Analogs

Hydrothermal fluids introduced along a fracture zone – Madison Fm. Gallatin Canyon Montana
Migration Potential

- Correct environments trap CO₂
- Faults are most-likely avenues of transport out of traps.
- Faults can self heal
- Faults don’t always reach the surface

After Breach of Sandstone Aquifer Seal Hydrothermal Fluids spread out Below Secondary Top Seal Lose Energy and Heat and often, System Self-Heals

Potential Groundwater Impacts

**CO₂**
- pH decrease
- Mobilization of heavy metals
  - Mineral dissolution
  - Detachment of metals from grain surfaces

**Brine**
- Organics, injection impurities, total dissolved solids
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)
• Metals not present in some high CO₂ environments. Some indication that metals are absorbed by mineral precipitation. (Stephens and Hering, 2004; Aiuppa et al., 1995)
Ecosystem Effects

Ecosystem effects of high CO₂ concentrations – the Laacher See as natural analogue

Martin Krüger, Dave Jones, Janin Frerichs, Julie West, Simone Gwosdz, Franz May, Ingo Möller

BGR & BGS
Ecosystem Effects

Laacher See: CO₂ vent at Site I

Changes in plant communities

Grasses
Polygonatum (acidophilic)

Distance (m)

% coverage

Bureau of Economic Geology
Ecosystem Effects Conclusions

- Areas with natural CO₂ seepage savely inhabited since hundreds of years
- These areas have a viable and productive agriculture
  - CO₂ seepage causes changes in biodiversity of plants and microbes (ecosystem type)
  - Change of soil chemistry might lead to change of soil value
- Effects of CO₂ leakage are spatially limited
- Change in plant and microbial communities to acid tolerant species (sometimes plant death at high CO₂ levels)
  - Generally, microbial cell numbers decrease with increasing CO₂
  - Positive effect of elevated CO₂ on selected microbial groups (Anaerobes)
- Altered geochemical environment (pH, O₂, mineralogy, nutrients)
- Substantial uptake of seeping CO₂ by plants and microbes
Value of Information

How can this knowledge be used to predict potential impacts?

• Scaling up from laboratory to basin
• Comparing system processes- (i.e CCS injection versus laboratory, controlled releases, analogs)
  – Subsurface conditions
  – Time scales
  – Mass flux
  – Flux rates
• Understanding variable impacts
Which Impact Will Occur?

Laacher See, Germany
No observable impacts

Mammoth Mt., USA
Tree damage

Both environments have high CO$_2$ flux. What's causing the different impacts?
How Analogous?

**Volcanic terrain** - high CO₂ analog

**Sedimentary basin** - common site for geologic CO₂ storage

Goff et al., 2001, Chemical Geology, High CO₂ Flux Measurements in Volcanic and Geothermal Areas, Methodologies and Results

McIntosh et al., 2004, Geological Society of America Bulletin
Understanding Knowledge Gaps

Shortcomings of Analogs

- Different system characteristics
- Time gap

**Industry**

~40 years

**Natural Systems**

100,000’s of years

1000-year storage requirement
The Importance of Communication

• Environmental impacts are a major public concern.
• Laymen gravitate toward using natural systems for understanding but commonly use them incorrectly.
• How can technical concepts be communicated?
Stakeholders and “Analogs”

Lake Nyos, Cameroon, August 1986
Release not an analog for geologic CO$_2$ storage
Concluding Remarks

- An environmental impact can be defined as the possible effect to the environment caused by the release of CO$_2$ and/or brine from a geologic CO$_2$ storage formation.
- The first step in environmental protection is choosing the correct storage site.
- Field tests, analog observations, laboratory experiments, and modeling give information useful for predicting environmental impacts.
- Scientists still need to understand how to apply current knowledge to predictions of environmental impacts.
- Environmental impacts are a major stakeholder concern and must be effectively communicated.
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http://www.storeco2now.com