Evaluation of long-term stability of caprock sealing under deep saline CO₂ sequestration environment

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Presentation Outline

- Introduction
- Research objectives
- Research methodology
- Research findings
Deep saline aquifers for CO₂ sequestration

Therefore, it is crucial to develop deep saline CO₂ sequestration projects close to industrial centers.

http://revolution-green.com/category/carbon/carbon/
http://www.fossiltransition.org/pages/carbon_storage_and_sequestration/30.php

Mitigation Measures to reduce CO₂ emissions

Carbon Capture and Storage (CCS) technique
Introduction

CO₂ sequestration in deep saline aquifers

- CO₂ is injected into the reservoir rock through injection well
- Reservoir rock is a permeable rock made up of sandstone filled with brine (mixture of ion + water)
- Depth of aquifer > 800 m. Aquifer properties - Temperature > 31.1°C and Pressure > 7.39 MPa. So, injected CO₂ remains in supercritical phase
- ScCO₂ density and viscosity < brine density and viscosity. So CO₂ tries to move upward direction. It is prevented by caprock - impermeable seal made up of shale, mudstone, siltstone or claystone. The specialty of caprock is the presence of a lot of clay minerals (Kaolin, Smectite, Illite, and Chlorite).

Why caprock is important?

- Prevent back-migration of injected ScCO₂
- Prevent ground heave (uplift)
- Avoid contamination of CO₂ with fresh underground water
- Avoid seismic events
- Contribute to mineral trapping

Although the whole CO₂ storage permanence depends on caprock integrity, the knowledge regarding its behavior in long term is still a question.
Aim: Investigation of caprock chemical reactivity under CO₂ sequestration environment in long-term.

- To find the reactivity of caprocks in the presence of CO₂ in laboratory scale
- To estimate the long-term reactions
- To estimate the porosity changes along caprock height

**Comparison of reactivity**

**Harvey 2 well, South-west Hub geo-sequestration Project, Perth (real caprock)**

**Eidsvold formation** in QLD (as a representation of caprock)

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>32</td>
</tr>
<tr>
<td>Goethite</td>
<td>6</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>9</td>
</tr>
<tr>
<td>Illite</td>
<td>20</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>6</td>
</tr>
<tr>
<td>Chlorite</td>
<td>13</td>
</tr>
<tr>
<td>Plagioclase</td>
<td>12</td>
</tr>
<tr>
<td>Other minerals (pyrite and montmorillonite)</td>
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</table>

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Composition (%)</th>
</tr>
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<tbody>
<tr>
<td>Quartz</td>
<td>36</td>
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<tr>
<td>Muscovite</td>
<td>7</td>
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<tr>
<td>Kaolinite</td>
<td>53</td>
</tr>
<tr>
<td>Other minerals (pyrite and montmorillonite)</td>
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</tbody>
</table>
Comparison of reactivity

Mudstone
- Laborator batch experiments
- Kaolinite, anorthite, chlorite and orthoclase mineral dissolution
- Quarts is a stable mineral in both caprocks
- Dissolution is significant in both types of caprocks.

Siltstone
- Laborator batch experiments
- Kaolinite, anorthite and muscovite dissolution

To find chemico-mineralogical alterations due to CO₂ injection in laboratory scale

Laboratory batch experiments

To increase reactivity
- Crushed caprock samples (75-425 µm) were used

Research Methodology

Provides the actual reservoir condition
- Salinity 4.5%
- Pressure 10MPa
- Temperature 40 °C for 37 weeks
Comparison of reactivity

Mudstone

Laboratory batch experiments

Kinetic batch modelling

Siltstone

Laboratory batch experiments

Kinetic batch modelling

Validate using laboratory experiments and predict long-term chemico-mineralogical changes due to CO₂ injection

- 10 years – Precipitation of beidellite clay and mordenite minerals
- 100 years – Precipitation of gibbsite, kaolinite and amorphous silica
- 1000 years – Precipitation of pyrophyllite, beidellite and calcite
- 1000 years – Precipitation of clinoptilolite mineral
- 5000 years – Precipitation of montmorillonite, equilibrium of kaolinite and k-feldspar

Research Findings
Research Findings

Comparison of reactivity

Mudstone
- Laboratory batch experiments
  - Kinetic batch modelling
    - Transport modelling

Siltstone
- Laboratory batch experiments
  - Kinetic batch modelling
    - Transport modelling

To find porosity changes along the caprock height

Low porosity increment of the caprock

Low critical height of the caprock

CO$_2$ attacking height along caprock
Research Findings

Transport modelling of mudstone

Diffusion

- The critical height of mudstone runs up to 7 m over 5000 years of reaction time
Research Findings

Transport modelling of siltstone

**Diffusion**

- **2μm for clay**
- **63 μm for other minerals**

- **4 μm for clay**
- **126 μm for other minerals**

- **12 μm for clay**
- **378 μm for other minerals**

- **48 μm for clay**
- **1512 μm for other minerals**

**• The critical height of siltstone runs up to 9 m over 5000 years of reaction time**

**• Based on lower critical heights and net porosity increments, the most suitable caprock is mudstone compared to siltstone**

**• Stored CO₂ migrates to 9 m after 5,000 years which cannot be neglected**
Research Findings

Overall research findings

Caprock reactivity under CO₂ sequestration environment

1. Fastest geo-chemical reactivity in the caprock can be seen during CO₂ injection period and then the mineral reactivity reduces with the CO₂ storage time.

2. Although the primary mineral dissolutions are significant in the caprock in short-term, secondary mineral precipitations such as clinoptilolite, pyrophyllite and beidellite are observed in long-run.

3. The critical depth of siltstone runs up to 9 m which is less that of mudstone. Therefore, mudstone can be considered as a favorable caprock sealing for safe CO₂ sequestration.

4. CO₂ migrates via mudstone caprock with 7 m thickness over 5,000 years while that of siltstone for 9 m.

- Primary mineral dissolutions are dominant in the caprock in short-term due to CO₂ injection. But secondary mineral precipitations appear in long-run.
- Mudstone can be considered as a favorable caprock sealing for safe CO₂ sequestration compared to siltstone
- Coupled effect of diffusion and geochemical reactions cannot be neglected during evaluation over geological timescale
Publications


THANK YOU